Article

Sorting Analysis of Household Food Waste - Development of a Methodology Compatible with the Aims of SDG12.3

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Abstract: Target 12.3 of the United Nations Sustainable Development Goals (SDGs) calls for halving per capita global food waste at the retail and consumer levels, by 2030.   The Food Waste Index is suggested as a methodology for grasping the situation.   This paper focuses on the consumer level (household food waste).   We argue that in order for generating useful information for devising and implementing effective measures for reducing food waste, it should be measured at Level 3 of the Food Waste Index, based on sorting analysis of generated waste, making a distinction between avoidable and non-avoidable food waste.   Furthermore, a breakdown by sub-categories that reflect the flow of food in the household could help identify target behaviours.   We have developed a categorisation scheme that is internationally agreeable and adoptable, and 1) generates useful information for policy-making and for tackling with reduction of food waste, 2) makes clear the concept of avoidable food waste, and 3) is practical and does not overcomplicate the work of grasping the situation of food wastage.   Results of workshops regarding this scheme suggest that the scheme satisfies the criteria.   This scheme has been applied to a few sorting analyses of household food waste in Japan, and their results are compared.

Keywords: Food waste index; Household food waste; Waste characterisation; Waste sorting analysis; Avoidable food waste; Preparation residues; SDG Target 12.3; Methodology development; Assessment of current situation

1. Introduction

FAO has indicated that about one-third of the food produced globally was lost every year [1].   This leads to a substantial amount of loss of land, energy, water and fertiliser [2].   Under these circumstances, Target 12.3 of the United Nations Sustainable Development Goals (SDGs) was set to "by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses".

As indicators of food waste for target 12.3, the Food Waste Index was developed by UNEP [3].   It has three-levels in accuracy and usefulness of data and Level 2 is the recommended approach.   At Level 2, the requirement is to measure food waste using suitable methods for each sector (all or part of retail, food service and household).

However, Level 2 index provides only figures about the total amount of food waste and does not distinguish between edible and inedible parts discharged from each sector. Such index could be used for grasping and tracking the status, but could not be used for designing and evaluating policies for preventing food waste.   In order to design policies to realise food waste prevention, we need more detailed information that can specify necessary behaviours to promote.

On the other hand, if we require classifying food waste into many complicated categories, the cost and effort to gather information will increase.   And if the concept of categories and the classification method is ambiguous and difficult to understand, the sorting procedure will take too much time and will cause many errors.   Moreover, the

users of the results may misinterpret the figures.   Therefore, it is necessary to make the concept of categories clear and easy to understand and to balance the requirement for detailed information with its cost.   Such consideration is also necessary for the international acceptability of the methodology.

This paper proposes an internationally agreeable method for the sorting analysis of household food waste, as there are many issues with existing measurement of household food waste, while it has a major share among the objects of the Food Waste Index [3].

2. Previous Research and Issues on the Classification System

2.1. Avoidability and Edibility

In order to clarify the information required for making food waste prevention policies, avoidability should be discussed first.   Edibility is related to avoidability because the edible part of food can be prevented from being wasted by eating it up.   The Food Waste Index introduces classification by edibility in Level 3.   FUSIONS [4] reviewed the terminology related to food loss and waste.   "Avoidable" is defined as "edible or possibly edible foods, regardless of whether they are edible at point of disposal, unplanned waste e.g., leftovers, preference losses".   However, there are some issues for classifying food waste by its edibility.

One of the issues is its situation-dependency.   UNEP, in explaining the definition of inedible, states that "what is considered inedible varies among users (e.g., chicken feet are consumed in some food supply chains but not others), changes over time, and is influenced by a range of variables including culture, socio-economic factors, availability, price, technological advances, international trade and geography" [3].

In some literature, authors judged the edibility of a food item according to typical food consumption habits in the countries being studied [5,6].   However, it still leaves ambiguity on the judgement of typical food consumption habits, and the judgement of some items on the borderline.

The Waste and Resources Action Programme (WRAP) in the U.K. sets a separate category of "possibly avoidable" for food and drink that some people eat and others do not, such as bread crusts and potato skins [7].   Other categories of food waste are "avoidable" and "unavoidable".   This type of categorisation could be a solution, but the boundary is still left ambiguous.   WRAP later changed the classification axis from avoidability to edibility [8].   For this change, they conducted a questionnaire survey to understand to what extent people in the U.K. actually eat some of the "possibly avoidable" and "unavoidable" items, or they perceive them as edible.   WRAP reclassified all items of "possibly avoidable" and "unavoidable" into "edible" or "inedible" by using its results.   This method is valid for categorising food waste items into "edible" and "inedible".

But the WRAP survey also showed that the perception of edibility and eating habits of "possibly avoidable" depended on the person, and the responses were varied [8].   From the viewpoint of avoidability, this raises a question of whether it is meaningful to divide items such as preparation residues into edible and inedible.   A method to reduce preparation residues would probably involve some improved or novel cooking manner, regardless whether the residue is considered edible or inedible.   This is rather different from measures for preventing edible parts being wasted.   Considering the usefulness of the data and the cost for measurement (identification), we concluded that in many cases it is not cost effective to assess the edibility of preparation residues.   Preparation residues should be treated as one category without dividing them into edible and inedible parts at the basic level of classification.   Parts of preparation residues should not be combined with other edible parts, even if they are judged as edible.

Another issue is how to classify unused food that contains both edible and inedible parts such as an apple which has edible flesh and an inedible core.   Food Loss and Waste Protocol [9] require separating even a whole apple into edible and inedible parts.   If it is difficult to separate them physically, the protocol recommends using conversion factors.

But that is still time-consuming.   This also diverges from the viewpoint of avoidability. If people did not buy the apple which they threw away, not only the flesh but also the core of the apple can be avoided from being disposed. So the whole apple could be treated as avoidable in this case.

This issue is also related to the concept of "excessive removal" in Japan, which is defined as edible parts of disposed food that were excessively removed when people removed the inedible parts for preparation at home, such as thickly peeled skin of radish [10].   This means that preparation residues should be divided into edible parts as excessive removal and "pure" inedible parts.   The Japanese Ministry of Agriculture, Forestry and Fisheries originally estimated the amount of "excessive removal" as the gap between the weight of actual residues from the food waste survey and the expected residues according to the conversion factors in the Standard Tables of Food Composition in Japan [11].   This estimation is possible when using data from food waste diary surveys.   It is, however, impossible to calculate it in the above manner when using data from sorting analyses, since researchers cannot obtain the data on the original amount of food corresponding to the preparation residues.   Considering the balance between the effectiveness for prevention and the cost for obtaining the data, it is probably reasonable to disregard "excessive removal".

2.2. Subcategories for Prevention

Several classification systems of edible /avoidable household food waste have been proposed.   In Japan, Kyoto City and Kyoto University proposed a classification system of food waste based on its cause ("untouched food" and "leftovers") and have been conducting sorting analysis of household food waste for many years since the 1980s [12, 13]. The Japanese Ministry of Environment followed a similar classification system and adopted three major categories of edible household food waste [10].   Categories based on its causes can be easily connected to the corresponding behaviours for its prevention. For example, untouched /unused food can be reduced by not buying too much and managing the refrigerator properly, while leftovers can be reduced by not cooking too much and eating up all the food that had been prepared.   Several recent studies in other countries also adopted a similar classification system.   Although they used different names for their systems, such as by life cycle stage [5] or by consumption status [6], identical categories of food waste can be observed: leftovers, whole unused food, partly consumed food, etc.

WRAP, on the other hand, have adopted the food type as the basis of its classification, and it classified food waste into 15 groups and subdivided them into 150 food types in 2012 [7].   Food waste from single ingredients, such as grilled meat, can be classified based on each ingredient, while many other dishes are a mixture of multiple ingredients and are classified as 'home made /prepared meals'.

WRAP also introduced a classification based on the preparation state of food, such as 'Fresh, raw or minimally processed', 'Cooked/prepared at home', 'Ready to consume when purchased', 'Cooked', 'Pre-prepared cooked', etc. [7].   This classification is deemed a combination of the state of the food at the time of sales and the state of cooking at the time of disposal.

Several classification systems are possible for subcategories.   What kind of classification system is suitable for informing policies to prevent household food waste?   Here we propose three criteria;

(1) it should be useful for proposing target behaviours /policies for prevention,

(2) it should make it clear and easy to understand the concept of categories,

(3) it should be practical and does not over-complicate the work of analysing the situation of food wastage.

The first criterion is the purpose of the investigation itself.   The second criterion is necessary to classify them easily and it is expected to reduce errors caused by misunderstanding and, together with the third criterion, is necessary for a broad dissemination of the scheme.

Classification by cause makes it easy to understand the relationship between food waste items and behaviours for prevention, and therefore is expected to have a high sensibility as an indicator of policy effectiveness. Classification by the state of food preparation has similar characteristics. However, it is difficult to determine the detailed classification of cooked /prepared foods into different states, as many items are prepared at home. Therefore, when criteria (2) and (3) are taken into account, classification by cause is considered to be better fulfilling the criteria.

Classification by food type is useful to reveal the target food items that have a large share, but it is difficult to classify the diverse mix of food items that are disposed as leftovers. It is considered more effective to classify avoidable food waste into two or three categories by cause first, and then into further sub-categories by food types if it is feasible considering criteria (3).

By setting up hierarchical levels in the classification system, it becomes possible to choose the level of detail according to the objectives and constraints such as cost. This is also useful in making survey data from different locations and by different entities comparable.

2.3 Packaging Attached to Unused Food

Another issue is whether containers and packaging containing food waste should be removed or not when measuring food waste. Food Loss & Waste Protocol requires that the weight of containers and packaging should be excluded when reporting the weight of food waste, and provides a method for that purpose [9]. However, as the Food Loss & Waste Protocol also acknowledges, this is extremely time-consuming in sorting analysis.

Based on a case study in Austria, Lebersorger & Schneider argued that the share of containers and packaging of food is small, and there is no need to remove them in sorting analyses aimed at food waste [5]. In the case of a study in the city of Matsumoto in Japan, on which we conducted an interview and a literature survey, a comparison of the composition with and without the packaging showed that even the largest difference between them was less than 1%. Therefore, if the influence of the packaging is presumed to be small and there are constraints such as cost, weighing without removing the packaging should be allowed.

3. Materials and Methods

3.1 Definitions and the Concept of Major Categories of Avoidable Food Waste.

We define that avoidable food waste consists of "unused foods" and "leftovers" among total household food waste, based on the above discussion. In our definition, avoidable food waste does not contain preparation residues even if they may be potentially edible. Unused foods are further divided into two categories: A: unused ingredients (food material for cooking) and B: unused ready-to-be-eaten foods (yet to be put on the table, or one whole unit of food items prepared until the last step before consumption). Hence, avoidable food waste consists of categories A, B and a third category C: leftovers (including leftover drinks).

Aside from this, we will classify the remainder of food waste as D: intentionally removed parts (food parts that are generally not eaten) as not constitutive of avoidable food waste. These include parts of food materials intentionally removed in the process of cooking, as well as parts that remain on the plate after meals, such as fruit seeds, clamshell, and bare corncob.

Table 1. Definition of major categories

Major categories		Definition of major categories
A/B Unused food	A Unused ingredients	Unused ingredients (unused entirely or in portion) (fresh food and processed food but not ready-to-be-eaten food*1)
	B Unused ready-to-be-eaten food	Ready-to-be-eaten food*1 that are yet to be put on the plate (table), or one whole unit of food with no traces of eating. Ready-to-be-eaten food except leftovers. In principle, pre-packaged ready-to-be-eaten food is classified into this category, but there are some exceptions. See *2.
C Leftovers		Ready-to-be-eaten food that can be assumed to have been served on the table and partially eaten and then thrown away*1. The food in this category is in principle not packaged, but there are some exceptions. See *2.
D Intentionally removed parts		Intentionally removed and discarded parts of food commonly not eaten. However, food that is no longer edible due to cooking errors or spoilage is excluded.

*1 : Ready-to-be-eaten food is food that has been prepared up to the last step before it is eaten or is ready to eat (e.g. ready meals, retort food, cup noodles, confectionery, pastries, etc.).

*2 : Exceptions are such food in packaging that can function as dishware (food expected to be eaten directly from packaging), which are normally expected to be consumed in one go (e.g.

Table 1 shows the definition of these categories. The items enclosed in the boxes with the thickest lines of Table 1 are the classifications of avoidable food waste that our research group has established. Figure 1 shows how avoidable and non-avoidable food waste are generated during the flow of processes from the input of foods into the household (buying etc.) to eating and disposal.
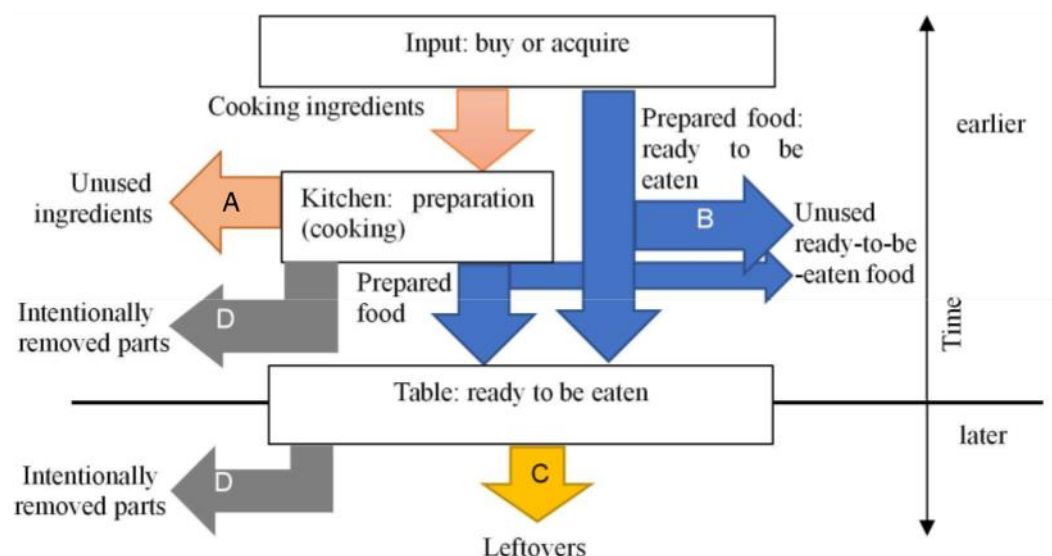

Figure1. Generation of waste in the flow of food in households

3.1.1. Category **A**: Unused ingredients

Cooking ingredients are foods that are generally expected to take part in some form of cooking or preparation before being laid on the table for consumption. They include fresh foods, such as vegetables, fruits, fresh seafood, and dressed meat; processed foods, such as dairy products (including milk), *tofu*, *natto* (fermented soybeans), bread (excluding pastry buns and other bakery products fully prepared for consumption), and ham or bacon, and other perishable processed products that are typically delivered to stores daily. Seasonings; some kinds of frozen foods, such as mixed vegetables; canned sweet corn; jams and various sauces in package and such products are also considered ingredients. Cooking ingredients are usually sold in designated sections of supermarkets.

Put simply, ingredients are foods typically bought at supermarkets in preparation for cooking. We classify food ingredients unused and disposed as category **A**.

3.1.2 Category **B**: Unused ready-to-be-eaten foods

Ready-to-be-eaten foods are foods prepared until the last step before consumption or are ready to eat and they include; sandwiches, *Jiao-zi* dumplings, steamed meat buns, fried foods, and salads sold as ready-to-be-eaten at supermarkets' deli or bakery sections, canned foods such as canned cooked sardines, foods contained in jars, such as pickles, ready-to-eat dishes packed in retort pouches such as curry, "dry foods" prepared up until the last step before consumption, such as instant cup noodles, sweets and snacks, including traditional Japanese sweets as well as western sweets.

We classify uneaten ready-to-be-eaten foods disposed without being eaten as **B**. Those that are partly eaten and disposed are classified as **C**.

Table 2. Detailed categories of the classification system and the levels system

Food waste		Level					Definition
		1	2	3	4	5	

Food waste	Avoidable food waste	A/B Unused food	A Unused ingredients	A1 Unopened ingredients	Unopened ingredients in packaging
				A2w Whole unused ingredients	Whole unused ingredients not in/no packaging
				A2wf Home-grown vegetables	Large amount of produce which is appeared to be home-grown such as with irregularities and branches
				A2p Partly used ingredients	Partly used ingredients in or without packaging
			B Unused ready-to-be-eaten food	B1 Unopened ready-to-be-eaten food	Unopened ready-to-be-eaten food in packaging including in unopened individual packages
				B2 Uneaten ready-to-be-eaten food	Whole unused ready-to-be-eaten foods without packaging, and partly unused ready-to-be-eaten foods in packaging, including foods in plastic wrap such as rice in plastic wrap However, obvious leftovers such as lunchbox remains are classified into leftovers even in packaging.
				B' Unopened drinks	Unopened drinks in packaging
		C Leftovers		C Leftover food	Ready-to-be-eaten or cooked food that appears to have been disposed after being served and partially eaten. As a principle, without packaging. However, partially eaten food left in packaging that is designed to serve as plate/bowl (food that is designed to be eaten directly from the packaging) also qualifies as leftover food.
				C' Leftover drinks	Leftover drinks in bottles or packaging
	Non-avoidable food waste		D Intentionally removed parts	De Possibly avoidable	Intentionally removed parts that are physically edible such as vegetable scraps, meat fat, fish skin, cooking oil, bread crust and kelp for soup stock. However, vegetable waste such as corn cores, which are clearly inedible and may affect the quantity, are classified into inedible parts.
				Di Inedible parts	Intentionally removed parts that are physically difficult to eat such as fruit scraps, seeds, bones, eggshells, shells, used coffee grounds and bagged soup stock. However, fruits scraps which are clearly edible and may affect its quantity such apple peels, are classified into "possibly avoidable".
		E Unclassifiable		E Unclassifiable	Very fine food waste that gets caught in kitchen sink strainers, or food waste blended with non-food waste that is difficult to sort further.

3.1.3 Category **C**: Leftovers

Ready-to-be-eaten foods or prepared dishes (for example, put on a plate and laid on the table) that appear to have been disposed after being partially eaten count as leftovers. As a principle, items classified as **C** are found without packaging. However, partially eaten food left in packaging that is designed to serve as plate/bowl (food that is designed to be eaten directly from the packaging) also qualifies as **C**: leftovers. Parts that may have been left on the plate but are not expected to be eaten, such as bones are not **C** (they are **D**: non-avoidable).

3.1. Detailed Categories of the Classification and the Levels Scheme

The detailed classifications of food waste are as shown in Table 2, which is in accordance with the conceptual diagram shown in Figure 1. Table 2 shows the subcategories that break down the above categories further. The table also indicates the five levels of the classification system based on the level of its detail.

3.2.1. Subcategories of avoidable food waste (categories **A**, **B**, and **C**) in the proposed classification

We classify unused foods **A/B** into **A**: unused ingredients (entirely or partly unused) and **B**: unused or uneaten ready-to-be-eaten foods.   Both **A** and **B** can be divided further into 1 or 2.   Subcategory 1 refers to packaged foods unopened and discarded, while 2 refers to foods that were never packaged or at some point were put in packaging but have been opened.

Hence, **A1** refers to packaged ingredients that have not been opened (note that it does not need to be sealed).   **A2** refers to ingredients not in packaging or in opened packaging, and these can be further classified into **A2w**: whole ingredients (i.e., uncut, etc.) and **A2p**: partly used ingredients.   Examples of **A1** would be discarded, whole, packaged food ingredients, such as a whole packaged cucumber, or a whole packaged quarter of a cabbage head[1].   Also, a remaining whole cucumber in an opened package that had contained a number of cucumbers is classified as **A2w**.   However a remainder of a cucumber partially cut off and used, regardless of the size of the portion remaining (as long as the portion can be used for preparation), is classified as **A2p**.   We would classify an opened package containing a quarter of a cabbage head as **A2p** as well.   Among **A2w**, fruit and vegetable appearing not to have been sold and purchased, but obtained from places such as household vegetable gardens are classified as **A2wf**.

B1 consists of ready-to-be-eaten foods in unopened packaging.   Regarding individual packaging, each individually packaged food counts as one.   For example, if there is an opened bag originally holding twenty individually packaged crackers, and only three crackers remain, and if the individual packages of those three crackers have not been opened, they each count as **B1**.   Never packaged or packaged but opened ready-to-be-eaten foods **B2** refer to ready-to-be-eaten foods that are yet to be put on the plate (table), or one whole unit of food with no traces of eating.   These include whole, individual pastry buns, sandwiches, etc.; if there is one bag that originally had five pastry buns without individual packages, and only three remained in that bag, those three will each count as **B2**.   If a ready-to-be-eaten item is contained in an opened packaging that does not function as a plate or a bowl (the packaging is intended for further storage) such as pickles and candies in opened packages, the item qualifies as **B2**.   Boiled rice wrapped in cling film for storage for later use is **B2**.

Additionally, apostrophes following each primary letter category indicate drinks (e.g., **B'**, **C'**, etc.).   We did not create subcategories for **C**: leftovers other than **C'** (leftover drinks), as leftovers are usually discharged in a mixed state, and is very cumbersome to sort further.

3.2.2. Subcategories of Intentionally removed parts **D**

We have defined intentionally removed and discarded parts of foods not commonly eaten ("intentionally removed parts") as food waste that does not constitute avoidable food waste.   However, we will further classify these into **De**: possibly avoidable that are removed as they are not commonly eaten much or not eaten at all, and **Di**: inedible parts that are physically difficult to eat.   For example, **De** consists of vegetable scraps, such as the skin and leaves of a *daikon* radish or skins of potatoes and carrots, while the brown skin of an onion, husks and bare cobs of corn, and the skins of taro count as **Di**.   In general, fruit skins count as **Di** (although there is exception such as apple skins, etc.).   Small amounts of such items can be neglected (follow the general principle), but if there is a significant quantity, their potential edibility should be assessed and categorised respectively.

"**De**: possibly avoidable" is used when it is desired to include the edible parts of "**D**: intentionally removed parts" as avoidable or possibly avoidable food waste[2], or when it is

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[1] At Japanese supermarkets, it is common to sell such big vegetable cut in half or quarters and wrapped in plastic film.

[2] If we were to incorporate "excessive removal" into avoidable food waste in accordance with MAFF and the Ministry of the Environment's pre-existing definition, that may mean the inclusion of our "De: possibly avoidable" into avoidable food waste.

desired to measure the effect of the diffusion of "eco-cooking" utilising peels and other potentially edible parts.   However, it is rather time-consuming to make individual decisions on whether an item falls under categories **De** or **Di** since the boundary of edible and inedible parts of food is obscure by nature as discussed in 2.1.   Therefore, we recommend classifying **D** into **De** and **Di** only when we need to know their amounts.

3.2.3 Category **E**: Unclassifiable

E: unclassifiable refers to very fine food waste that gets caught in kitchen sink strainers, or food waste blended with non-food waste that is difficult to sort further. Efforts should be made to sort as far as possible and to limit the amount classified as **E**. In the final report of the survey, the percentage of "**E**: unclassifiable" and its treatment should be stated clearly (e.g. whether counted as avoidable or unavoidable food waste)

3.2.4 Levels Scheme

We suggest a 5 levels scheme, according to the levels of detailed sorting, allocating the subcategories under the four major categories.   An appropriate level can be chosen, depending on the objectives of the survey and budget.   The basic classification is Level 3, which consists of the four basic categories plus "**E**: Unclassifiable", making five categories.   However from our experience, we can say that it is easier to divide them into Level 4 categories.   **D** is classified into **De** and **Di** only at level 5.   The reason is as described in section 3.2.2

3.3. *Overview of the Food Waste Sorting Analysis*

Table 3 shows the procedure of sorting analysis.   It is a common practice in Japan to dispose of food waste as burnable waste in municipal waste management.   Thus burnable waste will be the subject of sorting analyse, unless there is a separate collection for food (organic) waste.

Table 3. Steps for sorting (example)

Step	Photos	Activities
1		Collect sample waste (burnable /residual waste) by flat loader or box trucks. Note: If possible, take samples from different types of residential areas (housing types).
2		Lay out material and equipment, such as plastic tarpaulin sheets and tables.
3		Lay out all sample waste. Weigh the total amount of sample waste.

4		Remove unsuitable samples (commercial waste, large amounts of vegetation waste, oversize waste, etc.).
5		Sort waste: It is up to the investigators making decisions regarding rough sorting, roles and placements, and postures (standing, sitting, etc.).
6		Take photographs of items that were difficult to decide how to categorise (be careful not to mix them with photographs of items that were not difficult to sort).
7		When all detailed sorting is completed, measure the amount (weight) per category.
8		Take photographs to record the waste sorted into each detailed category, waste sorted by the larger classifications **A/B/C**, and the entire avoidable food waste.
9		Record the best before /use-by dates of foods for which packages remain. (optional)
10		Dispose of the sorted and weighed waste. Clean up the room or the area you used.

4. Results and discussion

4.1. Remarks on the Composition of Food Waste

4.1.1. Results of sorting analyses

We were able to put into practice the method suggested in this paper. The results of such sorting analysis of household food waste are shown in this section.

Since the conception of the methodology, the authors have applied it for several actual sorting analyses in Japan. In this paper, the results from Setagaya, Kodaira, Koganei and district X in Tokyo Metropolitan Prefecture, Kawaguchi (Saitama Pref.), Seika (Kyoto Met. Pref.), and Nagai (Yamagata Pref.) are introduced and compared. Some of the sorting analyses were the authors' own initiative, some were conducted by the local authority as part of research for preparing the local waste plan.

The sample waste was gathered from waste collection points with dedicated flat loader trucks, on routine collection days before the usual collection vehicle came around. Sample size varies: earlier analyses in Setagaya and district X took place as development and feasibility testing of the methodology, and involves a small sample. Later samples involve samples of more than 200kg. Here only the sorting results of burnable waste fraction are shown, as food waste contained in other separate collection fractions can be considered negligibly small. The exception is Nagai City, where separate collection of food waste has been implemented. In the central part of Nagai City, food waste is collected separately and composted. Waste sampled at each of the 21 sampling collection points was analysed separately for segregated food waste and for burnable waste. The sorted food waste is collected in large containers as shown in Figure 2. The accuracy of the separation was very high and none of the packaging from A1 and B1 (food in original packaging) was found. We could demonstrate that even if the food waste was collected separately with the packaging removed thoroughly, a level 5 classification was still possible.

Figure 2 Separated food waste in Nagai

Table 4 and Figures 3 and 4 show the results. Figure 3 shows the composition of the total food waste including non-avoidable parts, while Figure 4 shows the breakdown within avoidable food waste (categories A, B and C). These sorting analyses took place between July 2018 and February 2021. The level of detail in these analyses is not the same. For example, in Seika Town in December 2018, some sub-categories in A and B were not separated. A large part of what is now classified as subcategory B2 was included in category C (the definitions of subcategories were revised in Aug 2019, following the discussions after the initial sorting analyses). At Kodaira City in February 2021, sorting was done at Level 4, which does not classify category D into subcategories. Additionally, in Koganei, no effort was made to reduce the amount classified as E: unclassifiable for family type flats, which means that the accuracy of the results is compromised.

Comparison at level 3 of categories A, B, C, D, and E shows that there is not enough difference to establish a statistical significance between Setagaya, which is a central district of Tokyo conurbation, and Seika Town and Nagai City which are rural districts, to specify their respective characteristics. We consider that this is because there is no significant difference in lifestyles in Japan, whether in urban or rural areas, people basically go to the supermarket to buy food and prepare dishes at home.

Table 4. Results of the household food waste sorting analyses

Place of Analysis			Koganei			District X		Setagaya			
Housing Types			Detached	Flats family	Flats single	Mixed		Detached	Flats	Detached	Flats
Date of Analysis			Jun 19		Jul 19	Dec 18	Jul 18	Jan 21		Aug 19	
Total Sample Waste[kg]			181	224	133	82	70	259	258	54	77
Percentage of Food Waste[%]			44.8	54.6	25.9	41.5	44.3	27.3	21.4	27.3	34.7
category	sub-category		percentages of each subcategory within food waste								
A: unused ingredients	A1:unopened		2.5	1.6	11.6	3.6		4.1	7.6	8.6	7.8
	A2w:whole		3.3	2.2	6.2	3.2	7.0	3.2	2.9	0.3	7.1
	A2wf:home grown		0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
	A2p:partly used		6.0	2.9	10.0	3.6	5.9	7.2	13.0	4.1	9.2
B:unused ready to be eaten food	B1:unopened		3.1	1.3	6.2	2.8	3.4	4.6	6.2	0.9	4.2
	B2:partly used		0.2	0.0	0.0	2.6	1.4	5.6	1.9	0.5	0.0
	B':drinks		0.0	0.0	1.5	0.0	0.0	0.5	1.4	0.0	5.0
C:leftovers	C:food		17.2	7.0	27.0	15.1	9.8	17.4	25.3	20.6	11.2
	C':drink		0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
Non-avoidable	D:intentionally removed	De:edible	19.0	14.3	12.4	21.8	12.6	23.2	17.1	29.5	20.4
		Di:inedible	40.8	35.2	15.8	46.0	54.4	33.9	24.5	31.4	23.7
E: Unsortably Mixed Food Waste			7.6	35.5	9.3	1.3	5.4	0.2	0.0	4.3	9.9

Place of Analysis			Kodaira	Nagai			Seika		Kawaguchi		
Housing Types			Mixed	Total	Mixed burn	food w.	Detached		New Detached	Old Detached	Flats
Date of Analysis			Feb 21	Mar 20			Dec 19	Dec 18	Aug 19		
Total Sample Waste[kg]			415	1507	1130	376	300	306	104	105	97
Percentage of Food Waste[%]			33.5	40.1	21.6	99.0	50.4	44.8	27.8	32.3	37.9
category	sub-category		percentages of each subcategory within food waste								
A: unused ingredients	A1:unopened		5.1	2.2	5.5	0.0	4.9	12.2	6.4	10.4	2.6
	A2w:whole		2.0	6.4	7.2	5.8	8.0		7.4	2.8	6.2
	A2wf:home grown		1.4	10.7	2.2	16.3	2.4	5.9	0.5	0.0	0.0
	A2p:partly used		7.8	6.8	8.7	5.5	13.6	10.4	5.8	4.5	9.1
B:unused ready to be eaten food	B1:unopened		1.8	1.3	3.2	0.0	3.7	2.8	9.8	5.2	2.6
	B2:partly used		1.5	3.8	5.6	2.6	4.1		4.9	4.4	4.4
	B':drinks		0.1	0.0	0.0	0.0	0.0		0.0	0.7	0.0
C:leftovers	C:food		9.2	12.9	13.0	12.9	13.7	19.2	20.6	15.4	25.1
	C':drink		0.0	0.1	0.1	0.0	0.1		1.0	0.5	0.4
Non-avoidable	D:intentionally removed	De:edible	71.0	33.7	22.5	41.1	23.1	19.5	20.2	17.5	15.1
		Di:inedible		20.0	29.4	13.8	24.3	27.4	18.4	25.4	31.0
E: Unsortably Mixed Food Waste			0.0	2.2	2.5	2.1	2.4	2.7	5.0	3.2	3.6

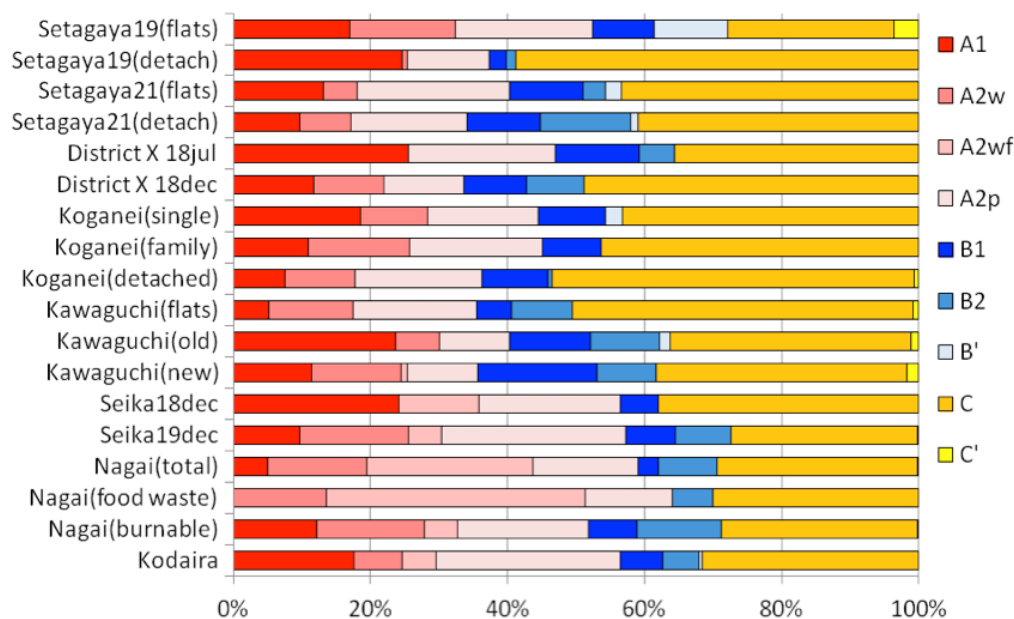Figure 3. Results of the household food waste sorting analyses
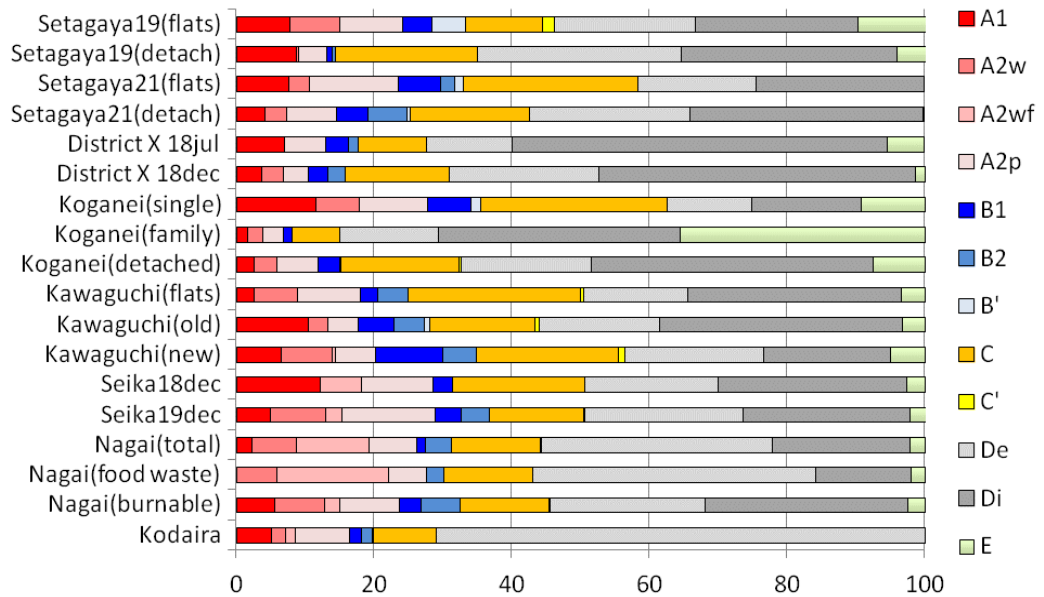
Figure 4. Proportion of categories within avoidable food waste

4.1.2. Possible differences between urban and rural areas

From the above results, we tried to identify the differences in trends between urban and rural areas. However, regardless of regional characteristics, no major differences between regions were identified in terms of the composition of total food waste and avoidable food waste, assumedly because the lifestyles of Japanese people are basically similar throughout the county. However, Setagaya and District X in the central part of Tokyo tended to have less of category A than in the rural areas (Seika Town and Nagai City). It is possible that residents in rural areas tend to prepare meals with raw ingredients while urban dwellers tend to rely more on processed food items, and the waste composition reflect this tendency. In the future, more survey results should be accumulated to verify this trend.

We can notice that the results of food waste in combustible waste in the rural areas of Seika Town in December 2019 and Nagai City are similar with a significant presence of wasted home-grown vegetables (A2wf). Moreover, in the separate collection of food waste in Nagai City, home-grown vegetables accounted for 16.3% of total separated collection of food waste, and 37.8% of avoidable food waste in this fraction. This separate collection is provided in the urbanised part of Nagai City to promote the composting of food waste even if it is difficult to find a space to do so at each household. Apparently in rural areas, there is an awareness on the need to actively recycle into compost the unused vegetables due to over harvesting or receiving too much. It can be pointed out that a characteristic of avoidable food waste in rural areas is the presence of home-grown vegetables.

4.2. Ease to Understand and International Applicability

4.2.1. Acceptance in Japan

The classification scheme must be intuitively easy to understand, both for conducting the analyses as staff member, and for understanding their results as policy-makers and as the general public. The common thread that emerges from the experience of these surveys is that the sorting staff's understanding of the classification was sufficient and did not cause any major confusion. In the case of Kodaira, it took about 2.5 hours for the 10 staff members to sort 140kg of food waste. In the 2021 Setagaya analysis, we managed to complete the sorting analysis for two locations in one day (each with ca.260kg of sampled household waste including 70kg and 55kg of food waste respec-

tively), also with a staff of about 10 people.   In some cases, recruited staff members were students who had previously never experienced a sorting analysis.   In the debriefing session for the analyses in District X, the 15 students who undertook the work commented that they found the classification scheme relatively easy to understand.   Judging from the progress of work and the responses of staff, it could be said that the proposed classification is straightforward and not difficult to understand.

4.2.2. International Consideration in the Development Phase

In the development stages of our proposed classification scheme, we have surveyed existing literature worldwide regarding sorting analysis focusing on food waste, and gathered information on categorisation adopted in those studies.   The prototype proposal was presented for consultation to experienced researchers at the Institute of Waste Management, BOKU University Vienna (ABF-BOKU), Agricultural Economics Department at Bologna University, and Faculty of Environment and Engineering, University of Southampton.   Moreover, we invited members of ABF-BOKU to Tokyo in August 2019, and they took part in the sorting process for the case described as "Setagaya19" in the section above.   An intensive debriefing session took place after the sorting and weighing process, with a scope on applying the classification scheme to sorting analyses in Austria. Several adjustments and refinement were made to the definition of subcategories reflecting the outcome of the session, to accommodate the differences in retail, cooking and eating customs in Japan and Austria.   We decided to suggest a levels scheme on the extent of detailed subcategories, which is also introduced in the guideline for household waste sorting analyses in Austria [14].   The classification scheme described in this paper is a result of such discussion.

4.2.3. Classification workshops with photo samples

We also tested if our categories are easy to understand worldwide among a wide range of people with different cultural and professional backgrounds.   As it is difficult to use "real" waste samples at indoor conferences and meetings, we decided to use photos of food waste items found in analyses conducted earlier.   This method was inspired by an earlier workshop conducted by Schneider [15].   About 35 items were selected, including "tricky" items that can fall under different categories depending on the way one thinks about them.

The participants of the workshops are asked to sort the photos into the abovementioned A, B, C, De and Di categories, after a brief explanation of the classification scheme by the facilitator.   We preferred to set this up as a group work of people with different backgrounds, as that will trigger discussions and deeper consideration among the participants.   The authors conducted this workshop at many occasions, such as international academic or professional conferences (e.g. Sardinia 2019, Meeting of Agricultural Chief Scientists of G20), seminars for international students (e.g. Keio University Japan, University of Cambridge UK), as well as at staff briefing before conducting sorting analyses based on this classification.

Table 5. Results of the photo-sorting workshops

item	tendency	Sardinia Oct '19		MACS G20 Tokyo WS Oct '19						Keio Uni Dec '19				Cambridge U. Feb '20			Chuo May
		1	2	1	2	3	4	5	6	1	2	3	4	1	2	3	
raw meat in unopened packaging	unanimous A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	A	A
mini tomatoes (4pcs)	unanimous A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A
banana (overripe)	mostly A	A	A	B	A	A	A	B	B	A	A	De	A	A	B	A	P
chilli pepper power (partly used)	unanimous A	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A
onion (cut / raw)	mostly A	A	A	De	A	A	B	A	B	A	A	C	A	C	De	C	A
green part of leek	mostly A (De)	De	A	De	A	AD	De	P		A	A	A	A	A	De	A	A
daikon (raddish) leaves	A or De	Di	De	A	P	AD	De	P		A	A	A	A	A	De	De	De	A
easter egg	A or B	B	B	C	B	B	C	B	A	B	A	A	A	A	A	A	A
grilled chicken wings (uneaten)	mostly B	B	B	B	B	BC	C	B	B	B	B	B	P	B	C	B	B
crepes (several pieces)	mostly B	B	B	B	B	C	C	B	B	C	B	P	B	C	B	B	C
spare ribs (burned)	mostly B	B	B	Di	B	BD	C	C	B	B	B	B	B	B	C	B	B
fried egg (no bite marks)	B or C	B	B	C	B	C	C	C	C	B	C	B	B	B	C	B	C
macaroni salad (partly used in packaging)	B or C	C	BC	B	C	C	B	C	C	B	B	C	A	C	B	C	C
cooked pasta (partly eaten, in packaging)	unanimous C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Coca Cola in bottle (partly finished)	unanimous C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	C	C
fruit jelly (partly finished, in packaging)	unanimous C	C	C	C	C	C	C	C	C	C	B	C	C	C	B	C	C
outer crust of pizza (bitten off)	mostly C (De)	C	De	C	C	C	C	P	C	De	De	De	C	C	C	C	C
apple (core with some flesh)	mostly De	De	CD	P	Cde	C	De	P	C	De	De	De	C	De	C	De	D
crust of toast bread (cut off)	mostly De	De	De	De	P	CD	De	P	De	De	De	De	P	A	C	A	C
carrot peel	mostly De	P	P	De	De	Di	Di	De	De	De	De	De	De	De	De	De	De
broccoli stem	mostly De	Di	P	De	P	Dei	P	P	De	Di	De	De	P	De	De	De	De
apple peel	mostly De	De	De	De	Dei	Dei	De	P	De	De	De	De	De	De	De	De	De
potato peel	mostly De	De	P	De	Dei	Dei	Di	P	De	Di	De	De	De	De	De	De	D
chicken skin and bone	De or Di	De	Dei	Di	De	Dei	Di	P	De	De	Di	Di	Di	De	Di	De	D
coffee コーヒー殻	unanimous Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di
egg shells	unanimous Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di
lemon wedges	varied	P	P	A	P	C	Di	P	B	A	De	C	P	C	C	C	C

(A, B, C, De, Di correspond to the categories.   P indicates pending (undecided) at the end of workshop)

Figure 5. Photos of workshops

Results of about 20 groups from the workshops, excluding those aimed for training of sorting staff are summarised in table 5.   The workshops include participants worldwide, covering all continents and from both developed and less developed economies. For many items such as raw meat packaged in plastic tray and wrap, there was unanimous agreement (in this case, category "A").   This implied that the basic concepts of our proposed sorting categories are universally agreeable.

However, there were discrepancies for some items.   For certain items, there was disagreement on whether they fall under "De" or "Di".   To a lesser extent, there were also cases of disagreement between "A" and "De".   The main factor for this is difference in food customs in the former case, and awareness or tolerance of food waste in the latter. By 'Tolerance' we mean an individual's value of whether he or she can allow the food item (or part of it) to be thrown away without pointing out that it could have been avoided.

We consider that for these items, it is not feasible to establish a universal standard with concrete examples. Suitable standards can be set for each country following the general concept of the proposed scheme, reflecting local customs and situations.

5. Concluding Remarks

In this paper, we have described the concept for sorting analyses aimed at providing information for policies to prevent household food waste, proposed a sorting category table based on that, demonstrated its feasibility in actual sorting analyses, and indicated the potential for international adoption. The most distinct feature of this proposal is the distinction between avoidable (edible) and non-avoidable parts. It has been pointed out that it can be difficult to draw a line between avoidable and non-avoidable food waste in the international context, due to differences in food customs around the world. This was primarily solved by a) making clear the concept of each main category and b) setting a category "intentionally removed parts", whereby "possibly avoidable" food waste (potentially edible preparation residues) was excluded from the definition of avoidable food waste,

Regarding the concept, in Chapter 2, we introduced the following three criteria.

(1) it should be useful for proposing target behaviours /policies for prevention

(2) it should make it clear and easy to understand the concept of the categories

(3) it should be practical and does not over-complicate the work of analysing the situation of food wastage.

The proposed classification was described in detail in Chapter 3. Regarding the first criterion above, it can be said that the classification enables to suggest target behaviours and ways to prevent food waste at home. The classification corresponds to the food flow in the home, and the main factors for the occurrence of category A, which is the ingredients /material for cooking, and B, which is food that is already prepared to be eaten, are different. It is also clear from the results of the classification survey shown in Chapter 4 that the overall trend is that more of A than B is generated. In addition, the proportion of C exceeds that of B. Therefore, in order to effectively reduce avoidable food waste at home, it is possible to suggest to each household, for example, effective ways to preserve ingredients and dishes. It is also important to encourage the use of refrigerators, which are indispensable for food preservation.

Regarding criterion (2), the definition of the categories is clear and easy to understand with the following two points, as explained in Chapter 4.

1) Sorting staff using this classification for the first time in a sorting analysis could classify food waste without much confusion.

2) When people from various parts of the world were asked to try the classification at several international workshops, the concept was correctly shared and there was no discrepancy in understanding, although there were some differences due to food culture and individual values, as shown in the results in sections 4.2.1 and 4.2.3. The most contentious part was the distinction between categories De and Di, i.e. whether a part that appears to be intentionally removed is potentially avoidable. To circumvent this, we defined "avoidable food waste" as categories A, B, and C. What is most important is not the unification of specific items, but those items with the same positioning in each society are classified in the same way around the world. Therefore, when sorting food waste based on this classification method, we would like to see researchers in each region customise the specific examples of foods to suit the local conditions.

Finally, regarding criterion (3), we suggested a levels system, whereby the organiser of sorting analysis can choose to which level of details the sampled food waste should be sorted into, depending on the purpose and availability of workforce. We found that the basic level (Level 3: A, B, and C) could be agreed upon widely and could be easily sorted. Even for the most detailed level (Level 5: A1, A2w, A2wf, A2p, B1, B2, B', C, C', De, Di, E), it was found that clarifying to the sorting staff the examples of foods that fall under each classification item in the briefing helped to eliminate confusion during the sorting analysis. As in the mentioned case studies, we have managed to sort as much as 150kg of food waste into level 5 subcategories in 2-3 hours with about 10 workers, we consider that the methodology is practical, and is not excessively complicated.

We hope that the framework for sorting analyses proposed in this paper will be adopted internationally to grasp the situation of household food waste. This will enable a proper grasp of the situation of food waste in one's own country as well as a proper international comparison on the situation of food waste. We believe that this will in the end contribute to devising effective measures for achieving SDG target 12.3 worldwide.

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