

Which Food Parts Are Considered Edible And Should Be Included In Food Waste Reduction Targets

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ABSTRACT: SDG 12.3 aims to reduce household avoidable food waste by half by 2030. This study introduces the "Tokyo Method," designed to quantify and categorize household food waste for reduction. The method divides avoidable food waste into three groups: A: unused ingredients, B: unused ready-to-be-eaten foods, and C: leftovers, with a goal of reducing their volume. Edible parts intentionally removed from the main food are placed in a separate category "De", while inedible parts like seeds and bones have their own classification "Di". An internet survey involving 1,254 participants assessed perceptions of 65 food items and their parts. Most respondents considered peels, cores, seeds, and stems of fruits as inedible, but there were exceptions like apple peels. Regarding vegetable parts like potato peels and cabbage leaves, a good number of respondents are aware that they could be eaten, but it is only a minority that believe they should be eaten, or they actually eat those parts. In conclusion, the study suggests excluding the "De" category in food waste reduction targets, as forcing the consumption of intentionally removed food parts is not a priority. This research sheds light on the complexities of food waste reduction, considering cultural and individual preferences regarding edible food parts.

Keywords: SDG target 12.3, Avoidable food waste, Tokyo Method, Questionnaire survey, Japan

1. INTRODUCTION

Level 2 of Food Waste Index for SDG target 12.3 recommends classifying food waste into edible (avoidable) and inedible (unavoidable) parts wherever possible, and reducing waste of edible parts. However, even in societies with homogeneous food cultures, it is difficult to clearly distinguish edible and inedible parts. Therefore, the separation of edible and inedible parts remains as a recommendation. The Japanese authorities designated the "edible portion of food" as the target of household food waste that should be halved by 2030. However, it is difficult to clearly classify household food waste into "edible food waste" and "inedible food waste". Under these circumstances, we developed the "Tokyo Method," a classification method that enables quantification of household food waste through waste sorting analyses. Our objective was to develop a method that is internationally agreeable and adoptable, and that (1) generates useful information for policymaking 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 (Okayama et al 2021).

In the household, food is input, used and eaten, and the remainder is output, as shown in Figure 1.

Food inputs are divided into two categories. The first are ingredients that are to be prepared (cooked), such as vegetables, meat, and fish, and the second are prepared foods or (almost) ready-to-eat foods, such as instant foods and frozen foods, or ready-to-eat items sold at takeaways.

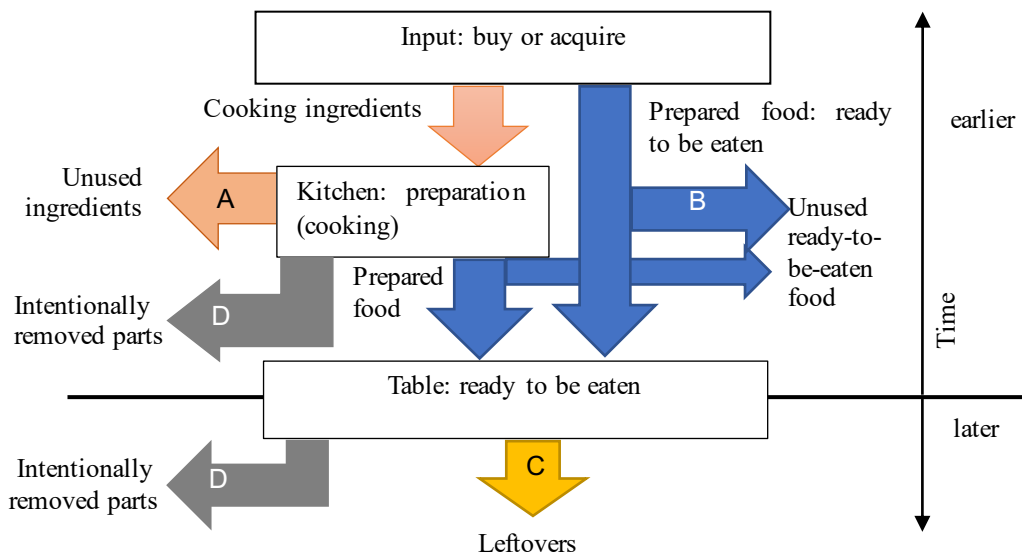


Figure 1. Generation of waste in the flow of food in households.

Table 1. Detailed categories of the classification system and the levels system of the Tokyo Method*

		A1 / A2 / B1 / B2 / C / C' / D / E		A / B / C / D / E	
Food waste	Avoidable food waste	A Unused ingredients	A1 Unopened ingredients	Unopened ingredients in packaging	
			A2w Whole unused ingredients	Whole unused ingredients not in/without packaging	
			A2wf Home-grown vegetables	Large amounts of harvest that appears to be home-grown such as with irregularities and extensive stems.	
			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 food in plastic wrap assumably intended for storage, such as steamed rice wrapped in cling film. However, obvious leftovers such as remains in disposable lunchbox are classified into leftovers even in packaging.	
	C Leftovers	B' Unopened drinks	Unopened drinks in packaging		
		C Leftover food	Ready-to-be-eaten or cooked food that appears to have been disposed after being served and partially eaten. In 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	C' Leftover drinks		Leftover drinks in bottles or packaging	
		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 have a significant 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, fruit scraps which are clearly edible and may have a significant quantity such as 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.	

Based on our discussion above, we define "unused food" and "leftovers" as "avoidable food waste" from households. Under our definition, avoidable food waste does not include intentionally removed parts in cooking (preparation residues), even if they are potentially edible. Unused food can be further divided into two categories: A: unused food ingredients (ingredients for cooking) and B: unused ready-to-be eaten (prepared) food (food that has not yet been placed on the table, or one unit of food that has been prepared to the last stage before consumption). A third category of avoidable food waste is C: leftovers, that is plate residues excluding parts that are deemed inedible and removed while eating. Thus, avoidable food waste consists of categories A, B, and C.

Apart from this, intentionally removed parts of food falls under category D, which has two subcategories. Removed parts that are potentially edible but not always consumed are classified as "De" (e.g. potato peel, fish skin), while physically (biologically) inedible parts such as seeds and bones belong to a separate classification "Di". Category De can be a margin for food waste reduction, but at the time being we do not include this as target for reduction. This classification D is quantifiable but difficult to reduce. As such wastes are inevitable when consuming the major (intended) part of food, we consider that they do not deserve to be included in the priority target items for reduction. Table 1 shows the classification of the Tokyo Method*. This classification of the Tokyo Method has been validated by multinational participants at Sardinia 2019, UN workshops etc., and has been confirmed to have a low margin of error in international understanding (Okayama et al 2021).

Note that formally, the United Kingdom addressed the complexity of the definition of edible /inedible by classifying food waste into three categories (Nicholes et al 2019):

i) Avoidable: food and drink that was edible at the time before it was discarded (e.g., bread slices, apples, meat).

ii) Possibly avoidable: food and drink that some people eat and others do not (e.g., bread crusts), food and drink that is edible in one preparation but not in another (e.g., potato skins).

iii) Unavoidable: food or drink that is not and could not be eaten under normal conditions (e.g., eggshells, meat bones, pineapple peels).

If we apply the Tokyo Method classification to this WRAP classification, "A & B": unused food and "C": Leftovers fall under "i) Avoidable", while De falls under "ii) Possibly avoidable" and Di under "iii) Unavoidable".

Nicholes et al (2019) specifically reclassified "ii) Possibly avoidable" into either edible or inedible in order to eliminate the grey zone between avoidable and unavoidable. They conducted a large-scale questionnaire survey in the whole UK asking whether people consider the items should be eaten, and whether they actually eat them. As a result, most of the items previously classified as "possibly avoidable", such as bread crusts and potato peels, were reclassified as edible.

On the other hand however, we decided to maintain the "De" classification. This is a part of food that may be edible, but the person who disposed of it did not want to eat or did not eat for whatever reason, and was intentionally removed. We do not intend to add De to the categories of Avoidable food waste, as we consider it a low priority as a reduction target. Category "De" was set up to indicate possibilities for the next step, to secure comparability with other sorting categorisation schemes, and for operational clarity of sorting under the Tokyo Method. By defining "De", it becomes clearer what falls under categories A, B, and C.

In this study, a questionnaire survey was conducted to clarify the extent to which food parts are generally considered by the public as "edible" (A,B,C, or De) and Di: physically inedible. This paper reports the results of the survey and adds some discussion.

* A manual for the Tokyo Method sorting analysis, describing the categories and procedures is available at the following website: <http://sdg123.starfree.jp/>

2. MATERIAL AND METHODS

The detail of the survey is as follows:

- Survey method: Internet survey
- Survey area: Nationwide (any region) in Japan
- Survey period: March 15 to 17, 2021
- Sample size: 1,200 males and females in 6 age groups (100 each) from 20s to 70s and over, total 1,254 valid responses
- Number of food (parts) items: 65
- Questions and options: Please select all options that apply to your situation of eating /not eating the following foods (parts).
 - 1) I think this food/part should be eaten
 - 2) I think I could eat this food/part if I wanted to
 - 3) I usually (usually) eat this food/part
 - 4) I may or may not eat this food/part, depending on the type
 - 5) I may or may not eat this food/part depending on how it is prepared
 - 6) This food/part does not fall into any of the above categories

The 65 items (parts) are foods (parts) commonly found as Category D when sorting household waste according to the Tokyo Method. For example, tomatoes are the most commonly eaten vegetable in Japan, but were excluded from this survey because discarded tomatoes and tomato peels are rarely seen in household waste. We purposely included "tricky items"; those items that triggered a discussion among the researchers while devising the initial version of Tokyo Method, as well as those that the sorting staff found puzzled while conducting the sorting analysis.

The 65 items (parts) included 6 seafood items such as fish peels and shrimp tails; 10 fruits (parts) such as apple peels and banana peels; 39 vegetables (parts) for example peels of potatoes, carrots, and radishes, outer leaves and cores of cabbage, spinach and komatsuna stubble (stump), base of enoki and shiitake mushrooms, cucumber and bell pepper stems, and broccoli stalks. Finally, there are three incidental items such as burnt toast.

Options 1-5 asked whether the item was objectively or subjectively considered edible, as well as the circumstances under which it was or could be eaten; option 6 is for an item that none of option 1-5 applies. Basically they are items that the survey respondents consider inedible in all circumstances, or the food itself was unknown to them or they had never been eaten it. In other words, foods (parts) with an dominantly high value of option 6 compared to 1-5 should in theory fall into category "Di" in the Tokyo Method.

3. RESULTS AND DISCUSSION

Analysing the results of the survey, we found that the food parts could be clustered into three groups: "Undoubtedly inedible group (Di)", "De and Di borderline group", and "Rather avoidable De (almost A or C) group. The reason why there was not a distinct "De" group is probably because of the intentional selection of the food parts.

3.1 Undoubtedly inedible group (Di)

This group consists of the following items (% of option 6): Shells of shellfish (92.7%), apple cores (77.6%), banana peels (90.1%), peach peels (73.4%), mandarin orange peels (73.7%), watermelon peels (72.2%), watermelon seeds (81.6%), strawberry calyx (green leaves attached to strawberry) (91.9%), brown onion skins (82.5%), pumpkin seeds (68.9%) pumpkin wads (soft part surrounding the seed) (76.7%), bell pepper seeds (70.2%), bell pepper stems (74.4%), edamame pods (Fig.2, 86.0%), cucumber stems (70.2%), corn husks (92.0%), corn cobs (90.5%), nut shells (85.1%), bottom of enoki

mushroom stem (86.4%), bottom of shiitake mushroom stem (63.1%), and used cooking oil (65.5%).

The peels, cores, and seeds of fruits, and seeds, calyxes, and roots of vegetables tend to be considered almost physically inedible, since less than 5% of the respondents answered "1 should eat" and more than 70% answered "6 other" with few exceptions.

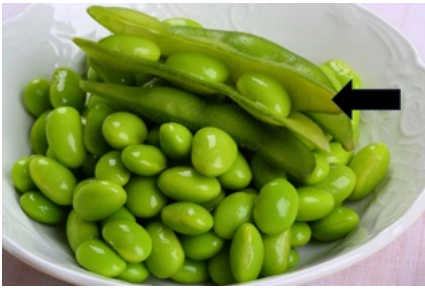


Figure 2. Edamame pod

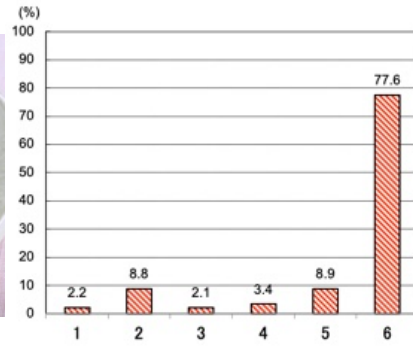


Figure 3. Apple Core

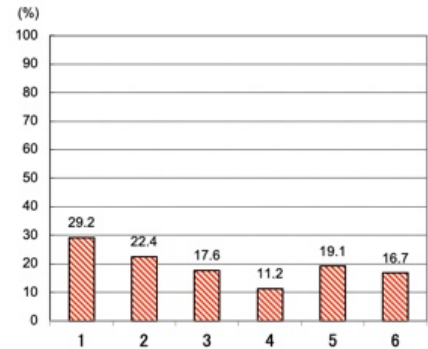


Figure 4. Apple Peel

Of the above, for apples, the core (Fig. 3) is classified as Di, but the peel (Fig. 4) is considered physically edible by 29.2% of the respondents who say it should be eaten and 17.6% who say it is usually eaten. In Tokyo Method, as a general rule fruit peels are classified as Di, with the exception of apple peels, which are classified as De.

It is not surprising that an overwhelming proportion (90.1%) chose option 6 for banana peels. We often find bananas discarded in waste sorting analysis with about 3-5 cm of the contents remaining with the peel (Fig. 5). Therefore, we asked about that portion as well (Fig. 6). While 20.0% responded that this portion should be eaten, 51.1% chose option 6. This means that more than half of the respondents answered that this part is not to be eaten. When we have found such items in the sorting analyses, we have been classifying them as "De" in the Tokyo Method. There was a discussion this part could even be considered as category C (unfinished leftovers) i.e., count them as avoidable. The results showed that many Japanese are rather surprisingly wasteful in eating bananas.



Figure 5. Banana "handle"

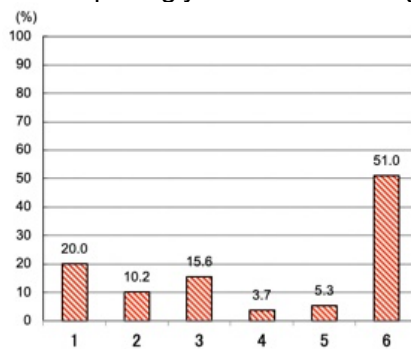


Figure 6. Contents of the end of the banana, the part you were holding when you peeled and ate it.



Figure 7. Mandarin Sections

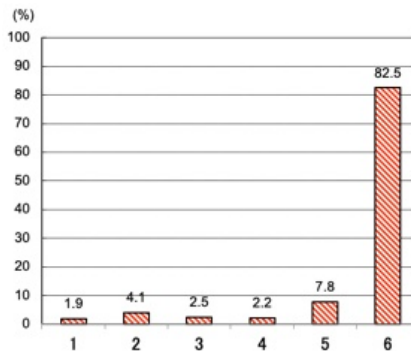


Figure 8. Outer Onion Skin

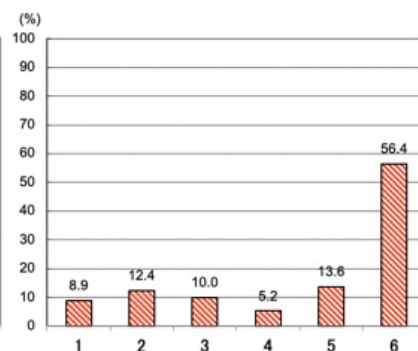


Figure 9. Bottom of Onion

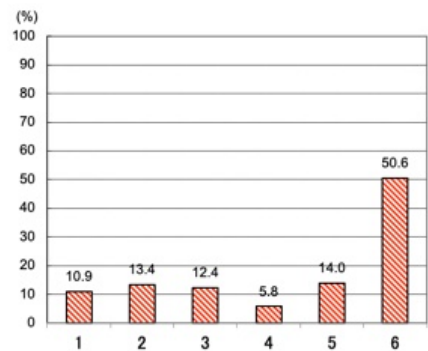


Figure 10. Tip of Onion

As for mandarin oranges, we often find in sorting analyses that only the juice inside the fruit is sucked out and the soft membrane of the sections inside is discarded (Fig. 7). We asked about this part, and found that many people eat the section membrane and consider that it should be eaten. In other words, if this part is discarded after absorbing the juice, it would be classified as De considering that the membrane is intentionally removed, while if the mandarin sections were discarded as is, it may be considered as B2 (whole fruit) or C (partly eaten).

For onions, its outer brown skin (Fig. 8) is designated as Di together with skin of corn cobs in the Tokyo Method as an exception to the general rule that vegetable skins are De. The bottoms of onions (56.4%, Fig. 9) and the tips of onions (50.6%, Fig. 10) are also designated as Di, however the survey results suggested it is difficult to say that they are absolutely inedible, since around 10% of the respondents answered "1 should eat them" and "3 I generally eat them".

Regarding Enoki mushrooms, we asked about three parts (Fig. 11). Enoki mushrooms are sold in bags each containing a bunch. The bags are often coloured or printed towards the bottom, and some consumers use the edge of printing as a guideline for cutting off the bottom part. Probably this is the reason why we find in sorting analysis bottom part of enoki cut off at line 3. Only the bottom-most part about 1 cm from the root was considered inedible by the respondents (Fig. 12), while the part above that, people consider edible and actually do eat (Figs. 13 and 14). Shiitake mushrooms, as with enoki mushrooms, which are both popular mushrooms in Japan, the bottommost part is considered inedible (Fig. 15) and the stem as edible and eaten (Fig. 16). These trends agree with the De / Di demarcation in the Tokyo Method.



Figure 11. Enoki Mushroom

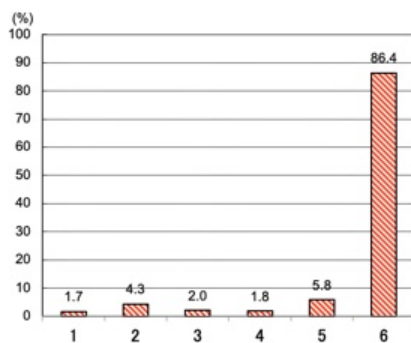


Figure 12. Enoki cut at line (1)

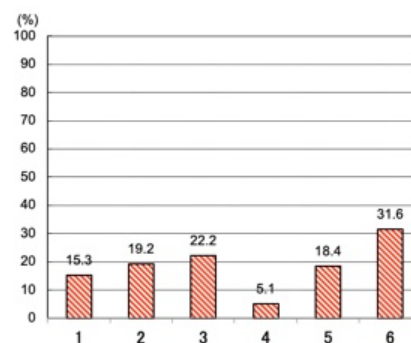


Figure 13 Enoki cut at line (2)

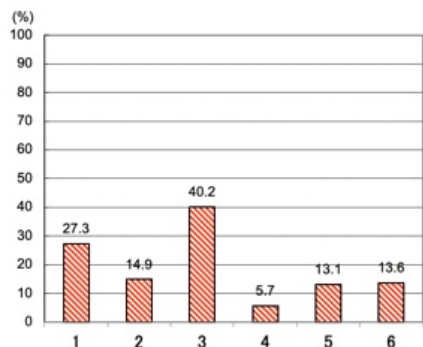


Figure 14. Enoki cut at line (3)

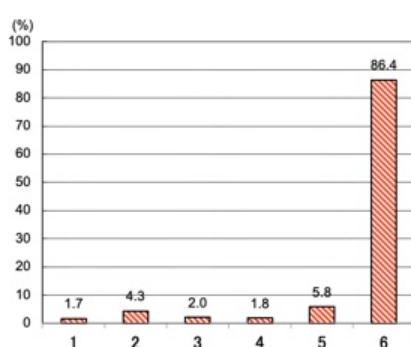


Figure 15. End of Shiitake Stem

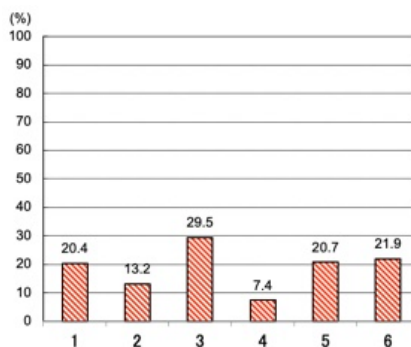


Figure 16. Shiitake Stem

3.2 De and Di borderline group

This corresponds to the group of food items with 30%~50% of the respondents choosing option 6 in the questionnaire. Category D is food (parts) that were intentionally removed and not eaten, and as mentioned earlier, Di is the part of a food item that is physically most difficult to eat. On the other hand, this group is understood as foods (parts) that are De (possibly edible) but near to Di.

The following food items are in this group: fish entrails, potato peels, carrot petioles (junction of carrot leaves and carrot), radish petioles, cut surface of partly used radish, outer leaves of cabbage, outer leaves of Chinese cabbage, outer leaves of lettuce, lettuce core, cabbage leaf core, cabbage

body core, Chinese cabbage stubble (stump), komatsuna stubble, spinach stubble, thin green onion stubble, leek stubble, and the inner part of the tip of a banana (as mentioned earlier). Food dropped on the floor and sweets dropped on the floor also fall in this borderline group.

Regarding fish, we asked about entrails or internal organs (Fig. 17), bones (Fig. 18), and skin (Fig. 19). Fish skin was considered rather as an edible part. Fish bones were also considered to be an edible part of fish depending on the type of fish and the way it is cooked. This result may be attributed to the fact that many types of small fish are eaten whole, as a wide variety of fish is consumed in Japan. The same applies for shrimp tails (Fig. 20). Therefore, in the Tokyo Method, fish skin and small shrimp tails were considered De, while fish bones and large shrimp tails were considered Di.

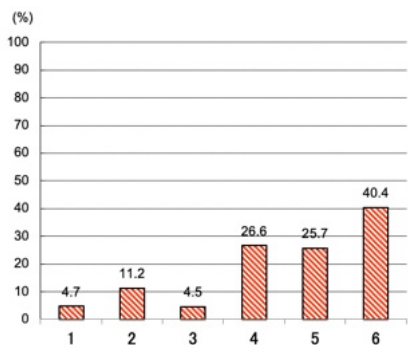


Figure 17. Fish Entrails

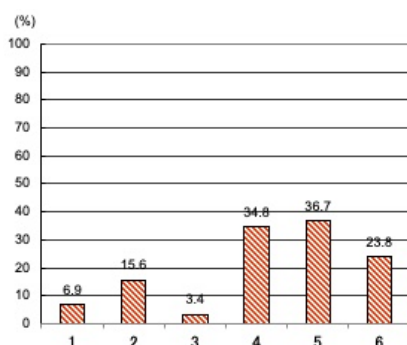


Figure 18. Fish Bones

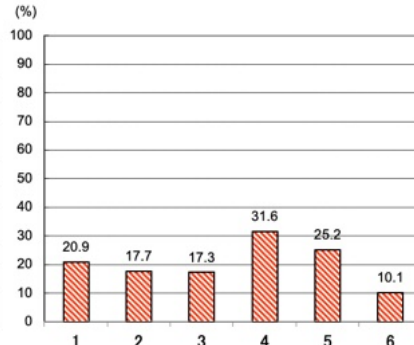


Figure 19. Fish Skin

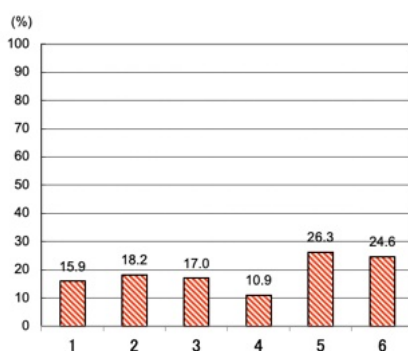


Figure 20. Shrimp Tail

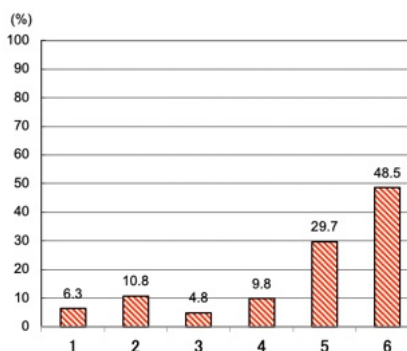


Figure 21. Potato Peel

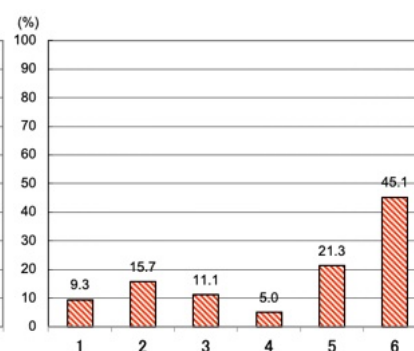


Figure 22. Cabbage Core

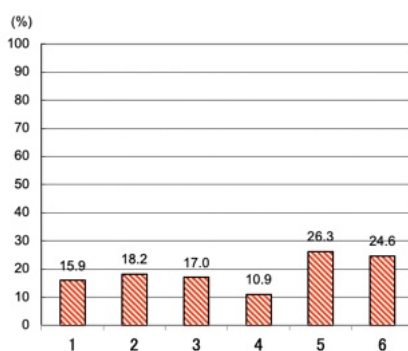


Figure 23. Petiole of Daikon

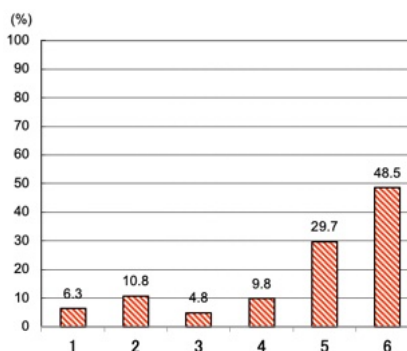


Figure 24. Petiole of Carrot

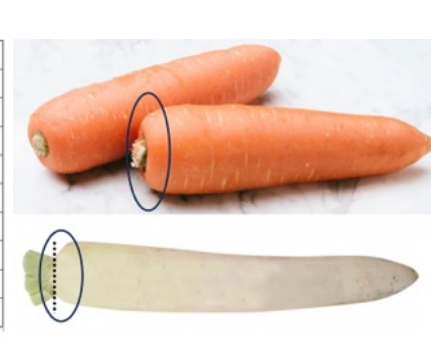


Figure 25. Petioles

As for potato peels (Fig. 21), 48.5% of respondents chose option 6, 6.3% was of the opinion "should eat," 4.8% said "usually eat," and 10.8% said "could eat if I wanted to," making it the part of the potato that "I could eat if I wanted to, but I don't eat much. The same tendency can be seen for the core of cabbage (Fig. 22), petiole of Japanese white radish (daikon) (Fig. 23), petiole of carrot (Fig. 24), and the inner part of the end of a banana (mentioned in Section 3.1). The reason why carrots are more "inedible" than the petioles of other root vegetable is probably due to their shape and toughness (Fig. 25). The outer leaf of cabbage (Fig. 26) was selected by 30.2% of respondents as "6", 14.1% as "should eat," 24.0% as "could eat if I wanted to," and 12.4% as "I generally eat", indicating that they are also parts that are perceived as edible but not eaten very often. The same tendency is observed for

the outer leaves of lettuce (Fig. 27) and Chinese cabbage (Fig. 28). In general, we can say that the outer leaves of tuberous vegetables are perceived as the part of the vegetable that can be eaten but not very often in practice. At some supermarkets, these outer leaves are collected on the spot to be composted (Fig. 29). The results conform with our categorisation of these items as "De" in the Tokyo Method.

Daikon (Japanese radish) peels (Fig. 30) and carrot peels (Fig. 31) as well as sweet potato peels (Fig. 32), share a similar trend with that for shrimp tails (Fig. 20). Apparently, this is understood as a part of the food that may be eaten depending on the cooking. The pattern of responses for stubble of komatsuna (leaf vegetable similar to spinach), spinach (Fig. 33), bases of thin green onion (Fig. 34) and chives, all fit into category "De". In summary, this confirms the general principle in the Tokyo Method where vegetable peels and cores are considered De, with the exception of the brown peels of onions and corn cobs, which are considered Di.

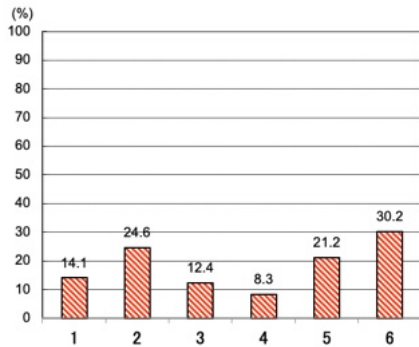


Figure 26. Outer Leaves of Cabbage

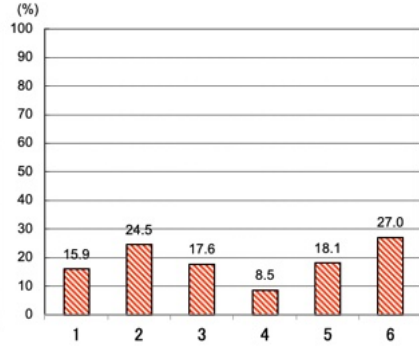


Figure 27. Outer Leaves of Lettuce

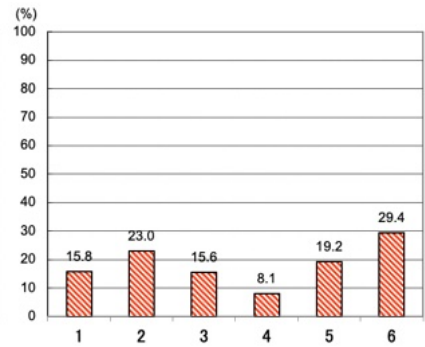


Figure 28. ibid. of Chinese Cabbage



Figure 29. Collection of Outer Leaves

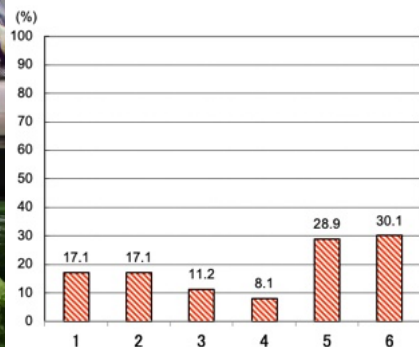


Figure 30. Daikon Peel

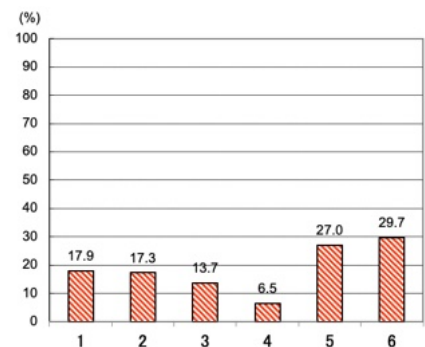


Figure 31. Carrot Peel

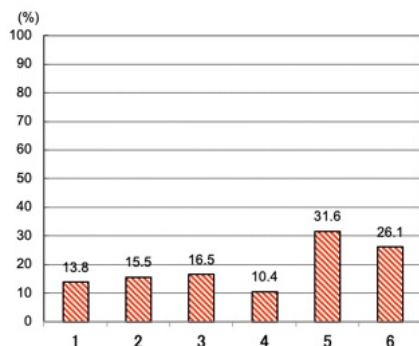


Figure 32. Peel of Sweet Potato

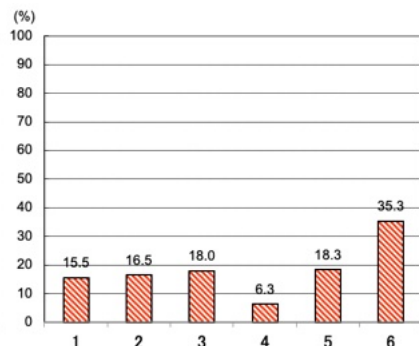


Figure 33. Spinach Stubble

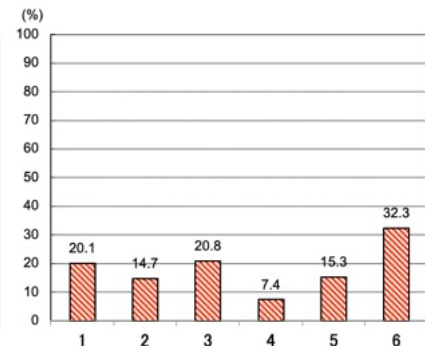


Figure 34. Base of thin green Onion

3.3 Rather avoidable "De" (almost "Avoidable") group

In the Tokyo Method, De is intentionally removed parts that could potentially be eaten. For many

items in this group, it is often difficult to demarcate whether it is De or either partly used A (ingredients), B (prepared food) or C (unfinished items).

As accidental food items, dishes (cooked foods) dropped on the floor (Fig. 35) and confectionery dropped on the floor (Fig. 36) are considered edible, with just over 20% saying they could eat them if they tried to, while 13.9% said they would eat the item, and 38.7% said "6: none of the above". In other words, in the composition survey, such food will be classified as "C" leftovers, and sweets will be classified as "B2" both in the avoidable category, but the awareness of those who throw them away is De (intentionally not eaten). In Japan, shoes are usually not worn at inside the house. Therefore, it is thought that the number of people who will pick up and eat what was accidentally dropped on the floor at home is larger than that of those doing the same in a restaurant (homes with pets may be an exception). For the accidentally burnt dishes (Fig. 37), 12.2% of the respondents answered "1) should be eaten", 25.6% answered "2) can eat if I want to", and 22.7% answered "6) none of the above (do not eat)", making them slightly more likely to be eaten than the dishes accidentally dropped on the floor (Fig. 35), but they are not actively eaten. In Tokyo Method, burnt dishes are classified as C uneaten or B2 cooked food, as such wastage (accident) could be avoided.

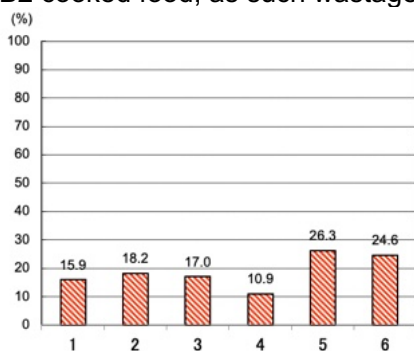


Figure 35. Food Dropped on Floor

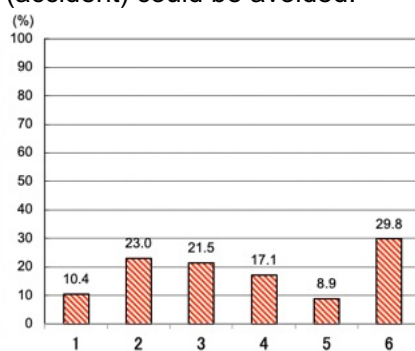


Figure 36. Confectionery Dropped on Floor

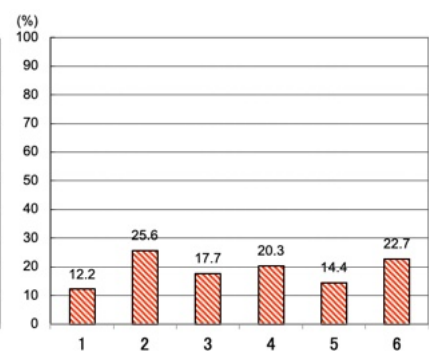


Figure 37. Burnt Dish

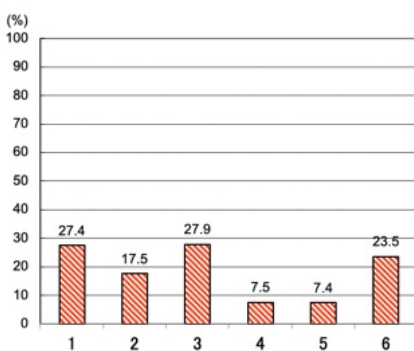


Figure 38. Fresh Parsley

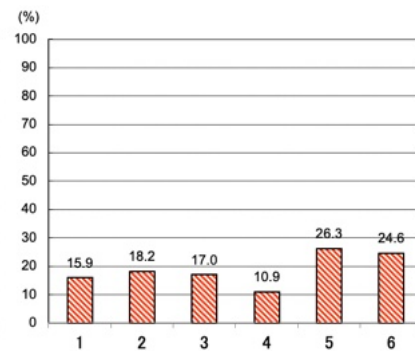


Figure 39. Cut /Sliced Lemon



Figure 40. Tsuma for Sashimi

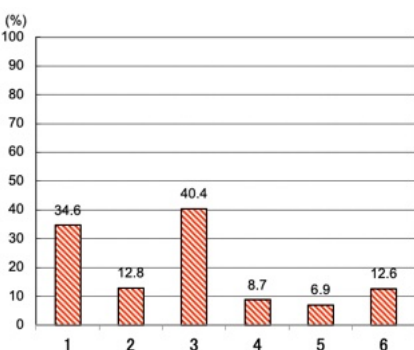


Figure 41. Tsuma for Sashimi

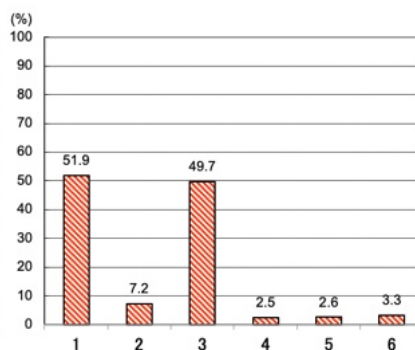


Figure 42. Bread Crusts

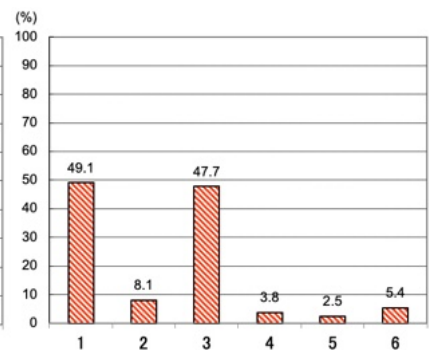


Figure 43. Pizza Crust

In developing the Tokyo Method, we had a good discussion on whether garnishes such as fresh parsley (Fig. 38) or cut /sliced lemon (Fig. 39) found in waste sorting analyses should be classified as A: ingredients, C: plate leftovers, or De: intentionally removed. In the questionnaire survey there was not

much difference between the responses of "rather should be eaten" and "I usually eat it", and "6 (do not eat it)". These foods were designated as De in the Tokyo Method.

Tsuma for Sashimi (Fig. 40) is thin slices of daikon (Japanese radish) that is mainly served with Sashimi (slices of fish to be eaten raw). Probably "tsuma" in packages of Sashimi sold in supermarkets is what Japanese people think of when they think of sashimi "tsuma". Japanese respondents were more conscious of eating tsuma for sashimi (Fig. 41), with 34.6% saying "1) they should eat it", 40.4% saying "3) they usually eat it", and 12.6% saying "6) not any of the above" (do not eat it). In the Tokyo Method this garnish is assumed generally as "De", however if it is evident that this tsuma was purchased specifically (e.g. a package of tsuma only, not as a garnish in a package of sashimi) it will be categorised as avoidable (category B).

Bread crusts were initially classified as possibly avoidable in the United Kingdom, and were reclassified as edible (Avoidable). In our survey, crusts of a slice of bread (Fig. 42) were also recognized as a normally eaten part, with 51.9% of respondents saying "1) they should be eaten", 49.7% saying "3) I usually eat them", and only 3.3% saying "6) none of the above (do not eat them)".

From this result, bread crusts could be classified as unutilized food (A2p in Tokyo Method), however as in the initial stance of WRAP, we considered that bread crust that was cut off and discarded is De as it was intentionally removed (but potentially edible). On the other hand, pizza crust edge was considered as "C: leftovers", as in the preliminary workshops almost all participants expressed that pizza as a dish is served with the intention that the whole including the crusty edge is to be eaten. In the survey, pizza crust edge (Fig. 43) showed the same tendency as bread crusts, with 49.1% saying "1) should eat it", 47.4% saying "3) I usually eat it," and 5.4% saying "6 none of the above (do not eat)". Grains of cooked rice left in rice cookers and bowls showed exactly the same trend, and these were classified as "C: leftovers".

4. CONCLUSIONS

Nicholes et al. (2019) classified "possibly avoidable" items mostly as edible (avoidable), while we decided to classify those as unavoidable. This is because we believe that when actually considering measures to reduce avoidable food waste by half by 2030, the initial priority should be to encourage people to eat up fruits that are thrown away as whole, use up vegetables and meat that are half used and thrown away, avoid wastage of frozen foods and leftovers, etc., rather than to encourage people to eat chicken skin and potato skin.

It is possible to consider the "De" classification in the "Tokyo Method" as physically edible, and include it in the reduction target. However, telling people to eat parts that they customarily remove intentionally is not a priority for food waste reduction measures, and this can be set aside as a secondary target for those who are already highly aware and committed.

One of the objectives of the Tokyo Method is to generate useful information for policymaking and for tackling with reduction of food waste. Probably it is more useful to consider what should be included as priority targets for reduction of avoidable food waste, rather than trying to accurately assess the edibility of food items.

ACKNOWLEDGEMENTS

This research was funded by the Environment Research and Technology Development Fund (JPMEERF 20183005).

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