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Surely you don't eat parsnip skins? Categorising the edibility of food waste

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Highlights:

- **A novel method for classifying food waste into edible & inedible parts is presented**
- **This method fills a major gap in global efforts to monitor changes in food waste**
- **Gap found between what people perceive as edible and what they state that they eat**
- **For many food parts, divergence in population regarding what is considered edible**
- **The method is suitable for replication studies in different countries and over time**

ABSTRACT

Food that is either wasted or lost, rather than being eaten, accounts for around a third of global food production and is linked to several environmental, economic and social issues. The reliable quantification of this wasted food is essential to monitor progress towards the United Nations' Sustainable Development Goal 12.3, which covers food loss and waste. Currently quantification of food waste is made difficult by many differing definitions, some of which require categorisation of food items into those parts considered edible and those considered inedible. Edibility is difficult to define as it is affected by cultural and social influences. This study presents a novel, easily-replicable,

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questionnaire-based methodology to categorise 'borderline' food items thrown away from households, e.g. parsnip skin, apple cores. The methodology captures self-reported information on what people eat (self-reported consumption) and their perceptions of edibility. Our results for the United Kingdom indicate that, for a given food 'part', there is divergence between individuals' responses to the survey questions: e.g. many people would 'never' eat carrot skins, whilst many others would 'always' eat them. Furthermore, there is a systematic difference between people's self-reported consumption and their perceptions of edibility. We suggest that both need to be considered to create a balanced categorisation of edible and inedible parts; we propose a method for incorporating both elements. Within this method, a threshold needs to be applied and the resultant classification, especially of those items close to this threshold, will inevitably be contentious. Despite this, the categorisation of what is considered edible using this methodology reflects the views of the majority of the population, facilitating the quantification of food waste. In addition, we envisage this methodology can be used to compare geographical differences and track changes over time with regard to edibility.

Keywords: Food waste, Edibility, Food behaviour, Questionnaire study, Behaviour and perception survey, Household behaviour

1. Introduction

Globally, approximately 1.3 billion tonnes of food produced is wasted every year, equivalent to a third of all food produced for human consumption (FAO 2011). Food waste occurs at almost every stage of the food supply chain; however, the amount of food wasted from households represents the largest proportion in developed countries (e.g. FAO 2011; FUSIONS 2016a). Not only does food waste represent a direct loss of the food itself, it is also associated with substantial environmental, social and economic impacts (FAO, 2014). These impacts – such as water shortages, soil erosion, deforestation, air pollution, greenhouse gas emissions and food security – have brought food waste to the forefront of many international organisations' agendas. Of note, the United Nations (UN) incorporated food waste into the Sustainable Development Goals (SDGs) as part of the 2030 Agenda

for Sustainable Development (UN 2017). Target 12.3 involves 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) by 2030 (UN 2017). Consequently, the effective quantification and monitoring of food waste is more important than ever before in evaluating progress towards this target.

There has been extensive research into quantifying food loss and waste. However, comparing estimates of food waste remains challenging, in part due to the lack of a single definition of food loss and waste (Chaboud & Daviron 2017). Definitions differ based on:

i) where in the food supply chain to start quantification – i.e. are crops ploughed back into the field considered food loss or waste?

ii) the 'destination' that food goes to - for instance, is food fed to animals classified as a waste? and

iii) whether the definition should cover just the food (the edible part of items) or should it also cover the inedible parts associated with food (e.g. bones, egg shells, etc), which is definitional element that this paper focuses on.

The definition applied within studies generally reflects the environmental, social or economic issue of interest associated with food waste (see Chaboud & Daviron 2017 for a full review). In addition, the use of terminology (food waste and/or loss) differs between definitions resulting in terms with multiple meanings. For example, the FUSIONS project refers to "food waste" as losses occurring across all stages of the food supply chain (FUSIONS 2016b). Comparatively, the FAO has used food waste for losses associated with the distribution and consumption stages (FAO 2011).

To address this issue, the Food Loss and Waste Accounting and Reporting Standard (FLWS) was developed to inform and motivate reporting entities to quantify and reduce their food waste (Food Loss and Waste Protocol, FLWP 2016). This is a global standard designed to aid countries in achieving a baseline and monitoring progress towards Target 12.3 of the UN Sustainable Development Goals.

The FLWS divides food waste into 'wasted food', defined as "any substance- whether processed, semi-processed, or raw- that is intended for human consumption" (p.15, FLWP 2016), and 'associated inedible parts', defined as "components associated with a food that, in a particular food supply chain, are not intended to be consumed by humans" (p.15, FLWP 2016). The wasted food component comprises parts of food that would be considered edible when in good condition, even if, by the time they are discarded, they have deteriorated to a point where they are not edible any longer (e.g. going mouldy, rotten, etc.). Therefore, associated inedible parts only includes the parts that are not intended to be eaten (and excludes food that has deteriorated). However, FLWS does not specify how an organisation should differentiate between the wasted food and the inedible parts.

For global reporting of food loss and waste, the Champions 12.3 network – a group of executives from governments, businesses, international organizations, research institutions, and civil society aimed at delivering the SDG 12.3 target – has produced guidance on the definitions and scope of this goal, to obtain a consensus on this issue (Champions 12.3, 2017). This makes the point that progress against this target could be assessed using total FLW (wasted food plus inedible parts associated with food waste), but if a country can differentiate these two fractions, they can report on just the wasted food component. Although definitions of these two fractions are given, no practical method for differentiating them is described or referenced.

Prior to the FLWS and SDG 12.3, WRAP (2009) had addressed the complexity in defining edibility by classifying food waste into three categories of loss:

i) "Avoidable: food and drink thrown away that was, at some point prior to disposal, edible (e.g. slice of bread, apples, meat).

ii) Possible avoidable: food and drink that some people eat and others do not (e.g. bread crusts), or that can be eaten when a food is prepared in one way but not in another (e.g. potato skins.

iii) Unavoidable: waste arising from food or drink preparation that is not, and has not been, edible under normal circumstances (e.g. meat bones, egg shells, pineapple skin, tea bags)." WRAP (2009)

These categories, or similar versions, have been used most extensively in studies of food waste (e.g. Koivupuro *et al.* 2012; Papargyropoulou *et al.* 2014; Hoover 2017). The classification by WRAP (2009, 2013) also formed the basis of the list of foods in the FUSIONS manual (Appendix 7, FUSIONS 2016b).

Despite the work achieved by WRAP, the categorisation of food waste into 'food' (i.e. edible parts) and its inedible parts has not – to date – had a clear, reproducible methodology. The FLWS acknowledges what is considered inedible will differ between people and various populations and may not necessarily relate to whether it is ingestible (FLWP 2016). For example, a food part could be ingestible (in that no harm will come from consuming the food) but still be considered inedible in some cultures. Edibility is therefore influenced by a range of cultural factors, e.g. via shared values, common practices, religious beliefs, social norms and personal preferences (Papargyropoulou *et al.* 2014; FLWP 2016). In short, what is frequently eaten in one country may be considered inedible in another.

In the case of WRAP's studies (WRAP 2008; 2009; and 2013), the classification of food parts was based on the views of the authors and their knowledge of the UK population. These views are subjective, relating to their own experiences of what family, friends and acquaintances consider edible. If their experiences are not representative of the population in question (the UK), this can affect the classification. Consequently, there is a need for an objective classification method that can account for different cultural influences between countries.

Recently, edibility of food items was explored in Denmark via a questionnaire methodology (Stancu & Lähteenmäki 2018). This questionnaire includes questions asking about the edibility of food items. For some items, the state of the item is also included e.g. browned bananas. For these items, this means

135 that the information about whether people consider them edible is influenced by its (deteriorated)
136 state, rather than being solely about whether people consider that part of the food edible (e.g. the
137 flesh of a banana in good condition). Furthermore, once the edibility of items had been established,
138 there was no determination of whether the items were in fact consumed by the population.
139
140 There is information on edibility contained within nutritional databases, such as those developed by
141 national governments to convert information gathered in studies on consumption into estimates of
142 nutrient intake. Examples include the *National Nutrient Database for Standard Reference* in the USA
143 (USDA 2015) and, in the UK, McCance and Widdowson's The Composition of Foods (Public Health
144 England, 2015). The FAO provide listings of nutritional databases from around the world[2].
145
146 Recent studies have used such databases to inform their estimates of the associated inedible parts.
147 For example, De Laurentiis et al. (2018) used data from three databases (Carnovale and Marletta,
148 2000; Public Health England, 2015; Rimestad et al., 2017). In many cases, there was good agreement
149 between sources on the percentage of a whole item that was inedible. However, there were plenty of
150 foods for which large discrepancies occur. De Laurentiis et al. discuss the case of figs where the
151 percentage inedible in the two sources containing data are 2% and 25%. The authors suggest that one
152 source classify the fig skins as edible and the other source classifying them as inedible. This raises two
153 issues with this data: it is often not clear which fractions (e.g. skins, pips, stalks, bones, fat) have been
154 classified as edible or inedible parts; neither is it clear how these decisions have been arrived at (e.g.
155 what criteria have been used). Therefore, there is a gap in the literature relating to how to classify
156 different parts of food items into edible and inedible parts.
157
158 These efforts to classify and quantify food waste have been developed against a backdrop of emerging
159 studies determining the complexity of food waste practices in the home (e.g. Evans 2014), highlighting

[2] http://www.fao.org/infoods/infoods/tables-and-databases/en/

160 the wide range of drivers that are influencing food waste (e.g. Thyberg & Tonjes, 2016, Hebrok & Boks
161 2017, Schanes et al. 2018) and the difficulties in finding solutions to tackling food waste (e.g. Porpino
162 2016, Romani et al. 2018, Stöckli et al. 2018, Reynolds et al. 2019).
163 The current study presents a novel methodology to categorise food waste into food and its associated
164 inedible parts accounting for cultural differences. The methodology section describes how a survey
165 was used to obtain information on whether people eat certain parts of food and, irrespective of if they
166 eat those parts, whether they consider them edible. The method allows *existing* food-waste
167 definitions that require a split between edible parts (wasted food) and associated inedible parts to be
168 put into practice in a transparent and reproducible way.
169
170 The survey was deployed in the UK, focusing on food waste from household. The results are presented,
171 including how the information was used to classify items found in detailed waste compositional
172 analysis and food-waste diaries as either edible or inedible for a recent report (WRAP 2018). This
173 simple methodology can easily be replicated in different geographies to obtain classifications that are
174 location-specific, considering cultural differences in the parts of plants, fungi and animals that are
175 eaten. We discuss the application of this method for reclassifying existing UK food-waste data and the
176 opportunities for taking this approach further, alongside its limitations.
177

178 ## 2. Materials and methods

179 The purpose of this study is to develop and evaluate a reproducible method to classify different parts
180 of food items into edible and associated inedible parts. For the purposes of this paper, food waste is
181 defined as the sum of edible parts that are discarded and inedible parts associated with food already
182 eaten or discarded:
183

184 $$Food\ waste = edible\ parts + inedible\ parts\ associated\ with\ food$$

185

186 Although other terms are used in the literature (e.g. 'edible parts' are also referred to as '(wasted)
187 food'), these are the terms that fit most closely with the wording used in the questionnaires (see
188 below), chosen to be easiest to interpret by research participants (i.e. the public).
189
190 The method described in this paper have been applied to food waste from UK households, which
191 includes the following collection routes / destinations: residual / general waste destined for landfill or
192 incineration, food waste in collections targeting food waste destined for anaerobic digestion or in-
193 vessel composting, food waste going down the sewer and food waste composted within the home.
194 The method could also be applied to material fed to animals, which, for the purposes of this study,
195 was not defined as food waste (see WRAP 2018 for more details). Furthermore, with minor changes,
196 it could be applied to food loss and waste in other parts of the supply chain.
197
198 ***2.1 The questionnaire***
199 The questionnaire contained 5 questions to identify self-reported information on which parts of food
200 people eat and perceptions of the edibility of parts of foods. The first two questions are the most
201 important to the methodology. The first question (*Which of these items do you eat, assuming they are*
202 *appropriately cooked and in good condition?*) focuses on which parts of food people report that they
203 eat. The second question (*Which of these items do you consider inedible and which could possibly be*
204 *eaten, even if you don't eat them yourself?*) concentrates on whether people consider these parts of
205 food edible (regardless of whether they eat them or not).
206
207 Each question is asked for 16 parts of food (e.g. parsnip skins; see results section and appendix for the
208 list). These were chosen on the basis that, i) they occur in relatively large amounts in the UK household
209 waste stream based on existing food waste data from WRAP (2013) (in particular, tables 46 and 47
210 indicated food items contributing large amounts of 'possibly avoidable' and 'unavoidable' food waste),
211 ii) they were considered 'borderline' between being edible and inedible by the authors (often being

classified as possibly avoidable in the past) and iii) they could help guide decisions about other, similar foods; for example, orange peel could be used to inform cultural perceptions for other citrus peel.

In the early drafts of the questionnaire, bones were one of the items asked in the first two questions. However, piloting of the questionnaire (see below) indicated that research participants sometimes struggled to answer these questions if they made stock from bones. This was because some of the bone would be incorporated into the stock (and therefore utilised), but most of the mass of the bones was still discarded as inedible. Bones make up a relatively large proportion of food waste from UK homes (around 200,000 tonnes per year in 2012, approximately one-eighth of all unavoidable food waste, WRAP 2013). Therefore, two further questions (numbers 3 and 4 in the questionnaire) were developed to ask the research participants whether they make stock from bones, and how often they did this.

The final question determined to what extent the respondent was responsible for the food preparation and cooking within the household, to see if this correlated with responses to the other questions.

The first four questions were developed from scratch – at the time of development, the authors were unaware of any existing questions to use in the question development. Input was sought from a range of people with experience in survey questions relating to food. The final question was adapted from WRAP's long-running tracker questionnaire on food waste (http://www.wrap.org.uk/sites/files/wrap/CFWP%20Survey%20Spring%202017.pdf). The questions were not formally tested (see section on limitations of the study) but were piloted with several colleagues who work on neither food-related topics nor social research. Refinements of the questions were made to the questions following this process (see above).

2.2 Population and sample

The questionnaire was distributed by an on-line polling company (Populus) using an on-line poll between 20th and 22nd September 2017. The sample of 1,092 adults was a nationally representative sample of adults in the UK. Quotas on age, gender and region were set. Targets for quotas and weights were taken from the 2012 National Readership Survey, a random probability face-to-face survey conducted annually with 34,000 adults. The data were weighted by Populus to the known profile of the UK using age, gender, and government office region, social grade, taken a foreign holiday in the last 3 years, tenure, number of cars in the household and working status.

2.3 Data analysis

To allow comparison between food items and questions, each response was attributed a 'score' to provide information relating to the edibility of a food item. These scores are listed in brackets after the response options in the appendix. A score of 1 was applied where a respondent had stated that an item is always consumed (in question 1) or perceived as edible under all circumstance (in question 2). In contrast, a score of 0 indicated that the item is never consumed or is perceived as inedible under all circumstances. Responses of "This is not relevant to me" for question 1 or "I have no opinion" for question 2 were excluded from the calculations of average scores. For each item, three averages were calculated: one for question 1, one for question 2 and an average of the two questions (see Table 1).

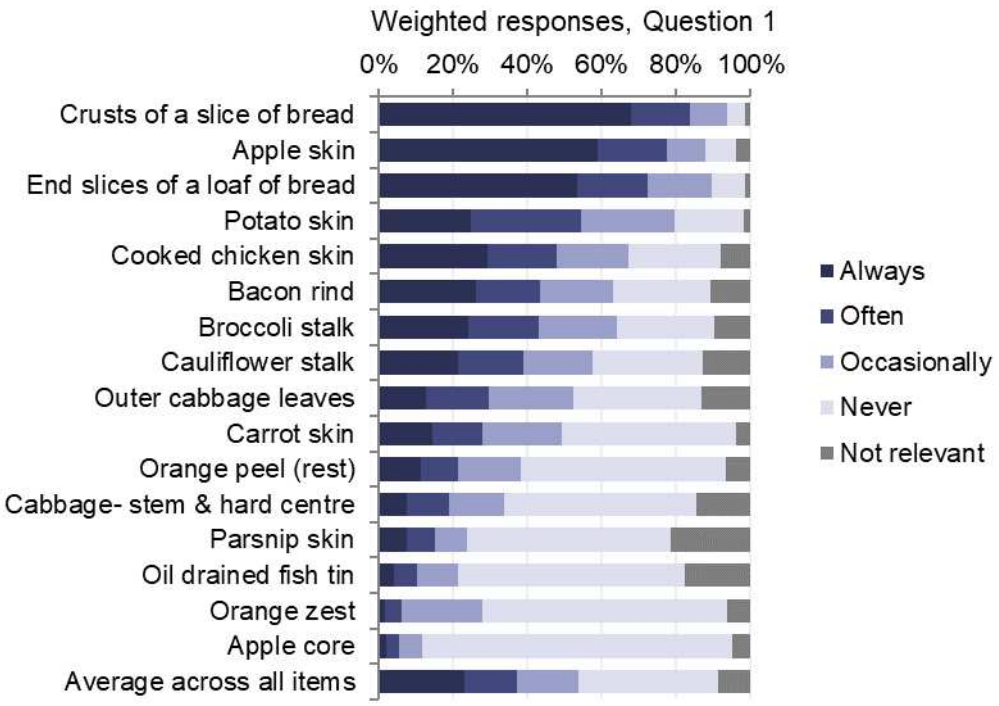
Initially, it was thought that responses from question 2 would predominantly be used in the classification of edible and inedible parts. However, as discussed later in this paper, the difference found between the average scores from question 1 and 2 suggested that there were multiple facets relating to the issue of edibility. Therefore, there would be merit in incorporating information from both questions into the categorisation process. It would lead to a more 'balanced' method that better reflects the underlying social and psychological phenomena. Consequently, the average score across question 1 and 2 was taken for each item and this was used, with the 0.5 threshold, to categorise food

items. Items that scored above a threshold of 0.5 were deemed ‘food’ (i.e. edible), whereas items with a score below were classified as ‘inedible parts’. The threshold value (0.5) was selected as this represents the majority view of the population. We present the full results of both questions in this paper so that the impact of these decisions can be seen and assessed by the reader.

Data analysis and production of graphs was conducted using Microsoft Excel and R v.3.4.1 (R Core Team 2017).

3. Results

The survey results indicate that, of the items listed, crusts of bread, apple skin and the end slices of a loaf of bread had the highest levels of self-reported consumption (Table 1 and Figure 1), with 'scores' of 0.73 to 0.83 (where 1 would represent all survey respondents stating that they 'always' consume these parts, and 0 representing all stating that they 'never' consume them). At the other extreme, apple cores were the least consumed with an edibility score of 0.07, reflecting the result that 83% of respondents reporting that they never eat apple cores, with the remaining 17% eating them 'occasionally', 'often' or 'always'. Responses to items were relatively polarised with one of the two most extreme responses ("I always eat this part of the item" and "I never eat this part of the item") selected 61% of the time compared to 31% for intermediate responses[3]. This suggests that, for most people, they either eat an item or don't eat it – the circumstances surrounding the decision are not so important. The main exception to was potato skins, where the division of responses between options was most evenly distributed: 55% of respondents gave 'intermediate responses'.



[3] The remaining respondents (9%) gave the response: 'This is not relevant to me (for example, I don't buy this type of food)'. Percentages quoted for this question add to 101% due to rounding. Subsequent rounding anomalies are for the same reason.

Figure 1: The weighted responses to Question 1 ('Which of these items do you eat, assuming they are appropriately cooked and in good condition?')

Only 5 of the 16 items obtained an edibility score of 0.5 or above from this first question (Table 1). There was a substantial gap between the scores of the top three items (all 0.73 or above) and the next item in the list: potato skin (0.54). There was a large spread of scores across the remaining items.

Food item	Previous classification in WRAP 2013	Self-reported consumption	Perception of edibility	Average score
Crusts of a slice of bread	Possibly avoidable	**0.83**	**0.94**	**0.88**
End slices of a loaf of bread	Possibly avoidable	**0.73**	**0.92**	**0.83**
Apple skin	Possibly avoidable	**0.78**	**0.86**	**0.82**
Cooked chicken skin	Possibly avoidable	**0.52**	**0.79**	**0.66**
Potato skin	Possibly avoidable	**0.54**	**0.77**	**0.65**
Bacon rind	Possibly avoidable	0.50*	**0.76**	**0.63**
Broccoli stalk[a]	Possibly avoidable	0.49	**0.72**	**0.60**
Cauliflower stalk[a]	Unavoidable	0.45	**0.71**	**0.58**
Outer cabbage leaves[b]	Possibly avoidable	0.24	**0.68**	**0.52**
Carrot skin	Possibly avoidable	0.32	**0.71**	**0.51**
Parsnip skin	Unavoidable	0.20	**0.61**	0.41
Cabbage- stem & hard centre[a]	Unavoidable	0.24	**0.58**	0.41
Orange peel (rest)	Unavoidable	0.25	**0.53**	0.39
Oil drained fish tin	Possibly avoidable	0.15	**0.56**	0.35
Orange zest	Unavoidable	0.13	**0.51**	0.32
Apple core	Unavoidable	0.07	0.41	0.24

*Table 1: The scores for items of food across question 1 and 2 and the average of both questions. Values shaded in grey are above a 0.5 threshold indicating that they are eaten often or always and deemed edible by the majority of the population surveyed. *Bacon rind is below the threshold of 0.5 at 0.496, rounded to 0.50 to 2 decimal places.*

For previous classification in WRAP 2013, the following categories were used:

[a] 'Tops/Stalks/Ends'

[b] 'Leaves'

The food items indicated as most consumed in question 1 (crusts of bread, the end slices of a loaf of bread and apple skin) were also indicated as most edible in question 2 (Table 1 and Figure 2). The responses for the perceived edibility were not as polarised as the responses to question 1: for question 2, 47% of people selected 'intermediate' response options, compared with the 31% of people in question 1.

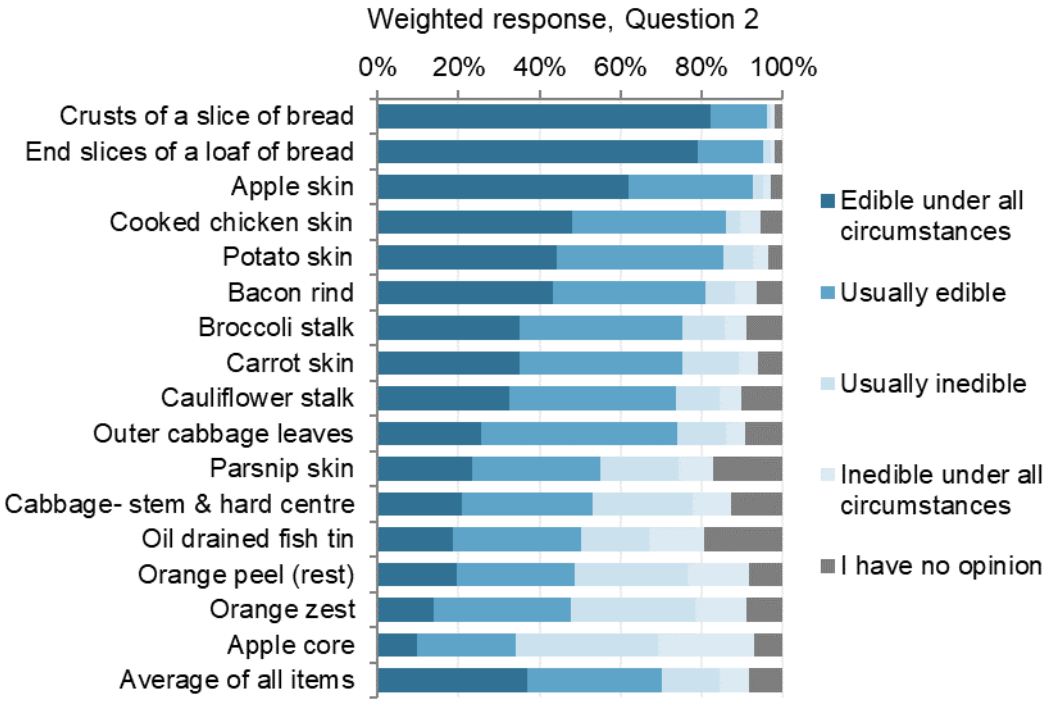


Figure 2: The weighted responses to Question 2 ('Which of these items do you consider inedible and which could possibly be eaten, even if you don't eat them yourself?').

For all food items, the score relating to perceptions of edibility was higher than the self-reported consumption score (Table 1 and Figure 3). This resulted in 15 out of the 16 items having an edibility score (i.e. relating to question 2) greater than 0.5; only apple cores scored below the threshold (0.41). This means that ten items have a score below 0.5 when asking about what people eat (Q1), but above this threshold when discussing what is considered edible (Q2). These include oil drained from fish tins, orange peel, bacon rind, broccoli stalk, carrot skin. For example, parsnip skins scored 0.2 on Q1 - i.e. most people don't eat them, but 0.61 on the edibility score, suggesting the majority thought they are

edible. In general, this suggests that many people are willing to state that items are edible, even if they don't personally eat them.

Table 1 also includes the previous classification for the 16 items in questions 1 and 2. This shows that most of the food parts classified from the new method as edible were previously classified as possibly avoidable, the exception being cauliflower stalks. Similarly, most of the food parts classified as inedible in the new method were classified as unavoidable previously (oil drained from a can being the exception in this case).

It was found that a strong positive correlation (R^2 = 0.92) exists between the scores for Q1 and Q2 (Figure 3), suggesting that there is a strong degree of consistency in responses. Therefore, on average, the responses to question 1 could be used to predict the responses to question 2, and vice versa, reasonably accurately. The regression trendline differs substantially from a slope of one ($x = y$), such that the gap between the scores from the two questions is largest for items with low scores (low perceived edibility, even lower self-reported consumption).

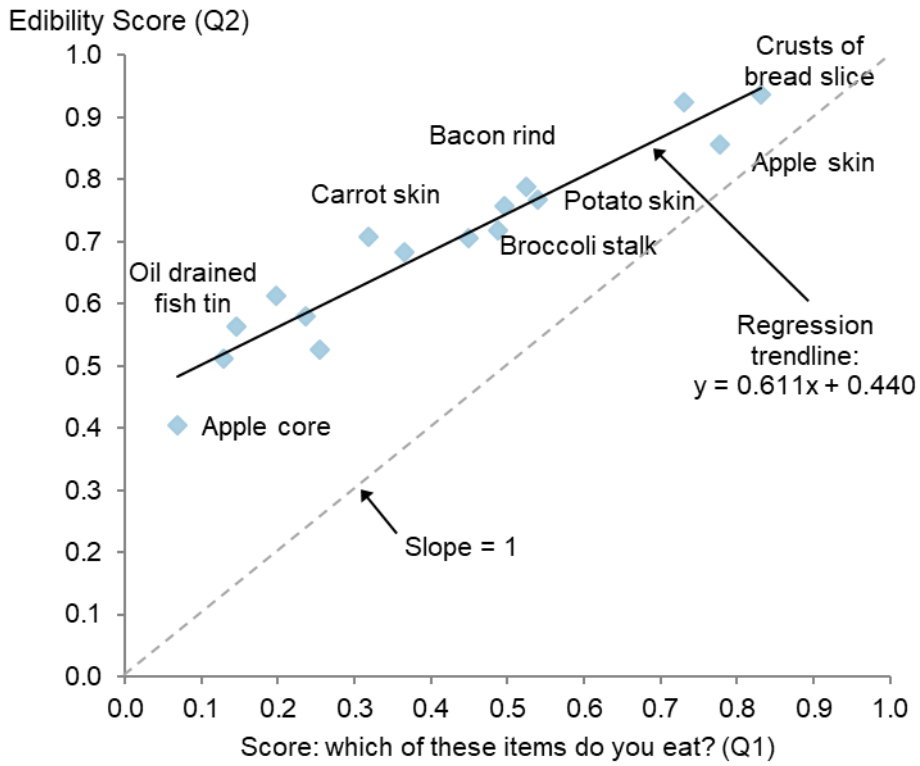


Figure 3: Correlation between average scores from question 1 and 2. A trendline for this relationship is displayed (R^2 = 0.920). A trendline of slope equal to one is displayed to illustrate where items would fall if they had the same score for each question. Some food items are labelled for illustrative purposes.

Given the difference in scores between the two questions, the choice of which questions to include in the classification of items between food (edible parts) and inedible parts strongly influences the results. For the classification of UK household data into edible parts (i.e. wasted food) and inedible parts (WRAP 2018), it was decided to use a combined metric using information from both questions. This was due to the authors' view that each question reflected a different aspect of people's view on the edibility of an item, and therefore both should be included in the metric. In short, whether people in a particular population believe an item is 'edible' is signalled by both whether people state that it is edible and whether they actually eat it. For instance, in the case of parsnip skins, people were more likely to say that these were edible than not; however, given that most people in the survey stated that they don't eat them, it would seem against the general findings of the survey to classify these as edible (using a cultural definition). For these reasons, a composite metric was used as it was felt to better reflect both self-reported consumption and perception of edibility. Using the average score of

the two questions, 10 of the 16 items are deemed edible including bacon rind, carrot skin, cabbage leaves, broccoli stalk and cauliflower stalk which would otherwise been considered inedible if just self-reported consumption were considered (Figure 4, Table 1).

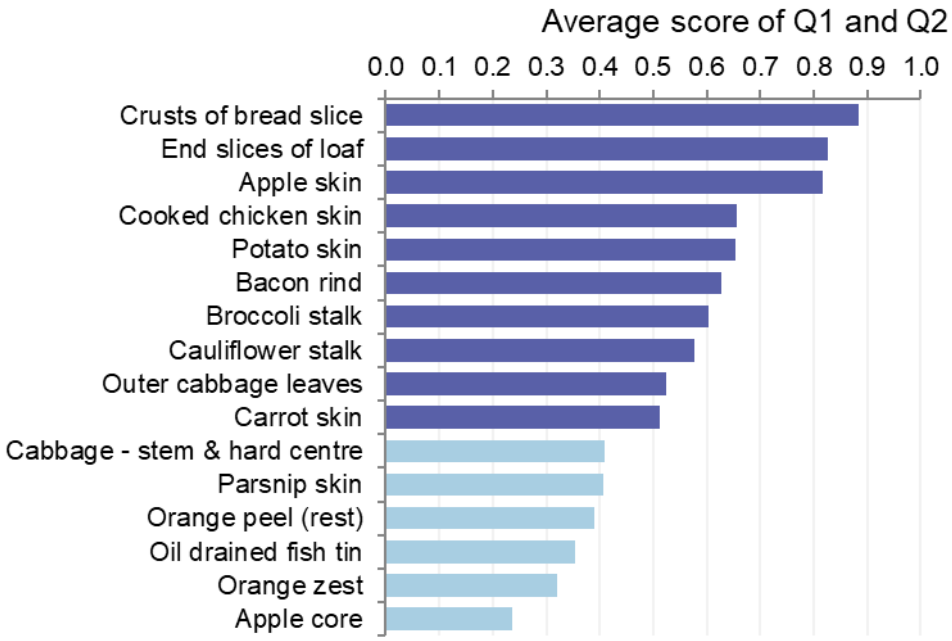


Figure 4: The average score of items from question 1 and 2. A score of 1 represents items that are always consumed and always edible whereas a score of 0 are foods that are never eaten and seen as being inedible. Bars in dark blue are above the 0.5 threshold applied to represent majority of the study population.

Questions 1 and 2 included response options if respondents deemed an item was not relevant (e.g. they didn't eat it) or if they had no opinion on its edibility. On average, across all the items listed in the survey, 91% of respondents thought they were relevant (Q1) and 92% had an opinion regarding edibility (Q2). Only 4 items were not relevant for more than 10% of the population and roughly the same percentage of the population did not have an opinion on the item (parsnip skins, oil drained from fish tins, cabbage- stem and hard centre, cauliflower stalk). The number of respondents who did not think items were relevant was positively correlated (R^2 = 0.83) to the number of those who did not have an opinion (Figure 4).

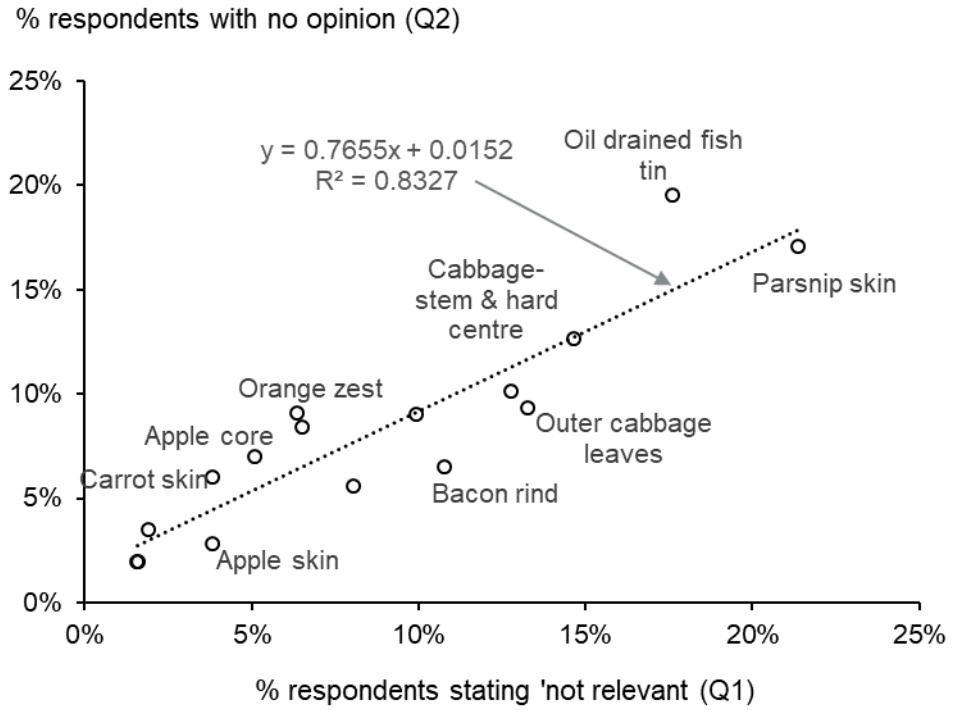


Figure 5: The correlation between the number of respondents answering not relevant for Q1 and who had no opinion for Q2.

As stated above, bones were not included in question 1 and 2 as, during a pilot study, respondents found it difficult to categorise bones if they were used to make stock, a process in which some of the mass of the bone is incorporated into the liquid of the stock. Consequently, two additional questions regarding the use of bones to make stock and the frequency of this practice were presented within the questionnaire. Of those surveyed, 28% of the population report making stock from bones and 72% didn't (0.3% responded 'Don't know'). Of those who reported making stock: 22% stated that they make stock every time that they have bones, 24% more than half the time, 21% about half the time, 17% less than half the time and 17% rarely. As not all the bones were used to make stock and such a small proportion of bone is incorporated within the stock, bones were classified as inedible parts in WRAP's most recent report on household food waste (WRAP, 2018).

382 The level of responsibility that the respondent had for the preparation and cooking of food within the
383 household was also asked. Dividing the population based on level of responsibility revealed only small
384 differences in the average score across all items (0.02 for Q1 and 0.06 for Q2). Therefore, it was found
385 that responses on self-reported consumption and perceptions of edibility were not strongly correlated
386 with the level of responsibility the respondent had for the preparation and cooking of food.
387
388 ## 4. Discussion
389 We present a simple, reproducible methodology which captures self-reported consumption and
390 perceptions of edibility which can be used to classify foods, or parts of food, as either edible (i.e.
391 wasted food) or inedible. The objective of the study was to classify items from a cultural perspective
392 (whether people within a given population generally consider them edible) rather than trying to
393 understand which items could be ingested without harm (i.e. technically edible). The results from this
394 study highlight the importance of collecting information on both perceived edibility and what people
395 claim to eat when considering the quantification of food waste, as the two can differ to a relatively
396 large degree.
397
398 Prior to undertaking the research, it was envisaged that the question on perceived edibility would be
399 used to classify items as edible or inedible. The rationale was that this question is most closely aligned
400 to the classification – it directly asks people their opinion about what is edible or inedible. This would
401 result in classification of several items such as orange peel as edible; however, responses to question
402 1 clearly demonstrate that orange peel is not regularly consumed by the majority of the population.
403 Furthermore, data on the amount of orange peel thrown away from UK households suggests that the
404 vast majority is not consumed (WRAP 2014).
405
406 The responses on perceived edibility clearly don't align with self-reported consumption and data on
407 household food waste – i.e. people are more likely to say that an item is edible than say they

themselves eat it. This may be an accurate representation of people's views and behaviour: people are less likely to consume items than deem them edible. However, it could also be influenced by the question wording and / or biases in the responses. The exact question wording ("For the same list of foods, which of these items do you consider inedible and which could possibly be eaten, even if you don't eat them yourself?") means that the food part only has to be considered ***possibly*** edible for someone to accurately choose one of the 'edible' options. In the case of orange peel, marmalade or cake baking may be examples where orange peel is consumed, which, combined with the question wording, could have increased the edibility score (Q2) relative to other question wording. Another source of possible bias is social desirability: respondents are aware that the questionnaire is about food waste and therefore respond according to minimise the perception that they are wasteful. Whichever the mix of factors at play, only using the answers from question 2 is unlikely to produce an accurate classification of food items: if we want to reflect cultural norms, the parts of foods which are actually eaten are also important.

Similarly, classifying food items based solely on responses to question 1 would also lead to a different, much shorter list of edible foods. The spread of scores from question 1 suggests a complex picture of consumption behaviour particularly with items, such as potato skins, chicken skins and broccoli stalks, which scored between 0.4 and 0.6. The mid-range scores for these items indicate that their consumption varies between members of the population and, for some items, may depend on the exact state of the item or how it is prepared. For example, potato skins might be consumed when cooked as a baked potato but not consumed when potatoes are regularly peeled prior to roasting. When classifying items (e.g. those found in waste compositional analysis or recorded in food-waste diaries), it is usually impractical to have different categorisation for the same item in different situations (e.g. to classify a potato skin as edible when baked, but potato peelings generated prior to roasting potatoes as inedible). Therefore, although applying a 0.5 threshold may not be perfect in that

it creates a sharp distinction within a graduated phenomenon, it does allow a pragmatic approach to classifying items as edible or inedible in situations where such a classification is useful.

Table 1 compares the classification based on the new method, with that used previously (WRAP 2013) to classify these items. As noted in the results, most edible items using the new method were previously classed as 'possibly avoidable'; most inedible items using the new method were previously 'unavoidable'. This high level of correlation suggests that the previous method for classification – the researchers using their experience and wider knowledge – gives similar results to using this new methodology. However, the two exceptions mentioned above suggest that the researchers' knowledge was not always in line with the majority of the public. Therefore, we consider that the new method is an improvement on that previously used by WRAP.

It is instructive to compare the approach in this paper to that in the study published by the Danish Centre for Food and Agriculture (Aarhus University, Denmark) who published the *Consumer Food Waste in Denmark* report (Stancu & Lähteenmäki 2018). In this report, the authors include a survey to determine whether food items are edible; however, there is no feedback on the actual consumption of items. Given the results from our survey, it suggests that consumption behaviour is an important aspect when classifying food items and therefore should not be neglected. Furthermore, in the Consumer Food Waste report, the state of the item is included for some foods (e.g. browned bananas; Stancu & Lähteenmäki 2018) but not others. The inclusion of a particular state for a food item likely changes the perception of edibility and therefore cannot be used to determine edibility of the item in a different state.

We achieved the incorporation of both behaviours and perception by averaging scores across question 1 and 2, which affects the classification of several borderline items. We believe this approach captures the complexity of cultural acceptability of food: what is eaten from question 1 and what people think

459 is edible from question 2. Ultimately, dividing food waste into two categories (edible and inedible) will
460 automatically result in a loss of detail as – as seen in the results of the survey – edibility lies on a
461 spectrum. Categorisation of items will inevitably result in a few items being classified as edible when
462 some members of the population believe them to be inedible, and vice versa. The occurrence of this
463 can be minimised by verifying results from the survey with compositional analysis, food and photo
464 diaries. The combination of these data sources should give sufficient detail to allow accurate
465 classification of food items and an in-depth analysis of food waste.
466
467 The results described in this paper have already been applied to existing datasets to reclassify UK
468 household food waste data: i.e. estimates for 2012 from WRAP (2013) were reclassified for WRAP
469 (2018). These new results are in accordance with the Food Loss and Waste Accounting and Reporting
470 Standard, which recommends using categories: wasted food and associated in edible parts (FLWP,
471 2016). The methodology was applied to guide the reclassification of these items from groups based
472 on avoidability (see introduction) to either edible or inedible. At the same time, food which is fed to
473 animals was omitted from the results, which resulted in an overall change in the total of UK household
474 food waste (for 2015) from 7.3 to 7.1 million tonnes (WRAP 2018). However, the amount of wasted
475 food (i.e. edible food waste) was 5 million tonnes in 2015, greater than the 4.4 million tonnes
476 previously classified as avoidable. This was because some items which were previously classified as
477 possibly avoidable were reclassified to edible, such as the crusts of bread and potato peel / skins (see
478 table 1). Items which were borderline and not included in the survey were classified by using the
479 survey results to guide decisions: e.g. using suitable proxies from the list of items in the survey.
480
481 We envisage that aspects of the questionnaire would need to be altered if this methodology were to
482 be applied in different countries or different parts of the supply chain (e.g. in agricultural production).
483 The food items selected for this study were based on common food items found in UK household
484 waste. The results of the relevance of the food items (Figures 1 and 2) indicate that the majority of

items were appropriate for the target population. Respondents who found the food items not relevant tended to also have no opinion on the item suggesting that these respondents either don't know or have no interest in food items that they do not consume. If the questions were deployed in another country, it may be appropriate to select different items: those frequently identified in food waste within the specific study region. Additionally, a threshold of 0.5 could be altered; however, in this study it was the authors' intention to categorise the items based on the behaviours and perceptions of the majority of the population. In locations where there are clear distinctions in eating practices between different groups within the population, selecting a 0.5 threshold may not be appropriate and a different approach to capture the balance between behaviours and perception may need to be applied.

Using this methodology offers researchers the opportunity to be descriptive about cultural practices rather than prescriptive. This will allow comparison between a range of cultural practices across the globe as well as the ability to track changes in cultural attitudes towards food items in the UK which may aid the evaluation of food waste reduction strategies.

This study primarily focuses on quantification: improving the classification of items in practice. Although it was not intended to directly inform the behavioural literature, the findings within this study may be of benefit to this area: for instance, in designing interventions for preventing food waste, it helps understand to understand how people view different parts of items. This information could be used to target particular foods, e.g. to influence the population so that more parts of food are consumed. This is topical: at the time of writing, the Love Food Hate Waste campaign has just launched a campaign called 'Compleat', encouraging people to eat all of certain food items, focusing on certain fruits, vegetables and bread crusts.

Any intervention of this sort should consider the wide range of implications that could ensue. For some food parts such as bacon rind, which is very high in fat, encouraging this to be eaten regularly could lead to negative health outcomes. More research is required to understand if more is eaten as a result, both in total and of the food in question. For health, this could be both negative (more calories) or positive if the parts in questions are vegetables. It could also impact on purchases – if for instance, broccoli stalks are consumed, it could lead to less broccoli being purchased, as a higher percentage of the item is consumed; again, more research is required in this area.

4.1 Limitations

There are several areas in which this methodology could be improved. Primarily, this methodology relies on self-reported information and is therefore subject to several cognitive biases, including social desirability bias as mentioned previously. In order to minimise these biases, the survey may benefit from further development and testing, particularly focusing on the wording of questions. This could be addressed through cognitive testing or focus groups which would help gain an understanding of social and cultural connotations linked to specific words e.g. whether the use of 'rind', 'skin' or 'peel' to describe food items influences the responses. In addition, future research in this area could look at the number of questions asked. The two main questions that this study relies on are relatively small in number due to wanting to develop a practical solution that could be adopted by practitioners, often with constrained budgets. There is the potential for a 'more-rounded' classification to be developed by asking a wider range of questions about edibility. However, in developing a methodology that will be adopted by practitioners, future studies should focus on understanding the minimum number of questions for a classification to be viable.

The food items selected for inclusion in the survey were done so based on previous research findings; however, it may be more apt to hold focus groups to determine borderline items from a sample of the population. The number of food items for this survey was limited to 16 as including additional items

into the survey risked incurring respondent fatigue. The categorisation of food items not included in the survey was done based on the use of proxies, for example, the peelings of many other root vegetables were considered inedible as parsnip skin was classified as inedible. This process was done at the authors' discretion and once again introduces subjectivity into the classification process. This could be addressed by deploying the survey to a larger sample, with different subsamples seeing a different set of food items. This would avoid respondent fatigue whilst collecting information on a wider range of food items. Alternatively, feedback from focus groups of respondents after completing the survey could be used to gain an insight as to why certain items were ranked in a certain order, for example, to gain an insight as to why carrot skin is viewed as more edible than parsnip skin. This would facilitate more rigorous classification of the food items not included in the survey.

Finally, the response options to questions 1 and 2 are discrete options that fall on a continuum. The scoring system assumes that research participants perceive these options as evenly spaced along a continuum; however, respondents may not perceive them in this way. Consequently, the application of scores to responses assuming equal spacing may not accurately reflect intentions or thoughts of the participants and could influence the conclusions drawn. This issue is difficult to address. A potential solution to visualise this continuum is to use *Think aloud* protocols in the piloting of questions (Ericsson & Simon 2010). This would require a small group of pilot participants to go through the survey and let them verbalize their thoughts and perceptions aloud.

Despite these limitations, this methodology provides a practical, low-cost solution, applicable in a range of geographies to achieve location-specific information on self-reported consumption and perceptions of edibility. Funding and time would be required to address the limitations mentioned above; however, the authors believe this methodology is an important step towards using cultural information to define edible and inedible parts of food items.

5. Conclusions

Food waste is a global issue which needs to be addressed urgently, and the accurate quantification of food waste is required to support effective food waste reduction strategies. One important step in this quantification is the ability to differentiate food waste into edible and inedible parts. This study presents an easily reproducible, questionnaire-based methodology to guide this classification. To the authors' knowledge, this is the first of its kind and an important starting point from which further progress can be made. It uses survey responses on what people claim to eat and what they think is edible to categorise items. The results from this study indicate that, with borderline food items, self-reported consumption and perception of edibility do not always overlap. We therefore consider it important to use a metric that combines both these aspects in order to reflect cultural acceptability of different parts of foods. It is the authors hope that this methodology will be utilised within international research to classify food waste accounting for cultural influences. Categorising food waste in this standardised way means that measurements can be compared, facilitating the development and efficient monitoring of global strategies to reduce food waste.

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689 **APPENDIX – Questionnaire developed for study**

690 Preamble: A not-for-profit organisation that regularly reports on the amount of food thrown away in
691 the UK is currently revising its definitions relating to food waste. To do this, it is finding out the
692 opinions of the UK population.

693 Q1: Please look at the list of foods below. Which of these items do you eat, assuming they are
694 appropriately cooked and in good condition?

Food item	I **always** eat this part of the item	I **often** eat this part of the item	I **occasionally** eat this part of the item	I **never** eat this part of the item	This is not relevant to me (for example, I don't buy this type of food)
Cooked chicken skin	☐	☐	☐	☐	☐
Bacon rind / fat	☐	☐	☐	☐	☐
Potato skin / peel	☐	☐	☐	☐	☐
Carrot skin / peel	☐	☐	☐	☐	☐
Parsnip skin / peel	☐	☐	☐	☐	☐
Stalk of a head of broccoli	☐	☐	☐	☐	☐
Stalk of a head of cauliflower	☐	☐	☐	☐	☐
Outer leaves of a cabbage	☐	☐	☐	☐	☐
Cabbage stem and hard centre	☐	☐	☐	☐	☐
Apple core	☐	☐	☐	☐	☐
Apple peel / skin	☐	☐	☐	☐	☐
Zest from orange peel (the outer coloured part of the peel)	☐	☐	☐	☐	☐
The rest of the orange peel (the white part)	☐	☐	☐	☐	☐
End slices of a loaf of bread	☐	☐	☐	☐	☐
Crusts of a slice of bread	☐	☐	☐	☐	☐
Oil drained from a tin of fish	☐	☐	☐	☐	☐

Q2: For the same list of foods, which of these items do you consider inedible and which could possibly be eaten, even if you don't eat them yourself? Again, please assume that the items are appropriately cooked and in good condition.

Food item	Edible under all circumstances	Usually edible	Usually inedible	Inedible under all circumstances	I have no opinion
Cooked chicken skin	☐	☐	☐	☐	☐
Bacon rind / fat	☐	☐	☐	☐	☐
Potato skin / peel	☐	☐	☐	☐	☐
Carrot skin / peel	☐	☐	☐	☐	☐
Parsnip skin / peel	☐	☐	☐	☐	☐
Stalk of a head of broccoli	☐	☐	☐	☐	☐
Stalk of a head of cauliflower	☐	☐	☐	☐	☐
Outer leaves of a cabbage	☐	☐	☐	☐	☐
Cabbage stem and hard centre	☐	☐	☐	☐	☐
Apple core	☐	☐	☐	☐	☐
Apple peel / skin	☐	☐	☐	☐	☐
Zest from orange peel (the outer coloured part of the peel)	☐	☐	☐	☐	☐
The rest of the orange peel (the white part)	☐	☐	☐	☐	☐
Orange peel / skin	☐	☐	☐	☐	☐
End slices of a loaf of bread	☐	☐	☐	☐	☐
Crusts of a slice of bread	☐	☐	☐	☐	☐
Oil drained from a tin of fish	☐	☐	☐	☐	☐

Q3: Do you make stock by boiling bones (e.g. chicken bones)?

- Yes
- No
- Don't know

Q4: (as if 'Yes' to Q3) You mentioned that you make stock by boiling bones. How often do you make stock?

- Every time that I have bones (for example, leftover from meat / carcases)
- More than half the time that I have bones
- About half the time that I have bones
- Less than half the time I have bones
- Rarely

Q5: How responsible are you for the preparation and cooking of food in your house, if at all?

- I have responsibility for all or most of it
- I have responsibility for about half of it
- I have responsibility for some, but less than half of it
- I'm not responsible for any of it