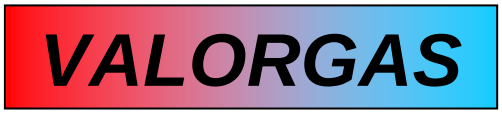

# SEVENTH FRAMEWORK PROGRAMME
# THEME ENERGY.2009.3.2.2
# Biowaste as feedstock for 2nd generation

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## D2.1: Compositional analysis of food waste from study sites in geographically distinct regions of Europe

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MTT Agrifood Research Finland

Revision [1]

# D2.1: Compositional analysis of food waste from study sites in geographically distinct regions of Europe

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**Revisions**

Changes from version [0] consist of the addition of a Table of Contents and list of names of those mainly involved in preparing the report

# Contents

**D2.1 Compositional analysis of food waste from study sites in geographically distinct regions of Europe**

# 1 Introduction

The work described in this Deliverable Report concerned the analysis of food waste based on its major food components. It was carried out firstly with the aim of contributing to our knowledge of the nature and properties of food waste, and in particular of any major regional differences in composition that could impact upon its behaviour as a feedstock for anaerobic digestion; and secondly to provide information on properties and quality to complement assessment of collection schemes. In addition to compositional analysis, preliminary physico-chemical characterisation was carried out on samples of source segregated organic waste.

# 2 Materials and methods

## 2.1 Categorisation system

A variety of categorisation systems have been developed for the main components of waste streams such as the organic fraction of municipal solid waste (OFMSW) and source segregated organic or food wastes from households. Before the VALORGAS project began, three of the partners (Valorsul, Greenfinch and UNIVE) had already carried out compositional characterisation of their waste streams using external or in-house categorisations, each with a slightly different focus. The work by Valorsul was based on the MODECOM system and on national guidelines (ADEME, 1997; DGQA (1989), and included a wide range of materials providing a detailed breakdown of potential contamination in source segregated collection systems. The categorisation used by UNIVE was based on the requirements for adapting source segregated or mechanically-recovered OFMSW to feedstock for anaerobic digestion (Cecchi et al., 2003; Bolzonella et al., 2006); while Greenfinch used an in-house system developed to provide insight into the behaviour of participants in source segregated domestic waste collection schemes. The VALORGAS project also benefitted from a major survey of food waste in England and Wales carried out by the UK government-funded Waste and Resources Action Programme (WRAP). The WRAP study included an extensive sorting programme that characterised domestic food waste into 174 types, combined into 13 major categories. The first task for the current work programme and deliverable was therefore to develop a categorisation system that was practicable to carry out, gave informative results and was compatible as possible with the existing schemes used by the partners and in the WRAP study, in order to maximise the usefulness and comparability of the outputs. The full set of food waste types used by WRAP (2008) and revised in WRAP (2009) was considered too complex and unnecessarily detailed for the current purpose but the major categories were adopted as a framework and mapped to the systems already used by VALORGAS partners. Certain items required special treatment in view of the purpose of the study. The WRAP (2008) categories for fruit and vegetables, which were themselves modified in the WRAP (2009) study, were simplified into two sub-categories of waste (peels, rinds, uneaten residues etc) and whole fruit and vegetables, to allow the possibility of distinguishing between avoidable and unavoidable waste which was a key element in the work by WRAP. A sub-category of 'Large stones, seeds and fibrous

materials' was added, as these items are sometimes rejected by automated pre-treatment systems or in manual sorting for laboratory-scale anaerobic digestion studies. A sub-category 'Bones' was added to 'Meat and fish', as bones are specifically excluded from many source segregated waste collection schemes and are often rejected in pre-treatment screening. A subcategory 'Eggshells' was added to the main category 'Dairy', because of the low biodegradability of this component. A combined category was introduced for confectionery, snacks and desserts as these items are difficult to distinguish and are present only in small quantities. Similarly, the WRAP category 'Condiments, sauces, herbs and spices' was combined with 'Mixed meals' due to the practical difficulty of distinguishing between these items in source segregated food waste. The resulting categorisation system used in the project, and its relationship to the other systems, is shown in Table 1.

## 2.2 Waste materials for compositional analysis

Waste samples for compositional characterisation were obtained from 23 collection rounds in 15 cities across four EU member states. The majority of the collection schemes sampled were located in the UK to ensure the evaluation included a range of collection schemes specifically targeting source segregated food waste.

### 2.2.1 UK

A total of 35 waste compositional analyses were carried out for 16 different collection rounds in 12 locations in the UK, as shown in Table 2.

**Table 2.** Sources of waste for UK compositional analysis

| | Location | Dates | Collection type | No. | Rounds |
|---|---|---|---|---|---|
| 1 | Ludlow [a] | 4 - 7, 10 - 14, 17 - 21 & 28 May 2010 | A | 15 | 5 |
| 2 | Craven Arms [a] | 6 May, 12 May, 19 May 2010 | A | 3 | 1 |
| 3 | Church Stretton [a] | 4 & 5 May, 10 & 11 May, 17 & 18 May 2010 | A | 6 | 2 |
| 4 | Flintshire [a] | 25 May 2010 | - | 1 | - |
| 5 | Presteigne | 27 May & 12 July 2010 | A | 2 | 1 |
| 6 | Ceredigion | 4 June, 18 June 2010 | B | 2 | 1 |
| 7 | Leatherhead | 10 Sep 2010 | C | 1 | 1 |
| 8 | Central Bedfordshire | 9 Sep 2010 | A | 1 | 1 |
| 9 | Ealing | 9 Sep 2010 | C | 1 | 1 |
| 10 | Richmond | 9 Sep 2010 | C | 1 | 1 |
| 11 | Surrey | 9 Sep 2010 | C | 1 | 1 |
| 12 | Hounslow | 9 Sep 2010 | C | 1 | 1 |
| | Total | | | 35 | 16 |

A Small (5 or 7 litre) kitchen caddies with larger (25 litre) kerbside bins collected weekly. Cornstarch bags are supplied free of charge on request

B As above but householder must buy bags or wrap waste in newspaper; only waste in bags analysed

C As a above but householder must pay for cornstarch bags

a Categories Mixed meals and Seed and stones not used in these cases; data therefore treated separately

In each case, food waste is separated from dry recyclable materials, green waste and residual waste by the householder and collected by a local authority or contractor from the kerbside on a weekly basis. The collection rounds were chosen because the waste was collected in biodegradable cornstarch plastic bags, and was not mixed with waste from other sources before delivery.

**Table 1.** Waste categorisation used for VALORGAS with mapping to related systems (numbers show order of categories in original source)

| WRAP revised (2009) | WRAP original (2008) | VALORSUL | VALORGAS | Greenfinch |
|---|---|---|---|---|
| 1 Fresh vegetables and salads<br>3 Fresh fruit<br>8 Processed vegetables and salad<br>14 Processed fruit | 7 Vegetables<br>5 Fruit<br>6 Salads | 1 Vegetables<br>13 Fruit<br>3 Salads | 1 1a Fruit and vegetable waste<br>1b Fruit and vegetables (whole)<br>1c Large stones, seeds and fibrous materials | 1 Fruit & veg peelings<br>2 Fruit & veg whole<br>17 Seeds & stones |
| 10 Staple foods | 4 Dried foods/powders | 8 Dried foods/powders | 2 Pasta/rice/flour/cereals | 3 Pasta/rice/flour<br>9 Cereal |
| 4 Bakery | 1 Bakery | 10 Bakery | 3 Bread and bakery | 4 Bread and bakery |
| 6 Meat and fish | 2 Meat and fish | 9 Meat and fish<br>32 Special - bones | 4 4a Meat and fish<br>4b Bones | 5 Meat and fish<br>6 Bones |
| 7 Dairy and eggs | 3 Dairy | 7 Dairy | 5 5a Dairy<br>5b Egg shells | 8 Dairy<br>7 Eggs |
| 2 Drinks | 9 Drinks | 4 Drinks | 6 Drinks | 10 Tea bags & coffee |
| 13 Confectionery and snacks<br>11 Cake and desserts | 8 Confectionery and snacks<br>11 Desserts | 5 Snacks | 7 7a Confectionery and snacks<br>7b Desserts | 11 Sweets & desserts |
| 9 Condiments, sauces, herbs and spices<br>5 Meals (homemade and pre-prepared) | 10 Condiments, sauces, herbs and spices<br>12 Mixed foods | 12 Condiments, sauces, herbs and spices<br>6 Mixed meals | 8 8a Condiments<br>8b Mixed meals | 16 Mixed meals |
| 15 Other<br>12 Oil and fat | 13 Other | 11 Other food | 9 Other food | 12 Other food material |
| | | | 10 Biodegradable bags | 14 Biodegradable bags |
| | | 2 Garden waste | 11 Garden waste | 13 Non food biodegradable w |
| | | 14 Paper<br>15 Cardboard - packaging<br>16 Cardboard - non packaging | 12 Paper and card | |
| | | 17 Plastic - film bags<br>18 Plastic - bottles<br>19 Plastic - polystyrene<br>20 Plastic - other<br>23 Ferrous metals<br>24 Non ferrous metals<br>21 Glass - packaging<br>22 Glass - non packaging<br>25 Composites<br>26 Textiles<br>27 Sanitary textiles<br>28 Combustibles - wood<br>29 Combustibles - other<br>30 Incombustibles<br>31 Special - packaged organics<br>33 Special - other | 13 13a Plastic containers<br>13b Plastic film (non-biodegradable)<br>13d Metals<br>13e Glass<br>13f Miscellaneous | |

A total of 100 bags were randomly selected from each source: if several delivery vehicles were expected from one source, an equal number of bags was selected from each load. The date and source of collection, total weight of the delivered load (Avery Weigh-Tronix weigh bridge) and the total weight of the selected bags (EHI-B Indicator balances, model PS-102) was recorded to 0.1 kg. The waste was transferred to the characterisation area and the weight of each bag was recorded to 0.1 g (Adam Electrical, model CDW-3). Each bag was opened and visually inspected for the presence of sharps prior to sorting the contents into the defined categories. The nature of any non-food biodegradable material, other food material and contamination was recorded. The weight of material in each sorted category was determined. A core characterisation team performed all the analyses in order to maintain consistency within the project. Photographic evidence was recorded at all stages of the process.

### 2.2.2 Finland

A single sample was taken from the Forssa waste treatment plant in south-west Finland. Envor Biotech Ltd, a waste management company, receives and treats food waste from markets, restaurants, catering services and households in the Forssa region (14 municipalities, around 2800 tonnes $year^{-1}$). In general, each collection scheme includes all types of food waste. All houses with five or more apartments, and stores and restaurants with more than 20 kg $week^{-1}$ have to source-segregate food waste. Individual houses or group of houses can also source-segregate waste for municipal collection, but this is uncommon Materials accepted by the scheme include food leftovers; fruit and vegetable peelings; coffee grounds, filters and teabags; eggshells and egg cartons; paper serviettes; cat faeces and litter; and garden waste (leaves, parts of plants, house plants and flowers). In the households, food waste is source segregated in biodegradable plastic bags or newspaper. If a large biodegradable plastic bag is placed inside the collection bin, this is also acceptable in the scheme. Collection is usually once per week.

For compositional analyses, a load consisting of source-segregated household food waste was selected from the material arriving at the waste management plant on 03.03.2011.

### 2.2.3 Portugal

Valorsul provides collection services for source segregated OFMSW to 2547 large producers (e.g. restaurants, canteens, hotels) and 1988 households in the Lisbon area. For households the waste is collected daily from 120-litre bins serving a number of properties (e.g. apartments) (Figure 1): each property has an individual bin, but biodegradable plastic bags are not provided. Materials accepted by the scheme include vegetables, bread, meat, fish, eggs, cakes and desserts, confectionery/snacks, tea bags, fruit peel and paper napkins. Excluded materials are liquid residues, packaging, crockery, cutlery, baking and aluminium foil papers, plastic bags, cigarette ends and textiles. The waste is transported in 15 $m^3$ refuse collection vehicles with compaction.


a) 120-litre bins with informational materials


b) Individual bins with informational materials

**Figure 1**. Collection system facilities in Loures, Lisbon area, Portugal (Victor, 2008)

For the compositional analysis, five samples of source segregated household waste only were taken from one of two collection rounds serving domestic properties. The first sample was taken in the first week of February 2011, and the remaining samples on four consecutive days in the following week. The selected load was discharged from the collection vehicle and mixed using a wheel loader. A sub-sample of ~250 kg was then taken by quartering the mixed sample which was then sorted by hand on a sorting table with individual components weighed to ±0.01 kg (ADAM scales, Milton Keynes, UK). Figure 2 presents a simple schematic of the process.

### 2.2.4 Italy

A single sample was characterised from Treviso, Italy. The collection system in the city is based on the provision of a centralised bin serving several houses for the collection of source segregated OFMSW: waste is generally disposed of in plastic bags, although the use of biodegradable plastic bags is becoming compulsory. The waste is transported to the Treviso processing site in conventional compaction vehicles. The sample for compositional analysis was taken from bulk material entering the processing site and was obtained by the quartering method, starting from ~200 kg of waste. The initial amount of waste was divided into four parts of ~50 kg each and two opposite segments were chosen: these two segments were mixed again, divided into four parts of ~25 kg and one of these was used as the main sample.

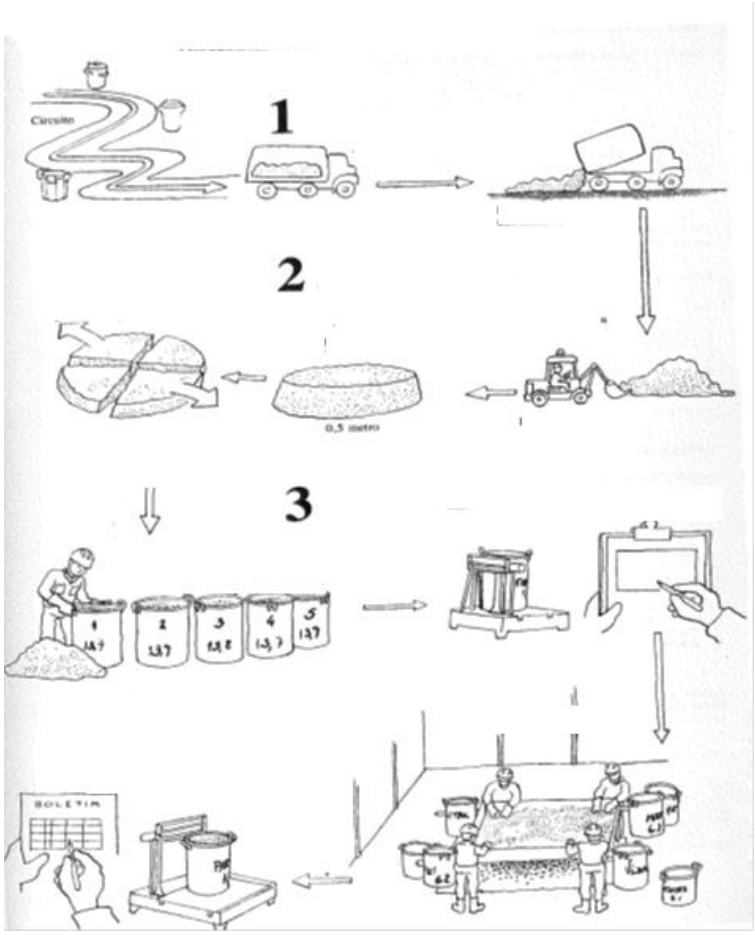



**Figure 2.** Schematic of sampling and characterisation process at Valorsul (DGQA, 1989).

## 2.3 Sample preparation for preliminary physico-chemical analysis

Although full physico-chemical characterisation of the food waste samples was not part of this deliverable, preliminary characterisation was carried out on samples from each of the four study areas to provide information in support of the compositional analysis and to ensure inter-laboratory comparability of analytical results. Analytical work was carried out in three locations: MTT Agrifood Research (MTT, Lab 1), University of Southampton (Soton, Lab 2), and University of Venice (UNIVE, Lab 3). Lab 1 ran parallel analyses on all samples, while Labs 2 and 3 duplicated these on one or more samples.

*UK.* A sample of ~200 kg was obtained from the Eastleigh food waste collection scheme. After the material was transported to the laboratory, the food waste was taken out of biodegradable plastic bags and any contaminants and non-biodegradable components were removed. The material was then processed by passing it through a macerating grinder (S52/010 Waste Disposer, Imperial Machine Company (IMC) Limited, Hertfordshire, UK). This produced a very homogeneous material which was further blended in a single container with a drill mixer to give a mix of which any part was as representative as possible of the entire batch collected.

*Finland.* A sub-sample from the Forssa plant was obtained as described in 2.2.2, but instead of being hand sorted it was first mechanically crushed and screened for plastics, then passed through a full-scale homogenizer at the waste treatment plant to give a particle size of ~2 mm.

*Portugal*. Three samples were taken at the Valorsul anaerobic digestion plant, corresponding to raw waste arriving at the plant, the digester feed, and the reject stream after a pre-treatment process involving manual sorting, shredding, sieving and hydropulping as described by Vaz et al. (2008)

*Italy*. The sample passed through the normal mechanical pre-treatment stages of the plant, including shredding, removal of ferrous iron non-ferrous metals and screening of the residual in a trommel screen (Bolzonella et al., 2006). A final shredding was then performed to reduce the substrate size and ensure homogeneity.

Representative sub-samples of 2-3 kg wet weight were packed in ice and/or frozen and sent from Italy, Portugal and the UK to MTT and from Portugal to UNIVE, arriving on the day after sending. Each sample was first homogenised and then divided into two portions, one for analyses conducted on fresh material, and one for drying. The fresh samples were stored frozen until used, and the dried materials were ground and stored in sealed containers.

The preliminary characterisation included the following analyses: pH, total solids (TS), volatile solids (VS), total organic carbon (TOC), total Kjeldahl nitrogen (TKN), calorific value (CV), lipid, protein, total phosphorus (TP), total potassium (TK), and elemental composition (CHN). Detailed descriptions of methods are given in Appendix A.

# 3 Results and discussion

## 3.1 Compositional analysis - UK

Tables 3 and 4 summarise the results of waste compositional analysis on the UK samples, and Figure 3 gives the values for each site normalised to 100% on a wet weight basis.

**Table 3**. Results of waste categorisation for 8 UK sites (all categories)

| | **Presteigne** | **Ceredigion** | **Leatherhead** | **Central Beds** | **Ealing** | **Richmond** | **Surrey** | **Hounslow** |
|---|---|---|---|---|---|---|---|---|
| | 2-day ave kg | 2-day ave kg | 1 day kg | 1 day kg | 1 day kg | 1 day kg | 1 day kg | 1 day kg |
| Fruit & Veg waste | 50.4 | 100.4 | 96.0 | 64.6 | 91.7 | 97.4 | 52.7 | 94.0 |
| Fruit & Veg whole | 12.3 | 15.8 | 14.2 | 15.7 | 8.6 | 12.0 | 7.8 | 16.1 |
| Seeds and stones | 2.0 | 0.6 | 1.4 | 0.1 | 1.7 | 0.0 | 2.1 | 0.0 |
| Pasta / rice | 0.3 | 1.3 | 2.8 | 2.3 | 4.6 | 0.0 | 0.0 | 2.0 |
| Cereal | 0.5 | 0.4 | 2.4 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| Bread & bakery | 18.1 | 20.1 | 19.9 | 13.7 | 6.3 | 16.5 | 6.9 | 9.0 |
| Meat & fish | 6.6 | 9.8 | 6.9 | 5.3 | 3.6 | 3.5 | 0.5 | 5.1 |
| Bones | 4.0 | 5.1 | 5.4 | 4.5 | 6.7 | 6.9 | 3.0 | 5.9 |
| Dairy | 0.1 | 0.7 | 1.4 | 1.7 | 0.0 | 0.5 | 0.0 | 2.4 |
| Eggs (inc shells) | 1.5 | 2.0 | 2.0 | 2.1 | 1.6 | 2.8 | 1.7 | 1.1 |
| Tea bags / coffee granules | 14.7 | 16.8 | 10.0 | 8.6 | 7.6 | 11.5 | 5.1 | 10.1 |
| Snacks / sweets / desserts | 0.2 | 0.4 | 2.1 | 3.0 | 1.8 | 0.0 | 0.0 | 0.0 |
| Mixed meals | 13.4 | 11.1 | 18.9 | 3.7 | 31.4 | 27.8 | 19.3 | 28.2 |
| Other food materials | 0.5 | 0.8 | 0.0 | 0.0 | 0.0 | 1.1 | 0.0 | 1.6 |
| Biodegradable bags | 6.1 | 3.8 | 10.8 | 2.3 | 7.5 | 9.7 | 6.7 | 8.5 |
| Contamination | 0.2 | 0.6 | 4.2 | 3.9 | 5.6 | 4.9 | 3.3 | 0.3 |
| Non-food biodegradable | 0.3 | 1.0 | 0.0 | 2.3 | 2.7 | 0.0 | 0.0 | 3.2 |
| Total (kg) | 131.0 | 190.7 | 198.4 | 135.7 | 181.4 | 194.6 | 109.1 | 187.3 |
| No of bags | 200 | 200 | 100 | 100 | 100 | 100 | 100 | 100 |

**Table 4**. Waste categorisation for 4 UK sites (without 'Mixed meals' or 'Seeds and stones')

| | Ludlow | | Craven Arms | | Church Stretton | | Flintshire | |
|---|---|---|---|---|---|---|---|---|
| | 3-week ave | | 3-week ave | | 3-week ave | | 1 day | |
| | kg | % | kg | % | kg | % | kg | % |
| Fruit & Veg waste | 55.5 | 49.8 | 60.8 | 52.7 | 62.3 | 53.8 | 34.0 | 48.2 |
| Fruit & Veg whole | 13.7 | 12.2 | 11.4 | 9.9 | 10.6 | 9.2 | 5.0 | 7.1 |
| Seeds and stones | - | - | - | - | - | - | - | - |
| Pasta / rice | 1.2 | 1.1 | 1.2 | 1.1 | 1.8 | 1.5 | 0.2 | 0.3 |
| Cereal | 0.3 | 0.3 | 0.3 | 0.3 | 0.5 | 0.4 | 0.3 | 0.4 |
| Bread & bakery | 13.7 | 12.3 | 15.3 | 13.3 | 11.6 | 10.1 | 8.5 | 12.0 |
| Meat & fish | 5.3 | 4.7 | 4.1 | 3.6 | 5.1 | 4.4 | 7.7 | 10.9 |
| Bones | 4.4 | 3.9 | 3.4 | 2.9 | 4.6 | 4.0 | 6.3 | 8.9 |
| Dairy | 0.7 | 0.6 | 0.3 | 0.3 | 0.7 | 0.6 | 0.4 | 0.5 |
| Eggs (inc shells) | 1.5 | 1.4 | 1.4 | 1.2 | 1.3 | 1.2 | 0.4 | 0.6 |
| Tea bags / coffee granules | 10.0 | 9.0 | 10.3 | 9.0 | 12.0 | 10.4 | 4.4 | 6.2 |
| Snacks / sweets / desserts | 0.3 | 0.3 | 0.5 | 0.4 | 0.6 | 0.5 | 0.1 | 0.1 |
| Mixed meals | - | - | - | - | - | - | - | - |
| Other food materials | 0.4 | 0.3 | 2.6 | 2.3 | 0.4 | 0.3 | 0.7 | 1.0 |
| Biodegradable bags | 2.3 | 2.1 | 2.4 | 2.1 | 2.2 | 1.9 | 2.1 | 3.0 |
| Contamination | 0.4 | 0.4 | 0.3 | 0.2 | 0.4 | 0.3 | 0.0 | 0.0 |
| Non-food biodegradable | 1.8 | 1.6 | 0.9 | 0.8 | 1.5 | 1.3 | 0.6 | 0.8 |
| Total | 111.5 | 100.0 | 115.4 | 100.0 | 115.8 | 100.0 | 70.6 | 100.0 |

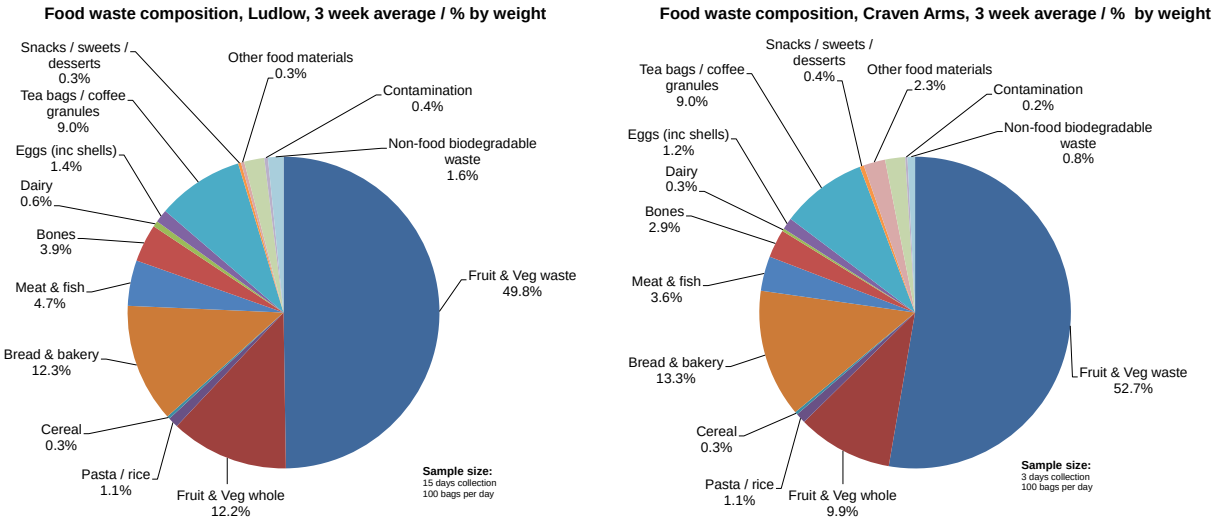
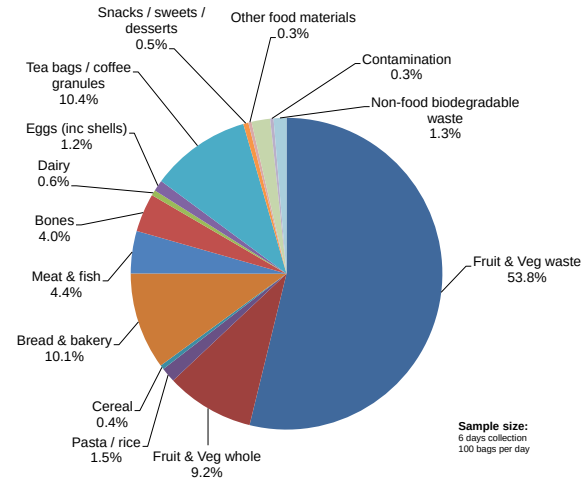
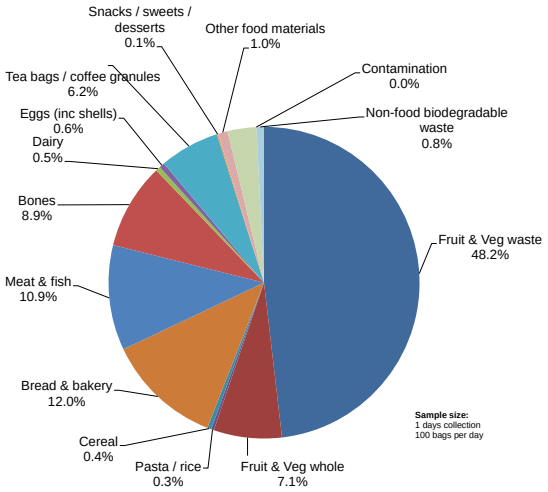



**Figure 3.** Food waste composition from 12 UK collection schemes (NB: Category 'Mixed meals' not used for Ludlow, Craven Arms, Church Stretton or Flintshire)

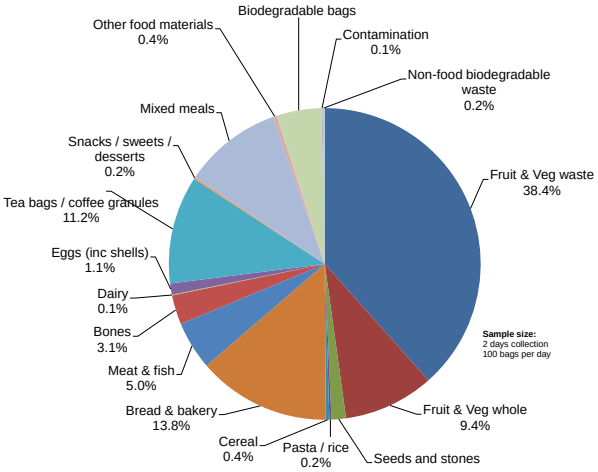
**Food waste composition, Church Stretton, 3 week average / % by weight**



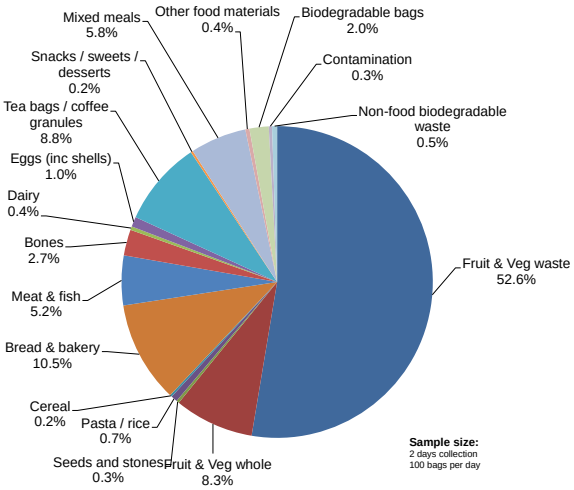

**Food waste composition, Flintshire, 1 day / % by weight**



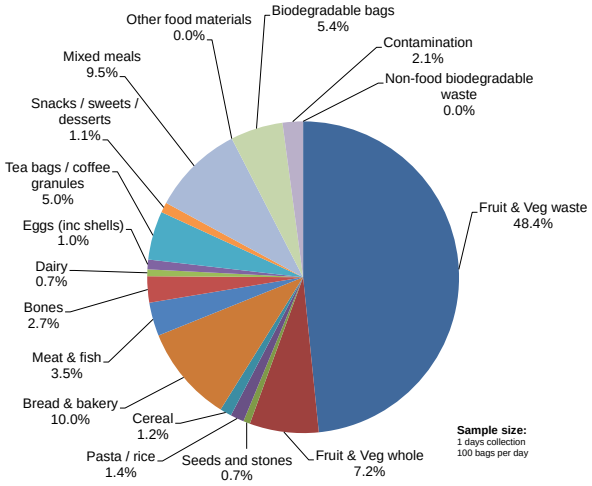

**Food waste composition, Presteigne, 2 day average / % by weight**




**Food waste composition, Ceredigion, 2 day average / % by weight**




**Food waste composition, Leatherhead, 1 day / % by weight**




**Food waste composition, Central Beds, 1 day / % by weight**

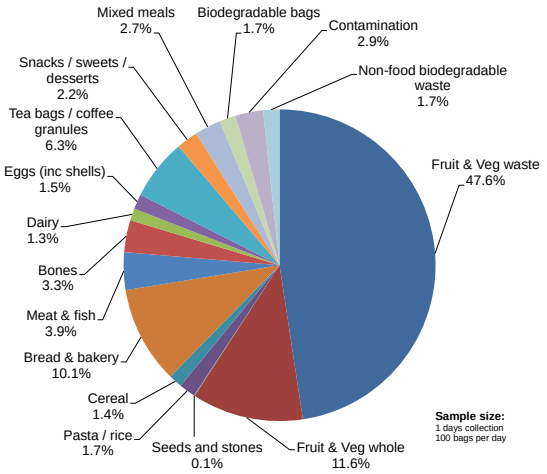



**Figure 3 continued.** Food waste composition from 12 UK collection schemes (NB: Category 'Mixed meals' not used for Ludlow, Craven Arms, Church Stretton or Flintshire)

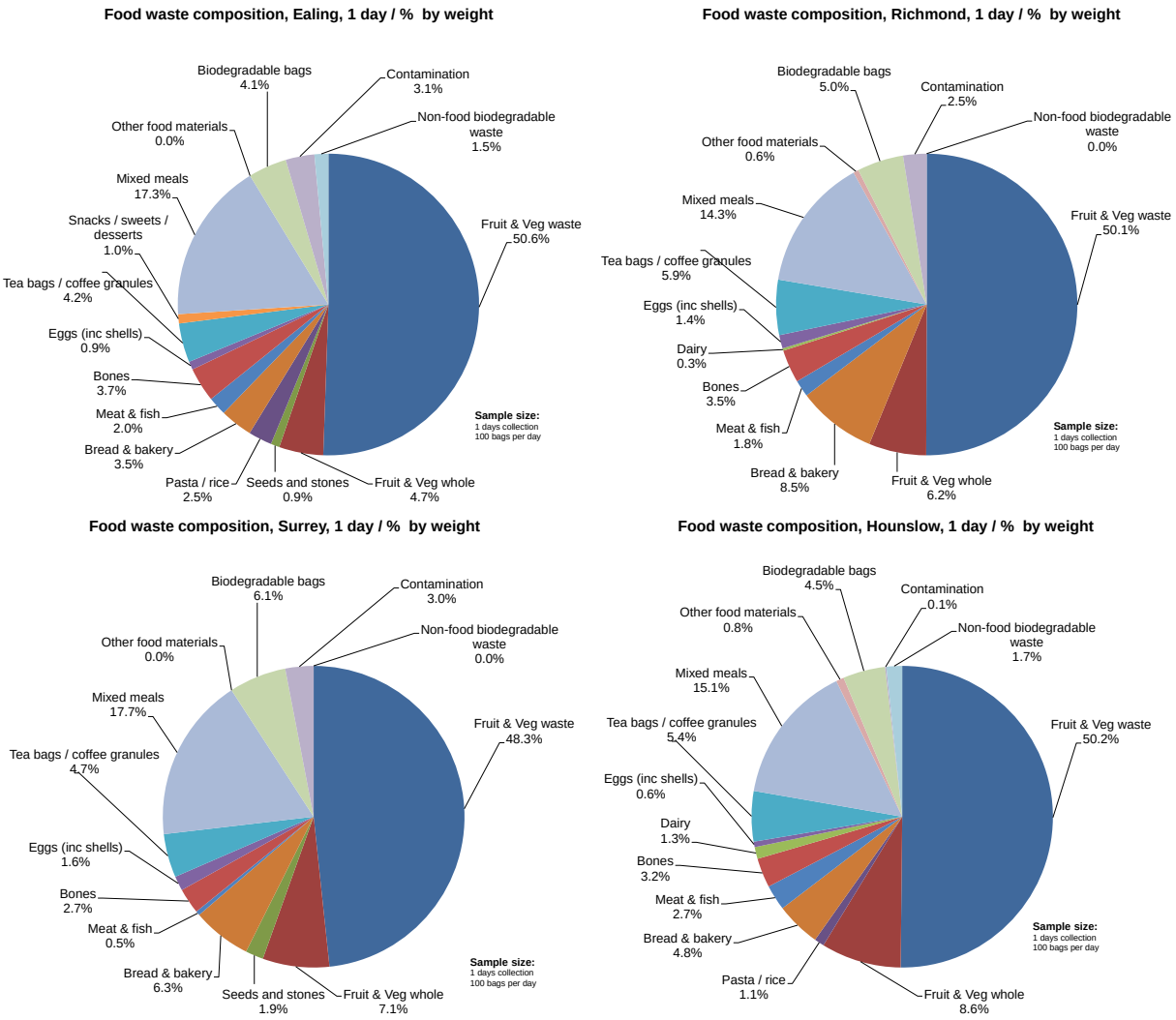



**Figure 3 continued.** Food waste composition from 12 UK collection schemes (NB: Category 'Mixed meals' not used for Ludlow, Craven Arms, Church Stretton or Flintshire)

The composition of the waste at all UK sites was closely similar. The average contamination was low at < 2% of the total sample weight, although the sites could be broadly grouped as low (2-3%: Leatherhead, Central Beds, Ealing, Richmond, Surrey) and very low contamination (< 0.5%: Ludlow, Craven Arms, Church Stretton, Flintshire, Hounslow), possibly reflecting how long the scheme had been established. Biodegradable bags for food waste collection made up around 4% of the total sample weight on a wet weight basis (range 1.7-6.1%). The average biodegradable plastic bag typically weighs 6-10 g (CeDo Ltd, personal communication): as each sort was carried out on 100 bags the expected dry weight of biodegradable plastic would be around 0.5-1% of the total, indicating that about 3% of the wet waste had adhered to the separated bags. In addition to contaminants such as non-biodegradable plastics and paper or card products, a small proportion of biodegradable non-food waste was identified (Tables 3 and 4), mainly consisting of paper, flowers, tissues, pet litter and newspaper. Figure 4 shows an example of sorted materials from Ludlow, including contaminants.


**Figure 4.** Ludlow waste after sorting

At the eight sites where the full set of sorting categories was used, ~56% of the food waste component of the sample (i.e. excluding contaminants, non-food biodegradable waste and also biodegradable plastic bags, as the latter are not used in all collection systems) consisted of the two categories 'Fruit and vegetable waste' and 'Fruit and vegetables whole'. Only one location, Presteigne, showed a slightly lower percentage value for these two categories on both days of sampling. The proportion of 'Fruit and vegetable waste' to whole fruit and vegetables was around 6:1 by weight. Other major categories were 'Mixed meals', 'Bread and bakery', and 'Tea bags and coffee', accounting for on average 11.6, 8.4 and 6.4% respectively of the food waste component.

*Variability between samples.* Figure 5 shows the results for the 8 sites where the full category set was used, expressed as a percentage of the food waste component only. The results for 15 days sampling in Ludlow are shown in Figure 6, expressed on the same basis and grouped according to the collection day (corresponding to a specific collection round). It can be seen that while there is some variation between categories at different sites this is similar in scale to that between different days on the same collection round.

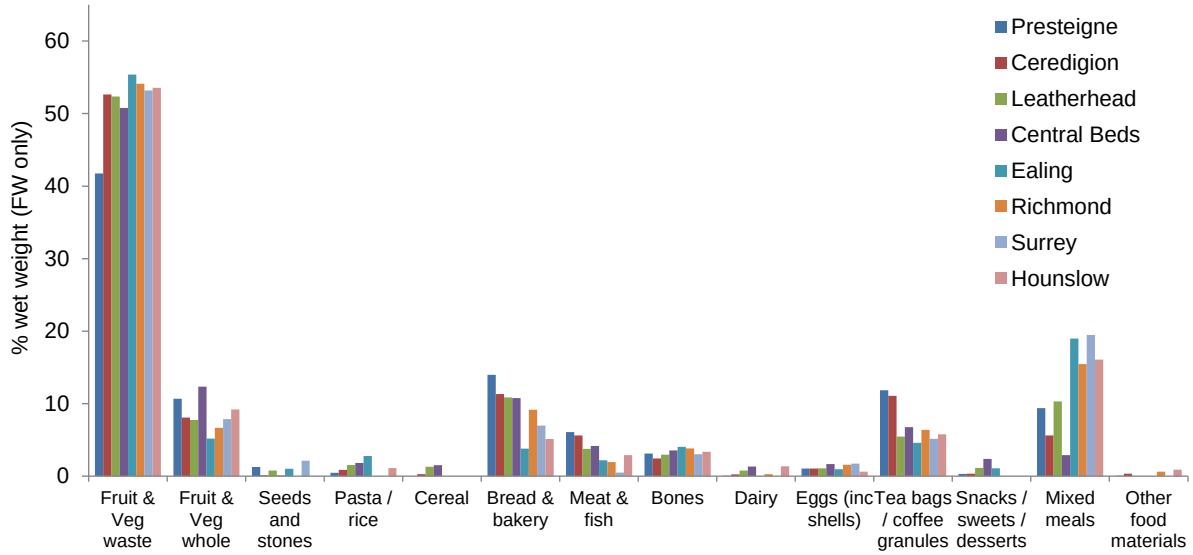



**Figure 5.** Food waste by category for 8 UK sites

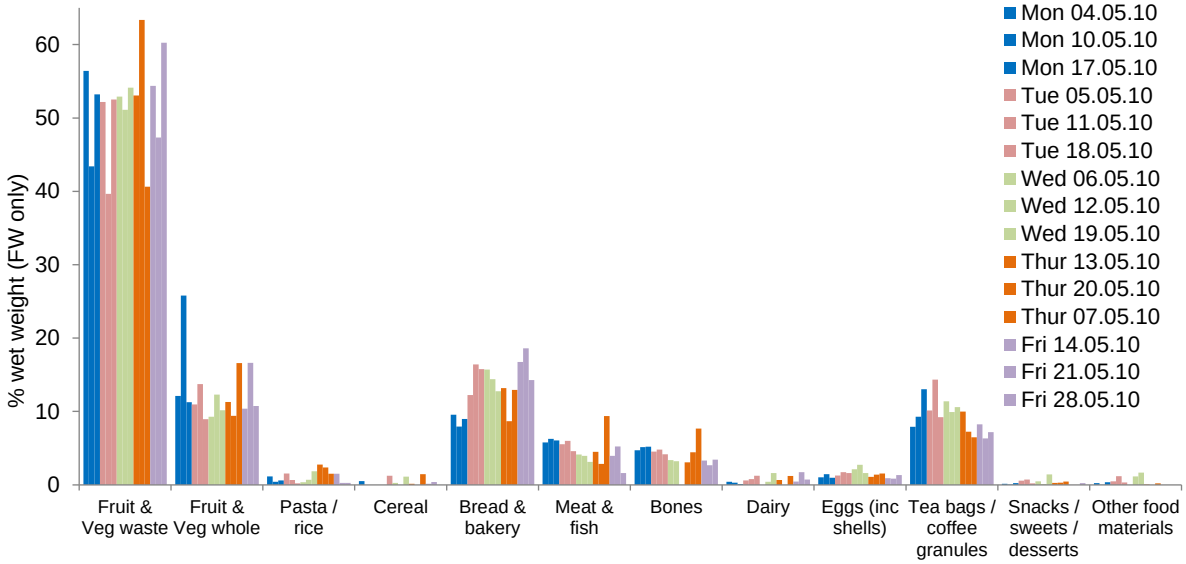


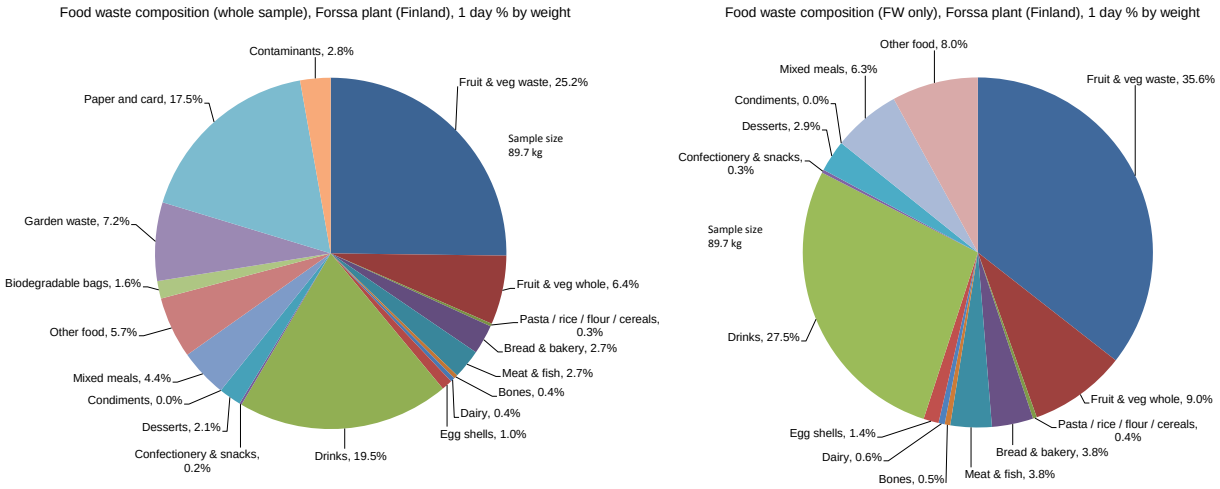

**Figure 6.** Food waste by category for 15 days collection from Ludlow, UK (3 consecutive weeks from 5 collection rounds)

## 3.2 Compositional analysis - Finland

Table 5 presents the results of characterisation of the sample from Forssa, Finland, and Figure 7 shows the data normalised to 100% on a wet weight basis, both in total and for food waste only.

**Table 5.** Results of waste categorisation for sample from Forssa, Finland

| | kg | % | Comments |
|---|---|---|---|
| Fruit and vegetable waste | 22.6 | 25.2% | |
| Fruit and vegetables (whole) | 5.7 | 6.4% | |
| Pasta / rice / flour / cereals | 0.2 | 0.3% | |
| Bread and bakery | 2.4 | 2.7% | |
| Meat and fish | 2.4 | 2.7% | |
| Bones | 0.3 | 0.4% | |
| Dairy | 0.4 | 0.4% | |
| Egg shells | 0.9 | 1.0% | |
| Drinks | 17.5 | 19.5% | mainly coffee grounds, some tea leaves |
| Confectionery and snacks | 0.2 | 0.2% | |
| Desserts | 1.9 | 2.1% | |
| Condiments | 0.0 | 0.0% | |
| Mixed meals | 4.0 | 4.4% | |
| Other food | 0.1 | 0.1% | mainly nutshells |
| - other food waste, identified but not separated | 5.0 | 5.6% | e.g. mixed coffee grounds and flour |
| Biodegradable bags | 1.5 | 1.6% | |
| *Contaminants* | | | |
| Garden waste | 6.5 | 7.2% | |
| Paper and card | 15.7 | 17.5% | |
| Plastic containers | 0.0 | 0.0% | |
| Plastic bags | 0.2 | 0.2% | |
| Metals | 0.0 | 0.0% | one small piece of aluminium foil |
| Glass | 0.3 | 0.3% | |
| Miscellaneous | 0.8 | 0.9% | pet litter |
| | 1.2 | 1.4% | e.g. textiles |
| Total | 89.7 | 100.0% | |




a) Whole sample b) FW only

**Figure 7.** Food waste composition from Forssa, Finland

The proportion of non food waste component in the sample was high at 27.5% of the total weight. The two main components categorised as contaminants were 'Paper and card' (17.5%) and 'Garden waste' (7.2%). Both of these materials are accepted for processing in the Forssa scheme, as is pet litter; the term 'contaminant' is therefore only relevant in the context of a pure food waste collection. Other types of contaminant (plastic bags and containers, glass, metals, and miscellaneous or composite items) made up < 2% of the total waste or around 2.5% of the food waste component, indicating a reasonably low degree of contamination. Biodegradable bags made up 1.6% of the total sample weight or 2.3% of the food waste component, similar to UK values. Figure 8 shows the material as received at the plant.

**Figure 8.** Source segregated waste from Forssa, Finland used in compositional analysis

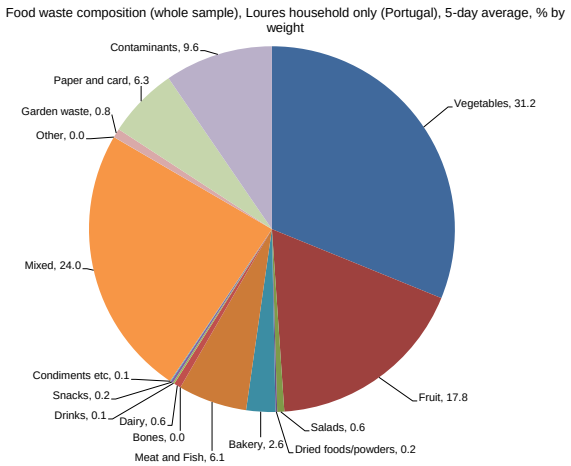
On a food waste only basis, excluding non-food components and biodegradable plastic bags, the total for the combined categories 'Fruit and vegetable waste' and 'Fruit and vegetable (whole)' was 44.5%. About one fifth of this was whole fruit and vegetables, with the remainder comprising peel, rinds etc. The category 'Drinks' made up 27.5% of the food waste component and consisted mainly of coffee grounds.

### 3.3 Compositional analysis - Portugal

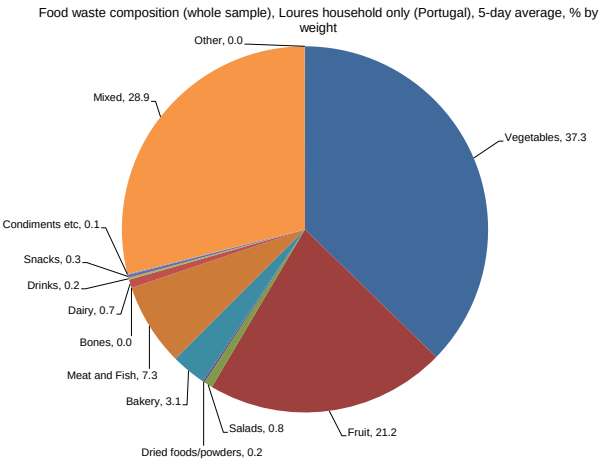
Table 6 presents the results of sorting of 5 days' waste from the domestic properties on collection round R2 in Loures, Portugal. Figure 9 shows the data normalised to 100% on a wet weight basis, both in total and for food waste only, while Figure 10 shows the sorting process and output.

**Table 6.** Waste compositional analysis for daily collection from households in Loures

| | *% wet weight* | 08/02/2011 | 15/02/2011 | 16/02/2011 | 17/02/2011 | 18/02/2011 | Average | Max | Min |
|---|---|---|---|---|---|---|---|---|---|
| **G1 - Putrescibles** | Vegetables | 28.6 | 30.3 | 25.3 | 37.8 | 33.8 | 31.2 | 37.8 | 25.3 |
| | Fruit | 23.5 | 22.1 | 10.5 | 20.5 | 12.2 | 17.8 | 23.5 | 10.5 |
| | Salads | 1.0 | 0.5 | 0.9 | 0.3 | 0.4 | 0.6 | 1.0 | 0.3 |
| | Dried foods/powders | 0.0 | 0.1 | 0.4 | 0.1 | 0.1 | 0.2 | 0.4 | 0.0 |
| | Bakery | 1.5 | 4.9 | 2.0 | 2.3 | 2.2 | 2.6 | 4.9 | 1.5 |
| | Meat and Fish | 5.8 | 5.2 | 6.5 | 4.7 | 8.3 | 6.1 | 8.3 | 4.7 |
| | Bones | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Dairy | 0.3 | 1.0 | 0.6 | 0.7 | 0.5 | 0.6 | 1.0 | 0.3 |
| | Drinks | 0.1 | 0.3 | 0.0 | 0.2 | 0.1 | 0.1 | 0.3 | 0.0 |
| | Snacks | 0.3 | 0.5 | 0.0 | 0.2 | 0.0 | 0.2 | 0.5 | 0.0 |
| | Condiments etc | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.1 | 0.3 | 0.0 |
| | Mixed | 22.7 | 18.6 | 33.9 | 18.4 | 26.3 | 24.0 | 33.9 | 18.4 |
| | Other | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| **G2 - Garden waste** | Garden waste | 0.7 | 2.0 | 0.0 | 0.2 | 1.0 | 0.8 | 2.0 | 0.0 |
| **G3 - Paper & cardboard** | Paper | 5.8 | 5.3 | 7.4 | 4.7 | 5.5 | 5.7 | 7.4 | 4.7 |
| | Card - packaging | 0.3 | 0.3 | 1.2 | 0.2 | 0.4 | 0.5 | 1.2 | 0.2 |
| | Card - non-packaging | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | 0.0 |
| **G4 - Contaminants** | Plastic - film | 6.9 | 5.6 | 6.7 | 5.4 | 5.4 | 6.0 | 6.9 | 5.4 |
| | Plastic - bottles | 0.0 | 0.1 | 0.5 | 0.1 | 0.4 | 0.2 | 0.5 | 0.0 |
| | Plastic - polystyrene | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| | Plastic - other | 0.3 | 0.8 | 0.9 | 0.3 | 0.5 | 0.6 | 0.9 | 0.3 |
| | Glass - packaging | 0.1 | 0.4 | 1.1 | 0.4 | 0.6 | 0.5 | 1.1 | 0.1 |
| | Glass - non-packaging | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Ferrous metals | 0.4 | 0.1 | 0.3 | 0.1 | 0.3 | 0.2 | 0.4 | 0.1 |
| | Other Metals | 0.2 | 0.3 | 0.2 | 0.1 | 0.2 | 0.2 | 0.3 | 0.1 |
| | Composites | 0.4 | 0.5 | 0.4 | 0.3 | 0.4 | 0.4 | 0.5 | 0.3 |
| | Textiles | 0.4 | 0.0 | 0.3 | 0.1 | 0.3 | 0.2 | 0.4 | 0.0 |
| | Sanitary textiles | 0.6 | 1.0 | 0.3 | 2.4 | 0.7 | 1.0 | 2.4 | 0.3 |
| | Combustibles - wood | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Combustibles - other | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| | Incombustibles | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.1 | 0.3 | 0.0 |
| | Special - packaged organic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Special - other | 0.02 | 0.0 | 0.04 | 0.04 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Total (%)** | | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | - | - |
| **Food waste (% of total)** | | **83.7** | **83.5** | **80.3** | **85.6** | **83.9** | **83.4** | - | - |
| **Weight of sample (kg)** | | **255.0** | **252.9** | **283.7** | **253.5** | **252.9** | **259.6** | **283.7** | **252.9** |




a) Whole sample




b) FW only

**Figure 9.** Food waste composition from Loures households, Portugal (5-day average)

a) Waste as received

b) Hand sorting on sorting table

c) Vegetable waste

d) Sorted fractions

**Figure 10.** Sorting process for characterisation of waste from Loures households

The sample included a proportion of 'Paper and card' (6.3% of total weight) and a very small amount of 'Garden waste' (0.8%). The main contaminant was plastic bags (6.0%): as biodegradable bags are not provided in this scheme, this represents a considerable input of contamination and a reduction in the potential for energy recovery from the biodegradable plastic. The remaining contaminants (plastic bottles, polystyrene foam and other plastics, glass, metals, composites, textiles, combustibles and special items - see Table 6) made up around 3.6% of the total weight, indicating that the degree of contamination without taking into account plastic bags was reasonably low. The sorters reported finding batteries in the collected sample on two separate occasions.

On a food waste only basis the average total for the combined categories 'Vegetables', 'Fruit' and 'Salads', corresponding to the combined 'Fruit and vegetable waste' and 'Fruit and vegetables (whole)', was 59.4%. The category 'Mixed meals' made up 27.2% of the food waste component, possibly reflecting the fact that the waste was delivered by a compacting vehicle. The collection in Finland was also carried out by compaction vehicles, however, and an alternative explanation is that the sorters noted a high proportion of soup in the waste, a popular dish both regionally and seasonally, which made identification of other components more difficult.

Figure 11 shows the variation between collection days for the food waste categories, and again suggests that day-to-day variation at a small scale may be as significant as any regional or seasonal variations.

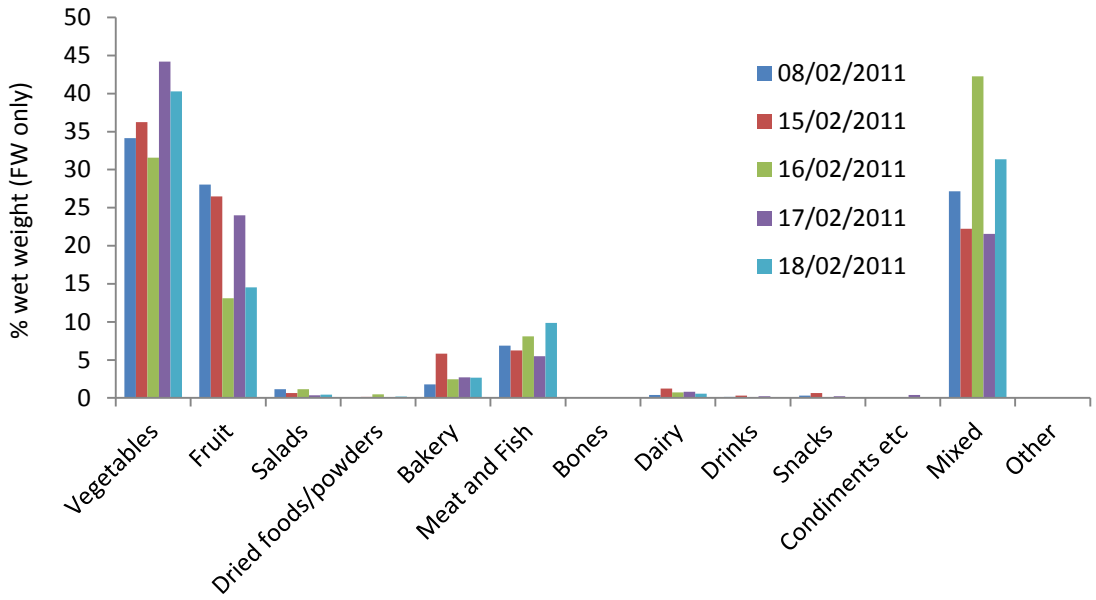



**Figure 11.** Variability in materials from Loures household collections (food waste only)

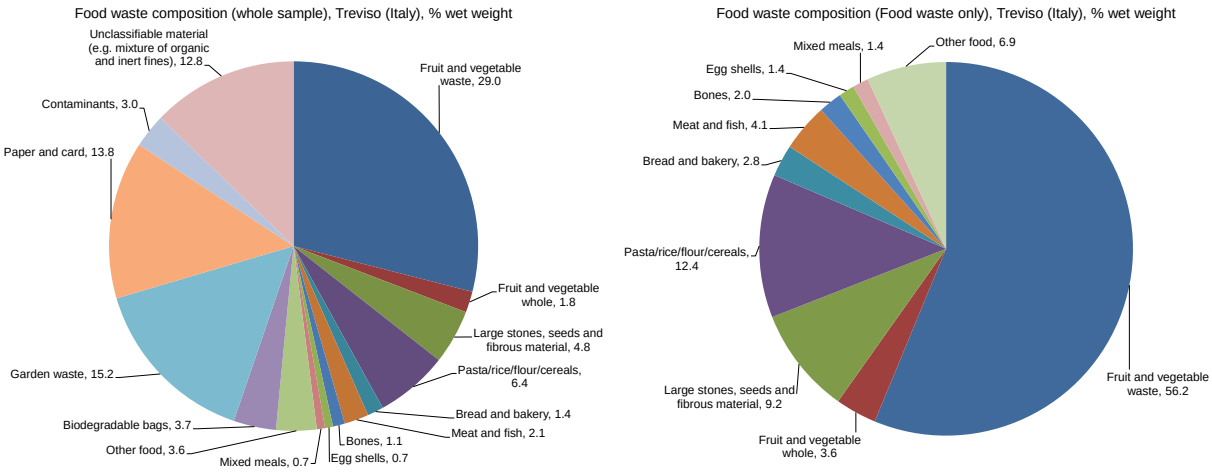
The results for domestic food waste collections were also compared with those from collection rounds serving large producers in the Lisbon area. The composition of the two waste streams was found to be closely similar, and confirmed that these two streams are likely to show the same behaviour when used as a feedstock for anaerobic digestion (Vaz et al., in review).

## 3.4 Compositional analysis - Italy

Table 7 presents the results of characterisation of the sample from Treviso waste plant, and Figure 12 shows the data normalised to 100% on a wet weight basis, both in total and for food waste only.

**Table 7.** Results of waste categorisation for sample from Treviso, Italy

| | % wet weight |
|---|---|
| Fruit and vegetable waste | 29.0 |
| Fruit and vegetable whole | 1.8 |
| Large stones, seeds and fibrous material | 4.76 |
| Pasta/rice/flour/cereals | 6.4 |
| Bread and bakery | 1.4 |
| Meat and fish | 2.1 |
| Bones | 1.05 |
| Dairy | 0.0 |
| Egg shells | 0.7 |
| Drinks | 0.0 |
| Confectionery and snacks | 0.0 |
| Desserts | 0.0 |
| Condiments | 0.0 |
| Mixed meals | 0.7 |
| Other food | 3.6 |
| Biodegradable bags | 3.7 |
| Garden waste | 15.2 |
| Paper and card | 13.8 |
| Plastic containers | 0.3 |
| Plastic film | 2.2 |
| Metals | 0.35 |
| Glass | 0.14 |
| Unclassifiable material (e.g. mixture of organic and inert fines) | 12.8 |
| Total | 100.0 |




a) Whole sample b) FW only

**Figure 12.** Food waste composition from Treviso, Italy (single sample)

The collected material contains a large amount of 'Garden waste' and 'Paper and card', at 15.2 and 13.8% of the total waste sample respectively. It also contains 3.0% of contaminants including plastic containers and film, metals, and glass, and 12.8% of unclassifiable materials (mainly a mixture of organic and inert fines). A further 3.7% is biodegradable plastic bags, with the result that food waste makes up only 51.5% of the incoming material on a wet weight basis and the level of contamination is relatively high.

On a food waste only basis, excluding all contaminants and biodegradable plastic bags, the combined total for 'Fruit and vegetable waste' and 'Fruit and vegetables (whole)' was 69.0%. This was made up of 56.2% 'Fruit and vegetable waste', 3.6% whole fruit and vegetables, and 9.2% of 'Large stones, seed and fibrous materials'; a much higher proportion than the < 1% found in UK collections, possibly suggesting a regional different in diet. The only other major component was 'Pasta/rice/flour/cereal' at 12.4% and no 'Dairy', 'Drinks', 'Confectionery and snacks', 'Desserts' or 'Condiments' were identified. The results were broadly similar to those found by Bolzonella et al. (2006) (Table 8).

**Table 8.** Comparison of analyses for material from the Treviso plant

| % wet weight | **Bulk material entering site** [a] | **Digester feed after sorting** [a] | **Current sample** |
|---|---|---|---|
| Organic | 59.1 | 75.7 | 70.4 |
| Plastic | 14.6 | 1.6 | 2.5 |
| Metals | 2.2 | 0.0 | 0.4 |
| Glass | 2.5 | 0.1 | 0.1 |
| Textiles | 1.3 | 0.5 | - |
| Wood | 1.5 | 0.4 | - |
| Paper | 16.5 | 20.5 | 13.8 |
| Inerts | 2.3 | 1.3 | - |
| Miscellaneous | - | - | 12.8 |
| Total | 100.0 | 100.0 | 100.0 |

[a] Based on Bolzonella et al. (2006)

### 3.5 Preliminary physico-chemical characterisation

The results of preliminary physico-chemical characterisation of the samples are given in Table 9, with those for some closely comparable UK food waste samples carried out as part of the Defra-funded research that ran in parallel with the early stages of the VALORGAS project (Banks et al., 2011).

The results showed a strong degree of similarity in the samples, especially from the viewpoint of key parameters in anaerobic digestion. Total and volatile solids contents were generally similar. The Valorsul raw waste had a slightly lower moisture content, and both this sample and the one from Treviso had a lower TS/VS ratio indicating the present of more inert materials. TKN values were all similar and as expected were relatively high on a wet weight basis, suggesting the potential for ammonia toxicity with this feedstock. Concentrations of plant nutrients (N, P and K) suggested that the digestate from this feedstock has significant potential for fertiliser replacement. The elemental analysis was in good agreement and the measured calorific value confirmed this is an energy-rich substrate.

The results show reasonably good inter-laboratory comparability, although difficulties were experienced with some other parameters due to the use of different analytical methods (results not reported here).

**Table 9.** Results of preliminary physico-chemical characterisation of waste samples

| | | UK | | | | | Finland | Italy | | Portugal | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Luton** [a] | **Hackney** [a] | **Ludlow** [a] | **Eastleigh** | **Eastleigh** | **Forssa** | **Treviso** | **Treviso** | **Lisbon raw waste** | **Lisbon to digester** | **Lisbon to digester** |
| | | (Lab 2) | (Lab 2) | (Lab 2) | (Lab 2) | (Lab 1) | (Lab 1) | (Lab 1) | (Lab 3) | (Lab 3) | (Lab 1) | (Lab 3) |
| *Fundamental characteristics for anaerobic digestion* | | | | | | | | | | | | |
| pH | | 5.12 ± 0.01 | 5.18 ± 0.01 | 4.71 ± 0.01 | 5.02 ± 0.01 | 5.70 | 5.34 | 6.16 | | | 5.93 | |
| TS | % WW [b] | 23.70 ± 0.06 | 25.74 ± 0.18 | 23.74 ± 0.08 | 25.89 ± 0.01 | 28.62 ± 0.07 | 27.02 ± 0.12 | 27.47 ± 0.03 | 24.43 ±4.57 | 33.80 | 6.31 ± 0.005 | 6.33 |
| VS | % WW | 21.84 ± 0.10 | 23.47 ± 0.31 | 21.71 ± 0.09 | 24.00 ± 0.03 | 26.83 ± 0.16 | 24.91 ± 0.05 | 23.60 ± 0.09 | 20.16 ± 3.75 | 27.60 | 4.93 ± 0.05 | 5.01 |
| VS | %TS | 91.28 ± 0.20 | 91.17 ± 0.91 | 91.44 ± 0.39 | 92.70 ± 0.12 | 94.18 ± 0.42 | 92.26 ± 0.26 | 86.60 ± 0.40 | 83.32 ± 5.87 | 81.7 | 78.19 ± 0.86 | 79.1 |
| TOC | %TS | 51.2 ± 1.2 | 51.3 ± 0.2 | 48.3 ± 1.0 | 48.76 ± 0.87 | | | | | | | |
| TKN | | 3.12 ± 0.01 | 3.13 ± 0.03 | 3.42 ± 0.04 | 2.91 ± 0.05 | 2.74 ± 0.05 | 2.39 ± 0.04 | 2.55 ± 0.03 | 2.84 ± 0.76 | 1.5 | 6.93 ± 0.07 | 4.30 |
| TKN | g $kg^{-1}$ WW | 7.39 ± 0.02 | 8.06 ± 0.08 | 8.12 ± 0.09 | 7.53 ± 0.13 | 7.84 ± 0.16 | 6.45 ± 0.1 | 7.02 ± 0.1 | 7.19 ± 2.06 | 5.1 | 4.37 ± 0.05 | 2.72 |
| CV | kJ $g^{-1}$ TS | 21.43 ± 0.12 | 21.64 ± 0.11 | 20.66 ± 0.18 | 20.97 ± 0.02 | 21.32 ± 0.08 | 21.39 ± 0.11 | 20.50 ± 0.01 | | | 25.23 ± 0.26 | |
| *Biochemical composition* | | | | | | | | | | | | |
| Lipids | g $kg^{-1}$ VS | 148 ± 4 | 157 ± 2 | 151 ± 1 | 149 ± 1 | 152 ± 2 | 156 ± 0.5 | 202 ± 0.5 | | | 314 ± 0.4 | |
| Crude protein | g $kg^{-1}$ VS | 213 ± 1 | 213 ± 2 | 235 ± 3 | 197 ± 4 | 183 ± 4 | 162 ± 0.4 | 186 ± 3 | | | 554 ± 6 | |
| *Nutrients* | | | | | | | | | | | | |
| TKN (N) | g $kg^{-1}$ TS | 31.2 ± 0.1 | 31.3 ± 0.3 | 34.2 ± 0.4 | 29.1 ± 0.5 | 27.4 ± 0.5 | 23.9 ± 0.4 | 25.5 ± 0.3 | 28.44 ± 7.62 | 15 | 63.9 ± 0.7 | 43.0 |
| TP (P) | g $kg^{-1}$ TS | 4.87 ± 0.08 | 6.41 ± 0.12 | 5.41 ± 0.32 | 2.82 ± 0.13 | 2.94 ± 0.01 | 2.73 ± 0.05 | 3.47 ± 0.06 | 3.26 ± 1.54 | 5.0 | 8.92 ± 0.12 | 4.0 |
| TK (K) | g $kg^{-1}$ TS | 12.3 ± 0.1 | 12.9 ± 0.6 | 14.3 ± 0.8 | 8.59 ± 0.27 | 11.2 ± 0.2 | 10.0 ± 0.2 | 10.0 ± 0.1 | | | 29.2 ± 0.4 | |
| *Elemental analysis* | | | | | | | | | | | | |
| N | %TS | 3.12 ± 0.01 | 3.13 ± 0.03 | 3.42 ± 0.04 | 2.91 ± 0.05 | 2.80 ± 0.02 | 2.46 ± 0.03 | 2.58 ± 0.05 | | | 5.72 ± 0 | |
| C | %TS | 51.2 ± 1.2 | 51.3 ± 0.2 | 48.3 ± 1.0 | 48.8 ± 0.9 | 50.6 ± 0.2 | 49.4 ± 0.04 | 47.2 ± 0.01 | | | 54.8 ± 0.1 | |
| H | %TS | 6.56 ± 0.04 | 6.67 ± 0.13 | 5.53 ± 0.63 | 6.37 ± 0.19 | | | | | | | |
| S | %TS | 0.21 ± 0.00 | 0.23 ± 0.03 | 0.15 ± 0.01 | | | | | | | | |
| O | %TS | 30.7 ± 1.2 | 29.8 ± 0.4 | 34.3 ± 2.5 | 34.7 ± 0.9 | | | | | | | |

[a] Samples analysed as part of the Defra funded project WR1208 (Banks et al., 2011) [b] WW = wet weight

### 3.6 Discussion

Table 10 presents the compositional analysis for the food waste component of samples from the UK, Finland, Portugal and Italy compared to results from the WRAP (2008) study, while Figure 13 shows the range for each compositional category. It is clear there are both differences between the samples, and also an important degree of similarity. In all cases Fruit and vegetable wastes form the largest proportion, making up on average from 45-70% of the total wet weight in each case. The proportion of 'Meat and fish' was similar in all countries, and this may be important as this category is likely to make a major contribution to the high protein and nitrogen content of food waste, which in turn can lead to stability problems in anaerobic digestion. The percentage of 'Bread and bakery' products was similar in Finland, Portugal and Italy and only higher in the UK; differences in the category will tend to be enhanced on a wet weight basis as these products have a high capacity to absorb any liquid present or generated as the waste begins to degrade in transport. Only waste from Italy showed a high proportion of the category Pasta/rice/flour/cereals. 'Mixed meals' and 'Drinks' showed a particularly wide range, probably reflecting both national differences (e.g. tea bags in the UK, coffee in Finland) and aspects of the waste collection system. The practicality and quality of categorisation may have been affected by whether the collected waste was compacted, as this made identification of separate components more difficult. The food waste composition found by the WRAP (2008) survey was very similar to that of the UK samples, with a slightly lower total for fruit and vegetable waste and corresponding small increases in other categories. These minor differences may reflect the fact that the WRAP survey was carried out by sorting the food components from mixed waste rather than characterising samples of source segregated food waste.

The study reported here did not take into account possible seasonal variations in food waste composition: the samples analysed were from summer in the UK, however, and winter or early spring in Finland, Portugal and Italy. To understand differences in composition it would also be of interest to characterise the proportion of domestic food waste not entering the source segregated stream.

**Table 10.** Comparison of results of compositional analysis for samples from UK, Finland, Portugal and Italy (Food waste component only)

| % wet weight | UK [a] | Finland | Portugal | Italy | Ave | WRAP [b] |
|---|---|---|---|---|---|---|
| Fruit and vegetable waste | 60.9 | 44.5 | 59.2 | 69.0 | 58.4 | 46.6 |
| Pasta/rice/flour/cereals | 1.5 | 0.4 | 0.2 | 12.4 | 3.6 | 2.5 |
| Bread and bakery | 9.0 | 3.8 | 3.1 | 2.8 | 4.7 | 13.4 |
| Meat and fish | 6.7 | 4.3 | 7.3 | 6.2 | 6.1 | 8.4 |
| Dairy | 1.7 | 2.0 | 0.7 | 1.4 | 1.4 | 3.5 |
| Drinks | 7.1 | 27.5 | 0.2 | 0.0 | 8.7 | 8.0 |
| Confectionery, snacks etc | 0.7 | 3.2 | 0.3 | 0.0 | 1.0 | 1.7 |
| Mixed meals | 12.3 | 6.3 | 29.0 | 1.4 | 12.2 | 12.9 |
| Other food | 0.2 | 8.0 | 0.0 | 6.9 | 3.8 | 3.0 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

[a] Data from 8 sites using all food waste categories [b] Based on WRAP (2008)

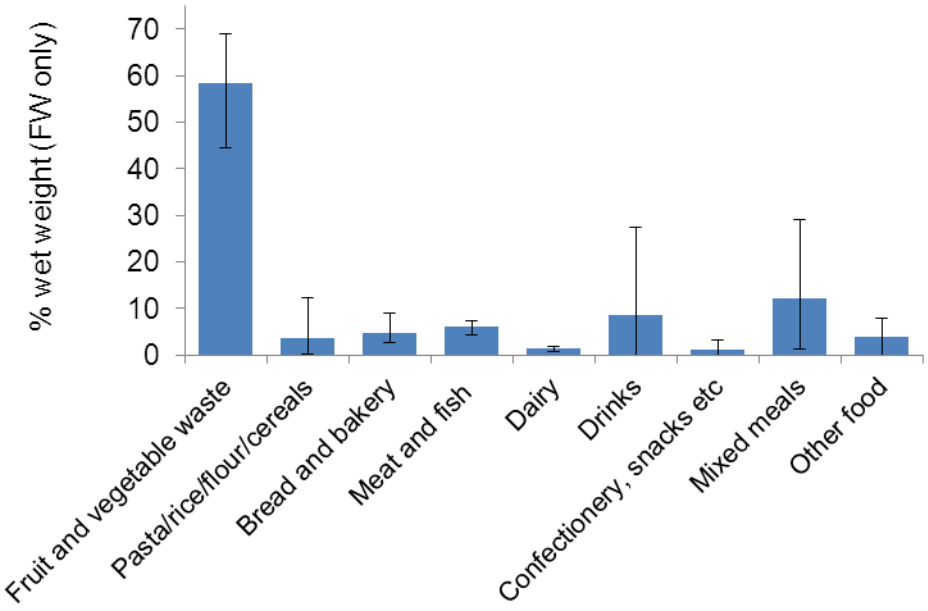



**Figure 13.** Comparison of results of food waste compositional analysis for samples from UK, Finland, Portugal and Italy. (Error bars show range).

Different degrees of contamination were found in the different collection schemes. The UK samples showed low or exceptionally low contamination. The samples from Portugal and Finland had low contamination levels similar to those for the UK, while the sample from Italy had a much higher proportion of contaminants. These results may reflect physical and logistical aspects of the collection system (e.g. bin size, collection frequency): Arnold et al. (2010) noted that a reduction in bin size led to an improvement in the proportion of food waste collected. More speculatively, the length of time for which source segregated collection systems have been operating may be a factor: the UK has only recently introduced source segregation for domestic organic wastes, and may therefore benefit from a sharper focus on food waste. The degree of contamination is a cause for concern for several reasons, including the risk of introducing potentially toxic elements (PTE) which may affect digestate quality, for example from the presence of batteries as reported in the sample from Loures.

The sorting also provided some other interesting insights into the nature and properties of domestic food waste as a substrate for anaerobic digestion. Between 1.2-1.4% of the wet weight of food waste consisted of eggshells: these have a high total solids content, do not contribute to the organic loading rate on a volatile solids basis and normally pass through the digester almost unaffected, although they could potentially contribute to maintaining alkalinity in some cases. Bones comprised respectively 3.3, 0.5 and 2.0% of the food waste component in the UK, Finland and Italy. No bones were reported in the samples from Portugal, possibly as these are explicitly excluded from the list of acceptable materials for the Loures collection: in most schemes bones are either excluded or rejected as they are not broken down in the digestion process, can harm equipment, and may cause problems in complying with Animal By-products Regulations (EC 1774/2002 and implementing regulations in each member state). Certain types of seed and fruit stone are similar to bones with respect to their potential to cause wear and tear on equipment: as noted above, there was a considerable difference in the proportion of this material reported, from < 1% in the UK to ~9% in Italy while Finland and Portugal did not record any.

Biodegradable bags made up 4.2, 1.6 and 3.7% of the total sample weight for the UK, Finland and Italy respectively, representing an even higher proportion with respect to the food waste component.

While these percentages were for wet and dirty material, the volatile solids content of the bags themselves is very high. Fully degradable bags may therefore contribute a small but useful proportion of the overall biogas yield from anaerobic digestion of food waste, while non-biodegradable bags represent a major source of contamination, equal to about 6% of the total sample weight in Portugal, and are likely to reduce the quality of the final digestate.

Despite some variation in the waste compositions, the values for key analytical parameters showed a high degree of similarity. This is understandable in the sense that while food preferences and cuisine may vary from region to region, the fundamental requirements of human diet and therefore of domestic food waste are likely to remain similar. The physico-chemical approach may be more powerful in terms of assessing the suitability of a material as a feedstock for anaerobic digestion; but waste categorisation and sorting can clearly provide valuable information on the degree of success a collection scheme has in obtaining its targeted materials.

## 4 Conclusions

Food waste in samples from 15 sites located in four countries was sorted and categorised according to its component food types. The results indicated that day-to-day variations in composition may be similar in scale to any seasonal or regional differences, but are unlikely to affect the physic-chemical properties of the material as far as its suitability as a feedstock for anaerobic digestion is concerned. Compositional sorting provides useful insights into the presence of specific components, and may be a powerful technique for gaining information on the performance of a source segregated schemes in terms of the degree and nature of contamination, especially if linked to examination of the type of collection system.

## References

Arnold, R., Banks C.J., Chesshire, M., Foxall, M. & Stoker, A. (2010). *Defra Demonstration Project: Biocycle South Shropshire Biowaste Digester*. Defra New Technologies Programme. http://archive.defra.gov.uk/environment/waste/residual/newtech/demo/documents/Biocycle-final.pdf. Accessed 10 February 2011.

Banks C. J., Zhang, Y., Walker, M. (2011). Optimising Processes for the Stable Operation of Food Waste Digestion: Technical Report Defra WR1208. Department of the Environment, Food and Rural Affairs, London, UK

ADEME (1997): MODECOM. A method for Characterization of Domestic Waste (Méthode de Caractérisation des Ordures Ménagères). 2nd Edition. Agency for Environment and Energy Management, Ademe Editions, Paris.

Bolzonella, D., Battistoni, P., Susinii, C. and Cecchi, F. (2006) Anaerobic codigestion of waste activated sludge and OFMSW: the experiences of Viareggio and Treviso plants (Italy). Water Science and Technology 53(8), 203-2011.

Cecchi, F., Traverso, P., Pavan, P., Bolzonella, D. & Innocenti, L. (2003) Characteristics of the OFMSW and behaviour of the anaerobic digestion process. In: Biomethanization of the Organic Fraction of Municipal Solid Wastes, Mata-Alvarez (Ed.) IWA Publishing, London, 141 – 179.

DGQA (1989). Technical Paper No. 1 - Solid Waste - Characterisation and Quantification - Methodology (DGQA), Portugal, 1989. Direcção Geral da Qualidade do Ambiente.

Vaz, F., Torres, A. and Neiva Correia, C. (2008). Case Study: The Characteristics of the Biodegradable Waste for the Anaerobic Digestion Plant in Lisbon Area. Water Science & Technology—WST, Vol 58 No 8 pp 1563–1568.

Vaz, F., Torres, A., Neves, M., Vidal, D., Neiva Correia, C., Heaven, S. and Gredmaier, L. (2011, in review) Characteristics of organic waste selectively collected in the Lisbon Area: differences between large producers (SC-OFMSW) and households (SS-OFMSW). Submitted to the 6th

International IWA Symposium on Anaerobic Digestion of Solid Waste and Energy Crops, Vienna 28 August - 1September 2011.

Victor, F. (2008) in: Factores determinantes para a recolha selectiva de resíduos orgânicos de origem doméstica: Caso de estudo da Urbanização da Portela**.** Master Degree Dissertation, September.

WRAP (2008). The Food We Waste. ISBN 1-84405-383-0 (version 2). WRAP, Banbury.

WRAP (2009). Household food and drink waste in the UK. ISBN 1-84405-430-6. WRAP, Banbury.

## Appendix A - Analytical methods

## Appendix A1 Determination of pH

**Principle of method:**
pH is measured potentiometrically in the undiluted liquid sample or in the 1:2 (*V*/*V*) sample/water slurry for semi-solid or solid sample.

**Apparatus:**
1. pH meter with means for temperature compensation
2. Combination electrodes
3. Magnetic stirrer and Telfon-coated stirring bar
4. Plastic or glass containers, of sufficient capacity to accommodate the volume of the sample, deionised water and 10% air volume.

**Reagents:**
1. Buffer solutions: pH 4.0, 7.0 and 9.2.

**Procedure:**
1. Calibration of the pH-meter:
*a.* Calibrate the pH-meter as prescribed in the manufacturer's instruction;
*b.* Use at least two of the buffer solutions that bracket the expected pH of the samples and are approximately three pH units or more apart.

2. Liquid sample (when the aqueous phase constitutes at least 20% of the total volume of the sample):
*a.* Place the sample in a clean glass beaker using a sufficient volume to cover the sensing elements of the electrodes and to give adequate clearance for the magnetic stirring bar;
*b.* Stir the sample at a constant rate to provide homogeneity and suspension of solids;
*c.* Thoroughly rinse and gently wipe the electrodes prior to measuring pH of the samples;
*d.* Immerse the electrodes into the sample beaker;
*e.* Record sample pH to one decimal place after stabilization is reached.

3. Semi-solid or solid sample:
*a.* Place a weight equivalent to 20 ml of the sample volume into a container;
*b.* Add 40ml deionised water, secure the cap and mix for 1 h on the magnetic stirrer;
*c.* Stop stirring just before the measurement;
*d.* Immerse the electrodes into the settling suspension;
*e.* Record the pH when the meter has stabilized and report the result as pH (water 1:2).

**References:**
1. BS EN 13037:2000 Soil improvers and growing media – Determination of pH;
2. US EPA SW-846 9045D Soil and waste pH;
3. US EPA SW-846 9040C pH electrometric measurement.

**Notes:**
1. Samples should be analysed as soon as possible;
2. If the waste is hygroscopic and absorbs all the deionised water, begin the experiment again using 20 ml of waste and 100 ml of deionised water;
3. Minimum stirring is required when measuring sample with high volatile components.

## Appendix A2 Determination of Total solids and volatile solids

**Principle:**
The test portion of sample is dried to constant mass in an over at 105 ± 5°C. The difference in mass before and after the drying process is used to calculate the total solids and the water content.

Then, the dried sample is heated in a muffle furnace at 550 ± 10°C. The difference in mass before and after the ignition process is used to calculate the content of volatile solids and ash.

**Apparatus:**
1. Drying oven, capable of maintaining a temperature of 105 ± 5°C;
2. Electric muffle furnace, capable of maintaining a temperature of 550 ± 10°C;
3. Porcelain crucibles;
4. Dessiccator with active silica gel desiccant with indicator;
5. Analytical balance, with an accuracy of 1 mg.

**Procedures:**
1. Place the crucibles in the drying oven for a minimum of 30 minutes. Put them in the desiccator to ambient temperature. If the crucibles are brand new, place them in the muffle furnace at 550°C for 30 minutes to burn off any organic residue and then put in the desiccator to cool;
2. Weigh the empty crucible using a balance of accuracy of at least 1 mg. Record the weight ($W_1$);
3. Add the sample to the crucible to make up around 2/3 of the capacity of crucible. Weigh the loaded crucible and record the weight ($W_2$). At least triplicate analysis should be done for one sample;
4. Place the crucibles containing the sample in the drying oven until constant mass has been reached, typically overnight;
5. Cool the crucibles with dried samples in the desiccator and weigh. Record the weight ($W_3$);
6. Place the crucibles with dried sample in the muffle furnace for 2 hours at 550°C.
7. Cool the crucibles with ash in the desiccator and weigh. Record the weight ($W_4$);
8. Clean the crucibles by washing thoroughly in water. Rinse with deionized water and dry.

**Calculation:**

$$\%TS = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

$$\%VS(based \cdot on \cdot total \cdot weight) = \frac{W_3 - W_4}{W_2 - W_1} \times 100$$

and

$$\%VS(based \cdot on \cdot total \cdot solids) = \frac{W_3 - W_4}{W_3 - W_1} \times 100$$

**References:**
1. BS EN 12880:2000 Characterization of sludges – Determination of dry residue and water content;

2. BS EN 12879:2000 Characterization of sludges – Determination of the loss on ignition of dry mass;
3. BS EN 13040:2000 Soil improvers and growing media – Sample preparation for chemical and physical tests, determination of dry matter content, moisture content and laboratory compacted bulk density;
4. Soil improvers and growing media – Determination of organic matter content and ash.

## Appendix A3 Determination of calorific value by bomb calorimetry

**Theory:**
Calorific value can be defined as the amount of energy released on burning by each unit of combustible mass. There are two types of calorific value (i.e., the gross calorific value and the net calorific value), and bomb calorimeter measures the gross calorific value.

The gross calorific value, also known as higher heating value (HHV), is the amount of energy released on burning by complete combustion of a mass unit of sample, at constant volume in an oxygen atmosphere, assuming that the final products of combustion consist of $O_2$, $CO_2$, $SO_2$, and $N_2$ in the gas phase together with water, that contained in the sample and that generated from the combined hydrogen, in liquid form.

The net calorific value, also known as lower heating value (LHV), is defined as the amount of heat released by combusting a specified quantity and returning the temperature of the combustion products to 150°C. LHV assumes the latent heat of vaporization of water in the reaction products is not recovered. It is useful in comparing fuels where condensation of the combustion products is impractical, or heat at a temperature below 150°C cannot be put to use.

Both calorific values are related through the equation:

$$LHV = HHV_d - 2.442 \times (W + 9 \times H_d) \times 0.01$$

where,
LHV: the lower heating value of the sample, kJ $g^{-1}$;
$HHV_d$: the higher heating value of the dry sample, kJ $g^{-1}$;
W: the moisture percentage of the sample, %;
$H_d$: the hydrogen percentage of the dry sample, %;
2.442: the heat of vaporization of water, kJ $g^{-1}$;
9: molecular weight ratio of water to hydrogen.

**Principle:**
A bomb calorimeter is a type of calorimeter used in measuring the heat of combustion in pure oxygen environment at high pressure. Electrical energy is used to light the sample. As the sample is burning, it will heat up the bomb vessel which is placed in the static polystyrene jacket. The temperature rise of the bomb vessel allows for calculating calorific content of the sample.

**Apparatus:**
1. CAL2k bomb calorimeter system: the filling station + bomb vessel + calorimeter + stainless steel crucible + cotton thread fuse, Digital data systems Ltd, South Africa;
2. Analytical balance with an accuracy of 1 mg.

**Reagent:**
1. Benzoic acid as standard, with a HHV of 26.454 kJ $g^{-1}$.

**Operation procedure:**
1. Place the stainless steel crucible onto its stand and attach a cotton thread fuse to the ignition wire and crucible;
2. Put the stand into the bomb vessel. Secure the lid;
3. Fill the bomb vessel with pure oxygen in the filling station until the pressure inside reaching 3 MPa;

4. Put the vessel into the static polystyrene jacket of the calorimeter. Secure the lid. Ignition will happen automatically when the temperature inside the jacket is stable;
5. Record the calorific value shown on the screen of calorimeter. A blank is made to account for the electrical energy input and the energy released in burning the fuse;
6. Input this blank value in the operation program at the data entry space ‘baseline’;
7. Open the lid of calorimeter. Take the bomb vessel out.
8. Release the pressure of the vessel by pressing the gas value with the special tool;
9. Open the lid of the vessel. Clean the vessel and the crucible;
10. Leave the vessel until it cools to room temperature;
11. Select ‘calibration’ program using the calorimeter screen;
12. Weigh around 1.0 g of benzoic acid with an accuracy of 0.1 mg in the crucible. Record the weight and input it to the operation programme of the calorimeter;
13. Place the crucible onto its stand and connect the ignition wire and benzoic acid with a cotton thread fuse;
14. Repeat the steps 2-4;
15. Weigh around 1.0 g of sample with an accuracy of 0.1 mg. Record the weight and input it into the calorimeter;
16. Record the calorific value shown on the calorimeter screen;
17. Follow the steps of 7-10, and then start the next measurement.

**Notes:**
1. When measuring the calorific value of liquid samples, benzoic acid may be added as a spike to assist the ignition;
2. The solid sample should be pressed inside the crucible if this is not done it will tend to ‘splash’ when igniting.

## Appendix A4 Determination of Kjeldahl Nitrogen

**General discussion:**
The Kjeldahl method is a means of determining the nitrogen content (in organic and ammonia form) of substances. This method may be broken down into three main steps:

1. Digestion – the decomposition of nitrogen in organic samples utilizing a concentrated acid solution. This is accomplished by boiling a homogeneous sample in concentrated sulphuric acid. The end result is an ammonium sulphate solution;
2. Distillation – adding excess base to the acid digestion mixture to convert $NH_4^+$ to $NH_3$, followed by boiling and condensation of the $NH_3$ gas in a receiving solution;
3. Titration – to quantify the amount of ammonia in the receiving solution.

**Apparatus:**
1. Tecator 1007 digestion system;
2. Kjeltec 1002 distilling unit;
3. Kjeldahl digestion tubes;
4. 250-mL Erlenmeyer flasks;
5. Analytical balance with an accuracy of 1 mg.

**Reagents:**
*1. Sulphuric acid concentrated;*
*2. Digestion catalyst: Kjeltabs Cu 3.5;*
*3. Standard Ammonium Chloride Solution:* dissolve 0.382 g anhydrous ammonium chloride (dried at 105ºC for at least 2 h) in Milli-Q water, and dilute to 100 ml using volumetric flask: 1.00 ml = 1.00 mg N = 1.22 mg $NH_3$. Stored in a stoppered glass bottle, this solution is stable for at least 1 month;
*4. Mixed indicator solution:* Dissolve 200mg methyl red indicator in 100ml 95% ethyl or isopropyl alcohol. Dissolve 100 mg methylene blue in 50 ml 95% ethyl or isopropyl alcohol. Combine solutions. Prepare monthly;
*5. Indicating boric acid solution:* Dissolve 20 g $H_3BO_3$ in water (heat if needed), add 10 ml mixed indicator solution, and dilute to 1 l. prepare monthly;
*6. Standard sulphuric acid titrant, 0.10N or 0.25N:* Dilute 2.72 or 6.80 ml concentrated sulphuric acid to 1000 ml with deionized water: 1.00 ml titrant = 14 × normality mg N. (For 0.1N, 1.00ml = 1.4 mg N)

**Safety:**
The Kjeldahl method requires the digestion of the sample using strong acid at high temperatures. Careful handling of the solutions is mandatory for laboratory safety. For added protection, acid digestions should be performed in a fume hood with adequate ventilation. Eye protection should be worn at all times and care should be taken when handling hot digestion tubes.

**Sample weight:**
The actual weight of sample required is dependent on nitrogen content and homogeneity. When homogeneity of sample is not a controlling factor the sample weight can be selected relative to the nitrogen content. Using a titrant concentration of 0.25 N the analytical sample should ideally contain 10-100 mg N. For selecting the size of sample a rough guide is given below:

| | |
|---|---|
| Homogeneous solid samples | 0.1-1.0 g |
| Non-homogeneous semi-solid samples | 1.0-3.0 g or more |
| Liquid samples (depend on N content) | 1.0-100 ml |

**Procedure:**

1. Digestion

a. Switch on the digestion block and set the temperature to 420°C;

b. Weigh an appropriate amount of sample to an accuracy of 0.1 mg, or measure a certain amount of sample if sample is liquid, into a digestion tube. A blank should be run through all steps of the procedure to compensate for any contribution from the reagents used;

c. Add two Kjeltabs Cu 3.5;

d. Carefully add 12 ml of concentrated $H_2SO_4$ and gently shake to 'wet' the sample with acid. If sample contains high-fat or carbohydrate, then use 15 ml $H_2SO_4$ and 1-3 drops of octanol as anti-foaming agent;

e. Attached the exhaust system to the digestion tubes and secure it with PTFE tape;

f. Set the water aspirator to full effect;

g. Load the rack with exhaust into the preheated digestion block;

h. After about 5 minutes turn down the water aspirator until the acid fumes are just contained within the exhaust head;

i. Continue to digest until all samples are clear with blue / green solution. This will normally be after 60-120 minutes;

j. Remove the tubes with exhaust still in place from digestion block and put them in the stand to cool for 10-20 minutes;

k. Carefully add deionized water to the tubes to make up the volume to about 100 ml. For solid samples, this step should be done while the digestion mixture is still warm to avoid $K_2SO_4$ salting out.

2. Distillation

*Starting up the distilling unit, which can be done when cooling the digestion mixture:*

a. Make sure that a empty digestion tube and a receiver flask are placed in their proper positions in the distilling unit and that the safety window in pulled down. Check that the two valves at the rear of the unit are closed (handles parallel to the back);

b. Connect the tube labelled 'tap water' to the water tap, and put rest three tubes in the sink;

c. Switch on power, and open for steam by keeping the small black handle labelled 'steam' in the down position. (This valve should always be open when the unit is not in use);

d. Turn on the cold water tap to a flow of about 1.5litre/min for about half a minute and the water level should be visible through the top and then the bottom window at the left side of the distilling unit. Close the tap;

e. After a minute or so, open the water tap again for 10-15 seconds and watch the steam entering the digestion tube through the white Teflon tubing. After another minute open the water tap to a flow about 1.5litre/min and leave it open;

f. Let the distillation continue until about 150ml of distillate has been collected. Move the platform with the receiver flask to its lower position. Then close the steam valve on the front panel;

g. Remove the digestion tube using heat protective gloves and the receiver flask.

*Distilling the digestion mixture:*

a. Place the digestion tube with diluted digestion mixture in its position in distilling unit and place the receiver flask with 25ml indicating boric acid solution on the platform;

b. Close the safety window;

c. Move the platform for the receiver flask to its upper position so that the distillate outlet is submerged in the receiver solution;

d. Gently press the alkali handle half way down to dispense about 50ml of 40% NaOH;

e. Open the steam valve. The boric acid receiver solution in the distillate flask will soon be green indicating the presence of ammonia;

f. When the indicating solution reaches the 150 ml mark of the flask, lower the platform for the receiver flask to its lower position. Close the steam valve and wait for a few more seconds to clean out the outlet tip;
g. Replace the digestion tube and the receiver flask with the next ones and continue in the same manner with all the samples. When removing a digestion tube, the teflon tube through which the steam enters the sample, should be placed in the metal clip. This makes it possible to replace a new digestion tube without touching the teflon tube;
h. It is better to titrate ammonia in distillate before distilling the next sample to allow the water to cool down in the distilling unit.

*Closing down the distilling unit*
a. Put an empty digestion tube and receiver flask into their position and close the water tap;
b. Remove the drain trough under the tube holder and the platform for the receiver flask and clean it with water. Wipe the unit clean from any spillage. Close the safety window;
c. Switch off power and open the valve in the middle position at the rear of the unit (handles vertical to the back) and drain out the water left in the distillation unit;
d. Leave the steam valve open to prolong the life of the tubing in the valve.

3. Titration
a. Titrate ammonia in distillate with standard 0.10 or 0.25 N of $H_2SO_4$ titrant until indicator turns to pale lavender.

**Calculation:**

*a.* Liquid samples: $$mgN/L = \frac{(A-B)\times 14.0\times N\times 1000}{mL(sample)}$$

*b.* Solid samples: $$\%N = \frac{(A-B)\times 14.0\times N\times 100}{mg(dry\cdot wt\cdot sample)}$$

where:
A = volume of $H_2SO_4$ titrated for sample, ml;
B = volume of $H_2SO_4$ titrated for blank, ml;
N = normality of standard sulphuric acid titrant.

**Notes:**
1. When the sample content of fats and / or carbohydrates is high, 1-3 drops of octanol, an antifoam agent, should be used to control the tendency for foaming;

2. Pure substances of known nitrogen content can be used as the calibration substances, for example acetanilide ($C_8H_9NO$), L-aspartic acid ($C_4H_7NO_4$), or amino acids of known composition;

3. Kjeldahl digestion does not always recover all forms of nitrogen in a sample. Nitrate and nitrate ions (which are unlikely to be present in digestion) in a sample must first be reduced prior to acid digestion for quantitative recovery. Salicylic acid followed by sodium thiosulfate has been used to pretreat the mixture to ensure complete reduction. For detailed procedure, please refer to BS EN 13654-1:2001 Soil improvers and growing media – Determination of nitrogen – Part 1: Modified Kjeldahl method.

## Appendix A5 Colorimetric method for the determination of total sugars using phenol-sulphuric acid method

**Principle:**
The phenol - sulphuric acid method is a colorimetric method that is widely used to determine the total concentration of sugars. A clear aqueous solution of the sugars to be analysed is placed in a test-tube, then phenol and sulfuric acid are added. Concentrated sulfuric acid is used to convert all non-reducing sugars to reducing sugars, and phenol reacts with reducing sugars and develops a yellow-orange colour which can be used to quantify the sugar concentration. This method is non-stoichemetric and therefore it is necessary to prepare a calibration curve using a series of standard sugar solutions.

**Procedure:**
1. Place 1 ml of blank, standard solutions, samples/pre-hydrolysed samples into 10-ml testing tubes;
***In a working fume cupboard***
2. Add 1 ml of 5% w/w phenol into each tube;
3. Add rapidly 5 ml of concentrated sulphuric acid into each tube - the stream of acid should be directed against the liquid surface rather than against the side of the test tube in order to obtain good mixing;
4. Close the tubes;
***Out of the fume cupboard***
5. Place them in an incubator at 25~30 °C for 30 min;
***In a working fume cupboard***
6. Open the tubes;
7. Transfer the solution from testing tube to a 10 mm quartz cell using disposable pipette;
8. Close the quartz cell;
***Out of the fume cupboard***
9. Read the absorption of the resulting yellow-orange solutions at 485 nm.

**Notes:**
1. A preliminary chemical hydrolytic procedure is usually needed to convert polysaccharides into monosaccharides prior to detection by colorimetric technique. That is conducted by mixing ground sample with 1M HCl at 100 °C for 20 hours.
2. This method is linear up to 160 mg glucose $L^{-1}$ with an absorbance of 1.7;
3. Blank is prepared by substituting distilled water for the sugar solution;
4. Sample control is prepared by substituting distilled water for the 5% phenol solution;
5. The colour developed is stable for several hours and therefore readings may be made later if necessary;
6. The amount of sugar may be determined by reference to a standard curve constructed for the particular sugar under examination;
7. The absorbance of the characteristic yellow-orange colour is better measured at 490 nm for hexoses and 480 nm for pentoses and uronic acids.

**Reference:**
1. Dubois M., Gilles K.A., Hamilton J.K., Rebers P.A., and Smith F. (1956) Colorimetric method for determination of sugars and related substances, Analytical Chemistry 28(3), 350-356.

2. Myklestad S.M., Skanoy E., and Hestmann S. (1997) A sensitive and rapid method for analysis of dissolved mono- and polysaccharides in seawater. Marine Chemistry 56(3-4), 279-286.

## Appendix A6 Determination of lipids

**Principle of method:**
This method employs n-hexane as the extraction solvent with Soxhlet extraction and the results of this method are appropriately termed "n-hexane extractable material (HEM)." Specifically, n-hexane can extract vegetable oils, animal fats, biological lipids, greases, soaps, waxes, relatively non-volatile hydrocarbons, and related materials, which have similar physical characteristics and common solubility in organic extracting solvents. As such, lipids measured using this method is an operationally defined parameter.

**Apparatus:**
1. Soxhlet extraction apparatus
2. Paper extraction thimble for Soxhlet apparatus
3. Water bath
4. Analytical balance with an accuracy of 1 mg.
5. Glass wool and small glass beads
6. Distilling apparatus
7. Drying oven, capable of maintaining a temperature of 105 ± 5°C
8. Desiccator

**Reagents:**
1. n-hexane (HPLC grade)

**Procedure:**
1. Dry the boiling flask of Soxhlet extraction apparatus and some small glass beads in an oven. Take them out and put into a desiccator.
2. Add and weigh 5~10 g of dried and ground sample into the paper extraction thimble. Record the exact sample weight put into the thimble (S, unit g). Fill up thimble with glass wool.
3. After cool to room temperature, take boiling flask and glass beads out of the desiccators. Place around 30 glass beads into the boiling flask. Weigh the boiling flask with glass beads (W1, unit: g).
4. Put 90 ml of n-hexane into the boiling flask.
5. Quickly set-up the Soxhlet apparatus containing the extraction thimble and sample and attach the boiling flask containing n-hexane and glass beads.
6. Adjust the heating control of the water batch so that a cycling rate of 20 cycles / h is obtained.
7. Extract for a period of at least 4 hours and after n-hexane shows no colour after it has contacted with sample.
8. Dismantle the Soxhlet extraction apparatus and connect the boiling flask with the distilling apparatus to remove n-hexane from extract.
9. Put the boiling flask into the oven for half an hour, and then take it out and place it into the desiccators. Weigh it after cooling to room temperature (W2, unit: g).
10. Clean up. Soxhlet extraction apparatus and glass beads should be cleaned by washing with hot tap water with detergent, rinsing with tap water and reagent water, and rinsing with solvent. Glassware may also be baked at 200-250 °C for 1 hour;

**Calculation:**

$$Lipids = \frac{W_2 - W_1}{S \times (100 - M)} \times 100$$

M: moisture content of the dried and ground sample (%);
Lipids: unit of g $g^{-1}$ TS.

**Reference:**

1. US EPA SW-846, Ed. (1998). Method 9071B: n-hexane extractable material (HEM) for sludge, sediment, and solid samples. Test methods for evaluating solid waste, physical / chemical Methods.

1. This method is entirely empirical, and the presence of non-oily extractable substance such as sulfur compounds, organic dyes, and chlorophyll, may result in a positive bias;
2. Use gloves to avoid adding fingerprints to the extraction thimble and boiling flask;
3. Employ a minimum of one method blank per twenty samples to verify that all solvent and equipment are contamination free. Prepare the method blank from 5 g of pre-cleaned glass beads, and carry it through the analytical process;
4. Run one matrix spike sample every twenty samples. Hexadecane (CH3(CH2)14CH3) and stearic acid (CH3(CH2)16COOH) with a weight ratio of 1:1 can be used as spike.

## Appendix A7 Determination of fibre content

**Principle:**
Fibre is an inhomogeneous mixture of various macromolecules. Most of these are structural polysaccharides (e.g. cellulose, hemicellulose and pectin), but also non-carbohydrates like the aromatic lignin, non-digestible proteins and others are normally counted as fibre constituents.

The most commonly used terms, based on chemical analytical techniques, are Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL). All of these methods are based on subsequent steps of chemical treatments to solubilise "non-fibre" components and final determination of the residue obtained. Depending on determination approach various kinds and amounts of fibre constituents are achieved in the residues.

Neutral Detergent Fibre (NDF) is defined to be the residue after treatment with a neutral detergent solution. In this procedure, sample is boiled for one hour with neutral detergent (ND). Enzymatic incubation before, during and after the ND treatment helps to break down protein and starch. The residue is then dried and ashed. The weight reduction by ashing is the sample content of hemicellulose, cellulose and lignin.

Acid Detergent Fibre (ADF) is defined to be the residue after treatment with an acid detergent solution. Sample is boiled with acid detergent (AD) for one hour, and dried and ashed. The weight reduction by ashing is the sample content of cellulose and lignin.

Acid Detergent Lignin (ADL) is defined to be the residue after initial treatment by the ADF method followed by removal of the cellulose fraction through extraction using 72% $H_2SO_4$, and then dried and ashed. The weight reduction by ashing is the sample content of Lignin.

**Apparatus:**
1. FibreCap 2023 system;
2. Ashing crucibles (45 x 60 mm) x18;
3. Analytical balance with an accuracy of 1 mg.

**Reagents:**
*1. Neutral Detergent Solution:*
Disodium ethylene diaminetetraacetate dihydrate ($C_{10}H_{14}N_2Na_2O_8 \cdot 2H_2O$) 18.61g x2
Sodium Borate decahydrate ($Na_2B_4O_7 \cdot 10H_2O$) 6.81g x2
Sodium lauryl sulphate (sodium dodecyl sulphate, $C_{12}H_{25}OSO_3Na$) 30g x2
2-ethoxyethanol ($C_4H_{10}O_2$) 10ml x2
Disodium hydrogen phosphate, anhydrous ($Na_2HPO_4$) 4.56g x2
Alfa-Amylase solution – Termamyl 300L, type DX available from Foss Tecator x2

Place 18.61g of EDTA (Disodium ethylene diaminetetraacetate, $C_{10}H_{14}N_2Na_2O_8 \cdot 2H_2O$) and 6.81g of Sodium Borate decahydrate ($Na_2B_4O_7 \cdot 10H_2O$), in a beaker and add some distilled water and heat until dissolved. Add 30g Sodium Lauryl Sulphate, ($C_{12}H_{25}OSO_3Na$), 10ml of 2-ethoxyethanol ($C_4H_{10}O_2$) and 4.56g Disodium Hydrogen phosphate, ($Na_2HPO_4$). Add water and heat until dissolved. Mix and dilute to 1000ml. Check pH which should be in the range 6.9-7.1. Adjust by NaOH if necessary.

Repeat this step twice to produce two 1000ml ND solutions.

*2. Acid Detergent Fibre Solution: 1.00N $H_2SO_4$ with CTAB*

Concentrated sulfuric acid 49.04 x2
Cetyl trimethylammonium bromide (CTAB, $CH_3(CH_2)_{15}(CH_3)_3NBr$) 20g x2

Weigh 49.04 g conc. $H_2SO_4$ into a 1000 ml volumetric flask containing 400 ml deionised water. Make up to volume with deionised water. Add 20 g of CTAB (Cetyl trimethylammonium bromide, $CH_3(CH_2)_{15}(CH_3)_3NBr$).

Repeat this step twice to produce two 1000ml AD solutions.

*3. Acid Detergent Lignin Solution: Sulfuric acid, 72%*
Concentrated sulfuric acid, 98%

Weigh 433 g of deionised water into 1000 ml volumetric flask and add 1201 g (or 653 ml) of conc. $H_2SO_4$ slowly with occasional swirling. The flask must be cooled in water in order to add the required weight of acid. Cool to 20°C and check if volume is right. If volume is too large, take out 5 ml solution and add 4.55 ml conc. $H_2SO_4$. If volume is too small, take out 1.5 ml solution and add 2.5 ml of deionised water. Repeat if necessary. Meniscus should be within 0.5 cm of the calibration mark at 20°C.

**Sample preparation:**
Solid samples are normally ground to less than 1.0 mm.

Semi-solid is difficult to handle particularly when where is a wide variation in particle size and / or hardness of constituents. Depending on the particular sample type, homogenizing, liquefying or ball milling may provide a suitable sample for analysis. if possible dry sample before milling.

**Analytical Procedure for Neutral Detergent Fibre (NDF):**
1. Label 18 capsules with an indelible pen and dry them with lids in the oven at 105°C for at least 30 minutes. Transfer to desiccator, cool for at least 5 minutes prior to weighing sample;

2. Weigh pre-dried capsule+lid ($W_1$), tare and weigh around 1 g of ground sample to an accuracy of ±0.1mg ($W_2$) into each capsule, secure lids. Place the capsules in the tray holder, and place the tray in place in the carousel. Triplicate analysis for each sample (totally 5 samples can be treated in a run), and the rest three capsules and lids are the control;

3. If the fat content is above 5%, samples should be de-fatted prior to analysis:
Add 1000 ml of ether to the extraction beaker. Place the try holder with the capsules in the solution and agitate for 30 seconds. Lift the tray holder out of the solution and drain the capsules from solvent. Repeat three times in three different containers with solvent. Remove tray holder and allow capsules to drain and air-dry in fume hood.
For samples containing fatty substances that cannot be removed directly, the extraction shall be carried out after the detergent treatment using acetone ($CH_3COCH_3$);

4. Put 1000 ml of hot water (80°C) and 21-28 ml of 2% Amylase to the extraction beaker. Place the carousel with capsules into the beaker and gently agitate to mix well. Allow standing for 15 minutes at room temperature;

5. Drain the solution out of the capsules. Wash once with cold water and drain;

6. Place extraction beaker with 1000 ml of Neutral Detergent (ND) solution. Lower the carousel unit into the reagent sufficient to immerse the samples. Gently agitate to thoroughly disperse samples and then fully lower the carousel into the reagent.

7. Put the beaker on the hot plate and place condenser on top of the extraction beaker. Open cold water tap (0.4 l/min) for the reflux system. Let it boil gently for 30 minutes. Always measure boiling from the time when the solution has reached the boiling point (determined by the presence of small air bubbles breaking the surface of the liquid);

8. Remove the carousel from the beaker and dry the lid membrane with a piece of soft tissue. Discard half (500 ml) of the extraction solution. Add another 500 ml of fresh ND solution and 21-28 ml of 2% amylase solution;

9. Lower the carousel into the extraction beaker and agitate. Put the beaker back on the hot plate and fit the condenser on the top;

10. Bring the solution up to boiling and boil gently for 30 minutes again. Meanwhile, preheat ~3 liters of water to boiling;

11. Remove the condenser. Remove the extraction beaker from the hotplate. Remove the carousel from the beaker and empty the beaker and capsules of liquid. If solution is present on the lid membrane, it might be difficult to filter the capsule. Tap the whole extraction carousel against a hard surface and dry the lid membrane with soft tissue. Return the carousel to the empty extraction beaker and 'spin' rotate to remove all of the liquid from the capsules and discard;

12. Fill the beaker with 1000 ml of boiling water (to mark). Wash by partially lowering the extraction carousel into the water ensuring that the capsules refill, gently agitate the carousel and raise it to empty the capsules and lower to refill. Do not use so much water so that the lids are covered with water. Empty the capsules and extraction beaker. Dry the capsule lid with soft tissue if necessary. Repeat the washing procedure twice more;

13. Add 1000 ml of hot water (~80°C) and 21-28 ml of 2% amylase to the extraction beaker. Return carousel to the beaker and agitate. Allow standing for 15 minutes;

14. Wash the capsules twice with cold water following the above washing procedure;

15. De-fatting with acetone if necessary;

16. Put the capsule tray on the drying stand, and dry capsules in an oven at 105±2°C for 5 h;

17. Cool the capsules to room temperature in a desiccator and weigh with a precision of ±0.1 mg ($W_3$);

18. Place the capsules in pre-dried and pre-weighed ($W_4$) ashing crucibles. It is important that the crucible used is high enough so that all of the ash is retained inside the crucibles as a standing capsule can fall during ashing;

19. The pressure inside the capsule can increase during ashing. To avoid this, make a small slit in the capsule using a scalpel prior to ashing;

20. Ash the capsules in the ashing crucibles for 4 h at 600 ± 10°C. Do not place capsules in hot furnace. Always try to heat them slowly by having them in a cold furnace from the beginning and then increase the temperature;

21. Cool the ashing crucibles slowly, at ~200°C place them in a desiccator. When room temperature is reached, weigh with a precision of ±0.1 mg ($W_5$);

22. Calculation:

$$\%NDF = Hemicellulose + Cellulose + Lignin = \frac{W_3 - (W_1 \times C) - (W_5 - W_4 - D)}{W_2} \times 100$$

where,
$W_1$ = Initial capsule weight, g;
$W_2$ = Sample weight, g;
$W_3$ = Weight of capsule + residue sample after extracting and drying, g;
$W_4$ = Weight of empty ashing crucible, g;
$W_5$ = Weight of total ash and ashing crucible, g;
C = Blank correction for capsule solubility;
D = Capsule ash, g.

The capsules can loose a small amount of weight during reaction with the reagents. A correction factor (C) to compensate for this loss is used in the formula for calculation of analytical results. Typically the correction factor (C) is >0.9990, corresponding to ~3 mg weight loss of a capsule during processing:

$$C = \frac{blank \cdot capsule \cdot weight \cdot after \cdot extractions}{blank \cdot capsule \cdot weight \cdot at \cdot start}$$

During the final ashing step some ash weight is obtained from the capsule itself (D). It is recommended to make an ash evaluation in each batch of samples being analysed. The ash weight contribution from the capsule is typically < 3 mg.

**Analytical Procedure for Acid Detergent Fibre (ADF):**
The first three steps follow the instructions for NDF 1-3;

4. Put 1000 ml of AD solution to the extraction beaker. Gently lower the carousel into the beaker ensuring all capsules have been wetted and then raise the capsules out again;

5. Place the carousel with capsules back into the AD solution avoiding getting fluid on the lid of the capsules. Dryness of the lids is essential;

6. Rotate the carousel gently and make sure that there is fluid in each cap;

7. Put the beaker on the hot plate and place condenser on top of the extraction beaker. Open cold water tap (0.4 l/min) for the reflux system. Let it boil gently for 60 minutes and rotate occasionally if desired. Always measure boiling from the time when the solution has reached the boiling point (determined by the presence of small air bubbles breaking the surface of the liquid);

8. Carefully take carousel out of the AD solution and carefully dispose of the solution down the sink with plenty of running water;

9. Place the carousel back into the empty beaker and spin it to displace the fluid. Dry the lids with soft tissue;

10. Fill the beaker with 1000 ml of boiling water. Lower the carousel into the boiling water and ensure all capsules have water in them. Twist the carousel backwards and forwards to rinse the capsules;

11. Remove the carousel from the water.

12. Dispose of the water down to the sink.

13. Replace the carousel back into the beaker and spin off any excess water. Dry the capsule lids with soft tissue;

14. Wash the capsules up to 4 times more with hot water following the above washing procedure. On the last rinse wash the lids of the capsules;

15-21. Follow the instructions for NDF 15-21;

22. Calculation:

$$\%ADF = Cellulose + Lignin = \frac{W_3 - (W_1 \times C) - (W_5 - W_4 - D)}{W_2} \times 100$$

See the instruction for NDF 22 for the meaning of each symbol.

**Analytical Procedure for Acid Detergent Lignin (ADL):**
The first steps follow the instructions for ADF 1-14;

Note: Please do not fill the capsule with sample higher than half the capsule height. Otherwise, the acid is difficult to be washed out later and the capsules will burn in the oven when drying.

15. Place ~700ml of 72% sulfuric acid into the beaker;

16. Place the capsule tray onto the drying stand. Lower the tray with capsules into 72% sulfuric acid for 4 hours in fume cupboard;

17. Wash the samples in cold water for times until wash off all acid (wash in warm water later if necessary), and make sure the pH of the washing solution is neutral at last;

18. Follow the instructions for NDF 15-21;

19. Calculation:

$$\%ADL = Lignin = \frac{W_3 - (W_1 \times C) - (W_5 - W_4 - D)}{W_2} \times 100$$

See the instruction for NDF 22 for the meaning of each symbol.

## Appendix A8 Acid digestion for the determination of total nutrients and potentially toxic elements

**Principle:**
The objective of the method is to remove the organic matrix of the sample and leave the elements dissolved in the solution phase. The final elemental concentrations represent closely the total concentration of the element present in the sample.

The following procedure aims for the extraction of elements (e.g. Cd, Cr, Cu, Ni, Pb, Zn, K and P) with Hydrochloric-Nitric acid digestion, using a heating block with reflux apparatus followed by determination of the extract.

**Reagent:**
1. *Concentrated nitric acid, $HNO_3$:* purified and certified for trace element analysis.
2. *Concentrated hydrochloric acid, HCl;*

**Apparatus:**
1. Heating block with reflux apparatus;
2. Volumetric flasks, 50 ml capacity;
3. Funnels, suitable for 50 ml volumetric flask;
4. Storage containers, 50ml: Before use, glassware and plastic-ware should be cleansed by carefully immersing in warm (1:9) nitric acid for a minimum of 6 h and then rinsed in deionized water and dried in a clean environment;
5. Analytical balance, with an accuracy of 1 mg.

**Acid digestion procedure:**
1. For fresh samples containing around 20-40% of solids. Weight accurately about 3-5g of sample into the test tube. For dried samples weight around 0.5-1.0g into the test tube. It is recommended to use dry sample whenever possible.
2. Add 7.5ml of HCl (Hydrochloric acid) about 35-36% w/v and leave for a few minutes.
3. Add 2.5mL $HNO_3$ (Nitric acid) about 70% w/v and mix gently cover and leave to digest at room temperature a minimum of 24 hours gently mixing occasionally. A period of 48 hours seems best.
4. Prepare a blank by mixing 7.5mL of HCl and 2.5mL of $HNO_3$ and add a few anti-bumping granules.
5. Put the tubes into the heating block and increase the temperature in steps, adjust the thermostat up to 100°C when the block reaches this temperature, increase temperature up to 150°C and then up to 200°C, when the block reaches its final temperature check that the acid inside the tubes is boiling gently, slowly increasing the temperature until gentle boiling is achieved.
6. Boil gently for 2hours ±10min. Allow to cool at room temperature.
7. Filter by gravity with acid resistant, cellulose paper into a 50.0mL volumetric flask (A 25.0 or 100.0mL flask can be used but must be taken into account in the calculations). Transfer quantitatively washing 5 times with ~5mL of warm 12.5% v/v $HNO_3$. Leave to cool down and make up to volume with 12.5% v/v $HNO_3$.
8. Transfer the content of the volumetric into plastic containers. This solution is stable for a minimum of 4 weeks.
9. When possible carry out standard additions to identify possible matrix interferences and calculate recoveries.

**Determination of extracted elements is conducted by Severn Trent Services:**

1. Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Lead (Pb), Phosphorus (P), Potassium (K), and Zinc (Zn) are determined using ICP-AES;
2. Selenium (Se) is determined using ICP-MS;
3. Mercury (Hg) is determined using cold-vapour AFS.

**Expression of results:**
1. When calculated on a real 'wet' weight basis:

$$C_w = \frac{(C_d - C_b) \times 50}{m}$$

where,
$C_w$: Concentration of nutrient (P or K) or potentially toxic elements in sample, mg $kg^{-1}$;
$C_d$: Concentration of the corresponding element in the digestion supernatant, mg $l^{-1}$;
$C_b$: Concentration of the corresponding element in blank, mg $l^{-1}$;
50: The volume of final diluted solution, ml;
m: The mass of the sample, g.

2. To determine results on a dry weight basis, a separate determination of percent solids must be performed in parallel with the microwave digestion process:

$$C = \frac{C_w}{TS}$$

where,
C: Concentration of elements in sample on a dry weight basis, mg $kg^{-1}$;
TS: Total solids, %.

**Reference:**
1. Methods for the Determination of Metals in Soils, Sediments and sewage sludge and plants by Hydrochloric – Nitric Acid digestion with a note on the Determination of the insoluble Metal content 1986. Methods for the Examination of Waters and Associated Materials. Environment Agency, the UK.

## Appendix A9 Elemental analysis for CHNSO

**Principle:**
The equipment used (elemental analyser) operates for analysis of CHN, and also S, using a flash combustion in which a sample contained within a tin capsule is dropped into a combustion/reduction reactor held at 900°C. This short flash combustion is accomplished when the tin capsule is exposed to a gas flow temporarily enriched with ultra high purity oxygen. The resulting oxidation raises temperatures to higher than 1700°C. The encapsulated sample, depending on its composition, combusts generating one or more of these gases: $N_xO_x$, $CO_2$, $H_2O$, and $SO_2$ in the oxidation zone. Then $N_xO_x$ is reduced to $N_2$ in the reduction zone. After passing the reactor, the gas mixture enters the gas chromatrographic column where the different components are time-separated and then measured by detectors.

Oxygen in solid sample is converted to carbon monoxide by pyrolysis at 1060°C in the presence of metallised carbon but with the absence of oxygen gas. The carbon monoxide is then separated from the other pyrolozates under steady state conditions, and measured as a function of thermal conductivity.

**Apparatus:**
1. FlashEA 1112 Elemental Analyser, Thermo Finnigan, Italy;
2. Analytical balance, with an accuracy of 0.1 mg.

**Applications:**
1. CHN analysis for solid sample;
2. S analysis for solid sample;
3. O analysis for solid sample;
4. CN analysis for liquid sample;
5. S analysis for liquid sample.

**Analysis methods:**
Shown in table A4.1. The detailed operational procedure is attached to the EA instrument.

**Note:**
EA analysis can be used to determine TOC of the solid sample:

$$TOC = A \times 10 - B \times (1 - \frac{VS}{100}) \times 10$$

where:
TOC: total organic carbon, mg/g;
A: carbon concentration in dried sample, %;
B: carbon concentration in ashed sample, %;
VS: volatile solids, %.

**Table A1.** Elemental analyser – summary of methods and principle of technique used

| | | Analytical determination | | |
|---|---|---|---|---|
| | | CHN | S | O |
| Reactors | Configuration | *Oxidation zone:*<br>Chromium oxide<br>*Reduction zone:*<br>Reduced copper<br>*$SO_2$ removal:*<br>Silvered cobaltous/cobaltic oxide | *Oxidation zone:*<br>Copper oxide<br>*Reduction zone:*<br>Electrolytic copper | *Pyrolysis zone:*<br>Nickel plated carbon |
| | Temperature (°C) | 900 | 900 | 1060 |
| Adsorption filters | | | *$H_2O$ removal:*<br>Magnesium perchlorate | *$H_2O$ removal:*<br>Magnesium perchlorate<br>*Acid gas removal:*<br>Soda lime |
| Gas chromatographic columns | | Multiseparation column | Sulphur separation column | Oxygen separation column |
| Detector | Type | Thermal conductivity detector (TCD) | Flame photometric detector (FPD) | Thermal conductivity detector (TCD) |
| | Temperature (°C) | 75 | 90 | 65 |
| Standards | | L-Aspartic acid;<br>Atropine;<br>Nicotinamide | Cystine;<br>Methionine;<br>Sulphanilamide | L-Aspartic acid;<br>Atropine;<br>Nicotinamide |
| Catalyst | | | Vanadium pentoxide | |

## Appendix A10 References for analytical methods used at MTT

**Appendix A10.1** References for analytical methods used in the Animal Production Laboratory MTT Agrifood Research, Finland:

Reference 1: Kjeldahl nitrogen was determined with standard method (method 984.13) (AOAC, 1990. Official Methods of Analysis. Association of Official Analytical Chemists, Inc., Arlington, VA. 1298 p. ISBN 0-935584-42-0), using Cu as a digestion catalyst and Foss Kjeltec 2400 Analyzer Unit (Foss Tecator AB, Höganäs, Sweden).

Reference 2: Water soluble carbohydrates (reducing sugars): Somogyi, M. 1945. A new reagent for the determination of sugars. Journal of Biological Chemistry 160: 61-68.

Reference 3: Ether extract after hydrolysis with 3M HCl: Anon 1971. Determination of crude oils and fats. Official Journal of European Community Legislations, 297: 995-997.

Reference 4: Neutral detergent fibre (NDF) with filtering apparatus: Van Soest, P.J., Robertson, J.B. and Lewis, B.A. 1991. Methods for dietary fibre, neutral detergent fibre and non starch polysaccharides in relation to animal nutrition. Journal of Dairy Science, 74: 3583-3597. Sodium sulphite was used in NDF-detergent solution and α-amylase in case of samples containing starch. NDF is expressed without containing residual ash.

Reference 5: Acid Detergent fibre (ADF) and Lignin (Permanganate-lignin): Robertson, J.B. and Van Soest, P.J. 1981. The detergent system of analysis and its application to human foods. In: James, W.D.T. and Theander, O. (eds.). The Analyses of dietary Fibre in Foods. New York, NY, Marcell Dekker. p. 123-158.

Reference 6: Minerals and trace elements (Ca, P, K, Na, Mg, Mn, Fe, Cu, Zn, S):Luh Huang, C.-Y. and E.E. Schulte. 1985. Digestion of plant tissue for analysis by ICP emission spectrometry. Communications in soil science and plant analysis 16: 943-958. Measurement was performed with ICP-OES (inductively coupled plasma optical emission spectrometry) (Thermo Jarrel Ash Iris Advantage, Franklin, USA).

**Appendix A10.2** Examples of different methods used at MTT

**Procedure of acid digestion in open bath**

1. Weight 0.5 g of the sample to the tubes
2. Add 5 ml of concentrated HNO3 and mix carefully
3. Sand bath at 50 °C overnight coated with small funnels
4. Next morning, 30 min at 60 °C. Take funnels away and mix. Increase temperature to the 120 °C and evaporate until 2-3 ml of the sample is left.
5. Cool the samples and add water to 50 ml and mix.
6. Filtration with Whatman No 1 paper.

***Procedure of Lignin determination***

1. Adjust sinters with samples.
2. Add 25 ml of mixture of saturated $KMnO_4$ and buffering solution (2:1) and mix for smooth mixture.
    a. Buffering solution: Iron(III) nitrat nonahydrate $Fe(NO_3)_3$, silver nitrate $AgNO_3$, potassium acetate $CH_3COOK$, acetic acid $CH_3COOH$, tert.-butanol $C_4H_{10}OH$, distilled water

3. Mix three times during 90 min.
4. Soak up the mixture and rinse with demineralisation mixture and soak up again.
    a. Demineralisation mixture: oxalic acid dehydrate $C_2H_2O_4*2H_2O$, 95% ethanol, concentrated HCl, distilled water
5. Add 25 ml of the demineralisation mixture, mix and macerate black particles. Leave for 1 hour and mix after every 20 min. If needed, repeat the treatment. Soak up the mixture.
6. Rinse twice with 80 % ethanol.
7. Close the vacuum and rinse with acetone. Leave for 2-3 min and open vacuum again. Rinse again with acetone.
8. Wipe off the surroundings of sinters and place to the oven for 105 °C overnight.
9. Cool sinters in the desiccators for 1 hour and weight.
10. Place sinters to the oven for 2 hours at 500 °C, cool for 2 hours and weigh.

## Appendix B - Results of UK waste categorisation

**Table B1.** Sources of waste for UK compositional analysis

| | Location | Dates | Collection type | No. | Rounds |
|---|---|---|---|---|---|
| 1 | Ludlow [a] | 4 - 7, 10 - 14, 17 - 21 & 28 May 2010 | A | 15 | 5 |
| 2 | Craven Arms [a] | 6 May, 12 May, 19 May 2010 | A | 3 | 1 |
| 3 | Church Stretton [a] | 4 & 5 May, 10 & 11 May, 17 & 18 May 2010 | A | 6 | 2 |
| 4 | Flintshire [a] | 25 May 2010 | - | 1 | - |
| 5 | Presteigne | 27 May & 12 July 2010 | A | 2 | 1 |
| 6 | Ceredigion | 4 June, 18 June 2010 | B | 2 | 1 |
| 7 | Leatherhead | 10 Sep 2010 | C | 1 | 1 |
| 8 | Central Bedfordshire | 9 Sep 2010 | A | 1 | 1 |
| 9 | Ealing | 9 Sep 2010 | C | 1 | 1 |
| 10 | Richmond | 9 Sep 2010 | C | 1 | 1 |
| 11 | Surrey | 9 Sep 2010 | C | 1 | 1 |
| 12 | Hounslow | 9 Sep 2010 | C | 1 | 1 |
| | Total | | | 35 | 16 |

A Small (5 or 7 litre) kitchen caddies with larger (25 litre) kerbside bins collected weekly. Cornstarch bags are supplied free of charge on request

B As above but householder must buy bags or wrap waste in newspaper; only waste in bags analysed

C As a above but householder must pay for cornstarch bags

a Categories Mixed meals and Seed and stones not used in these cases; data therefore treated separately

**Table B2**. Results of waste categorisation for 8 UK sites (all categories)

| | Presteigne | Ceredigion | Leatherhead | Central Beds | Ealing | Richmond | Surrey | Hounslow |
|---|---|---|---|---|---|---|---|---|
| | 2-day ave kg | 2-day ave kg | 1 day kg | 1 day kg | 1 day kg | 1 day kg | 1 day kg | 1 day kg |
| Fruit & Veg waste | 50.4 | 100.4 | 96.0 | 64.6 | 91.7 | 97.4 | 52.7 | 94.0 |
| Fruit & Veg whole | 12.3 | 15.8 | 14.2 | 15.7 | 8.6 | 12.0 | 7.8 | 16.1 |
| Seeds and stones | 2.0 | 0.6 | 1.4 | 0.1 | 1.7 | 0.0 | 2.1 | 0.0 |
| Pasta / rice | 0.3 | 1.3 | 2.8 | 2.3 | 4.6 | 0.0 | 0.0 | 2.0 |
| Cereal | 0.5 | 0.4 | 2.4 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| Bread & bakery | 18.1 | 20.1 | 19.9 | 13.7 | 6.3 | 16.5 | 6.9 | 9.0 |
| Meat & fish | 6.6 | 9.8 | 6.9 | 5.3 | 3.6 | 3.5 | 0.5 | 5.1 |
| Bones | 4.0 | 5.1 | 5.4 | 4.5 | 6.7 | 6.9 | 3.0 | 5.9 |
| Dairy | 0.1 | 0.7 | 1.4 | 1.7 | 0.0 | 0.5 | 0.0 | 2.4 |
| Eggs (inc shells) | 1.5 | 2.0 | 2.0 | 2.1 | 1.6 | 2.8 | 1.7 | 1.1 |
| Tea bags / coffee granules | 14.7 | 16.8 | 10.0 | 8.6 | 7.6 | 11.5 | 5.1 | 10.1 |
| Snacks / sweets / desserts | 0.2 | 0.4 | 2.1 | 3.0 | 1.8 | 0.0 | 0.0 | 0.0 |
| Mixed meals | 13.4 | 11.1 | 18.9 | 3.7 | 31.4 | 27.8 | 19.3 | 28.2 |
| Other food materials | 0.5 | 0.8 | 0.0 | 0.0 | 0.0 | 1.1 | 0.0 | 1.6 |
| Biodegradable bags | 6.1 | 3.8 | 10.8 | 2.3 | 7.5 | 9.7 | 6.7 | 8.5 |
| Contamination | 0.2 | 0.6 | 4.2 | 3.9 | 5.6 | 4.9 | 3.3 | 0.3 |
| Non-food biodegradable | 0.3 | 1.0 | 0.0 | 2.3 | 2.7 | 0.0 | 0.0 | 3.2 |
| Total (kg) | 131.0 | 190.7 | 198.4 | 135.7 | 181.4 | 194.6 | 109.1 | 187.3 |
| No of bags | 200 | 200 | 100 | 100 | 100 | 100 | 100 | 100 |
| | % | % | % | % | % | % | % | % |
| Fruit & Veg waste | 38.4 | 52.6 | 48.4 | 47.6 | 50.6 | 50.1 | 48.3 | 50.2 |
| Fruit & Veg whole | 9.4 | 8.3 | 7.2 | 11.6 | 4.7 | 6.2 | 7.1 | 8.6 |
| Seeds and stones | 1.5 | 0.3 | 0.7 | 0.1 | 0.9 | 0.0 | 1.9 | 0.0 |
| Pasta / rice | 0.2 | 0.7 | 1.4 | 1.7 | 2.5 | 0.0 | 0.0 | 1.1 |
| Cereal | 0.4 | 0.2 | 1.2 | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| Bread & bakery | 13.8 | 10.5 | 10.0 | 10.1 | 3.5 | 8.5 | 6.3 | 4.8 |
| Meat & fish | 5.0 | 5.2 | 3.5 | 3.9 | 2.0 | 1.8 | 0.5 | 2.7 |
| Bones | 3.1 | 2.7 | 2.7 | 3.3 | 3.7 | 3.5 | 2.7 | 3.2 |
| Dairy | 0.1 | 0.4 | 0.7 | 1.3 | 0.0 | 0.3 | 0.0 | 1.3 |
| Eggs (inc shells) | 1.1 | 1.0 | 1.0 | 1.5 | 0.9 | 1.4 | 1.6 | 0.6 |
| Tea bags / coffee granules | 11.2 | 8.8 | 5.0 | 6.3 | 4.2 | 5.9 | 4.7 | 5.4 |
| Snacks / sweets / desserts | 0.2 | 0.2 | 1.1 | 2.2 | 1.0 | 0.0 | 0.0 | 0.0 |
| Mixed meals | 10.2 | 5.8 | 9.5 | 2.7 | 17.3 | 14.3 | 17.7 | 15.1 |
| Other food materials | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.8 |
| Biodegradable bags | 4.7 | 2.0 | 5.4 | 1.7 | 4.1 | 5.0 | 6.1 | 4.5 |
| Contamination | 0.1 | 0.3 | 2.1 | 2.9 | 3.1 | 2.5 | 3.0 | 0.1 |
| Non-food biodegradable | 0.2 | 0.5 | 0.0 | 1.7 | 1.5 | 0.0 | 0.0 | 1.7 |
| Total (%) | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

**Table B3**. Results of waste categorisation for 8 UK sites (food waste only)

| | Presteigne | Ceredigion | Leatherhead | Central Beds | Ealing | Richmond | Surrey | Hounslow |
|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % |
| Fruit & Veg waste | 41.8 | 52.6 | 52.3 | 50.8 | 55.4 | 54.1 | 53.2 | 53.6 |
| Fruit & Veg whole | 10.7 | 8.1 | 7.7 | 12.3 | 5.2 | 6.7 | 7.9 | 9.2 |
| Seeds and stones | 1.3 | 0.1 | 0.8 | 0.1 | 1.0 | 0.0 | 2.1 | 0.0 |
| Pasta / rice | 0.5 | 0.9 | 1.5 | 1.8 | 2.8 | 0.0 | 0.0 | 1.1 |
| Cereal | 0.0 | 0.3 | 1.3 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| Bread & bakery | 14.0 | 11.3 | 10.8 | 10.8 | 3.8 | 9.2 | 7.0 | 5.1 |
| Meat & fish | 6.1 | 5.6 | 3.8 | 4.2 | 2.2 | 1.9 | 0.5 | 2.9 |
| Bones | 3.1 | 2.4 | 2.9 | 3.5 | 4.0 | 3.8 | 3.0 | 3.4 |
| Dairy | 0.1 | 0.2 | 0.8 | 1.3 | 0.0 | 0.3 | 0.0 | 1.4 |
| Eggs (inc shells) | 1.0 | 1.1 | 1.1 | 1.7 | 1.0 | 1.6 | 1.7 | 0.6 |
| Tea bags / coffee granules | 11.8 | 11.1 | 5.5 | 6.8 | 4.6 | 6.4 | 5.1 | 5.8 |
| Snacks / sweets / desserts | 0.3 | 0.3 | 1.1 | 2.4 | 1.1 | 0.0 | 0.0 | 0.0 |
| Mixed meals | 9.4 | 5.6 | 10.3 | 2.9 | 19.0 | 15.4 | 19.5 | 16.1 |
| Other food materials | 0.1 | 0.3 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.9 |
| Total (%) | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

**Table B4**. Results of waste categorisation for 8 UK sites (merged categories)

| | Presteigne | Ceredigion | Leatherhead | Central Beds | Ealing | Richmond | Surrey | Hounslow |
|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % |
| Fruit and vegetable waste | 53.7 | 60.8 | 60.9 | 63.2 | 61.6 | 60.8 | 63.2 | 62.8 |
| Pasta/rice/flour/cereals | 0.5 | 1.1 | 2.8 | 3.3 | 2.8 | 0.0 | 0.0 | 1.1 |
| Bread and bakery | 14.0 | 11.3 | 10.8 | 10.8 | 3.8 | 9.2 | 7.0 | 5.1 |
| Meat and fish | 9.2 | 8.1 | 6.7 | 7.7 | 6.2 | 5.8 | 3.5 | 6.3 |
| Dairy | 1.1 | 1.3 | 1.9 | 3.0 | 1.0 | 1.8 | 1.7 | 2.0 |
| Drinks | 11.8 | 11.1 | 5.5 | 6.8 | 4.6 | 6.4 | 5.1 | 5.8 |
| Confectionery, snacks and de | 0.3 | 0.3 | 1.1 | 2.4 | 1.1 | 0.0 | 0.0 | 0.0 |
| Mixed meals | 9.4 | 5.6 | 10.3 | 2.9 | 19.0 | 15.4 | 19.5 | 16.1 |
| Other food | 0.1 | 0.3 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.9 |
| Total (%) | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

**Table B5**. Waste categorisation for 4 UK sites (without 'Mixed meals' or 'Seeds and stones')

| | Ludlow | | Craven Arms | | Church Stretton | | Flintshire | |
|---|---|---|---|---|---|---|---|---|
| | 3-week ave | | 3-week ave | | 3-week ave | | 1 day | |
| | kg | % | kg | % | kg | % | kg | % |
| Fruit & Veg waste | 55.5 | 49.8 | 60.8 | 52.7 | 62.3 | 53.8 | 34.0 | 48.2 |
| Fruit & Veg whole | 13.7 | 12.2 | 11.4 | 9.9 | 10.6 | 9.2 | 5.0 | 7.1 |
| Seeds and stones | - | - | - | - | - | - | - | - |
| Pasta / rice | 1.2 | 1.1 | 1.2 | 1.1 | 1.8 | 1.5 | 0.2 | 0.3 |
| Cereal | 0.3 | 0.3 | 0.3 | 0.3 | 0.5 | 0.4 | 0.3 | 0.4 |
| Bread & bakery | 13.7 | 12.3 | 15.3 | 13.3 | 11.6 | 10.1 | 8.5 | 12.0 |
| Meat & fish | 5.3 | 4.7 | 4.1 | 3.6 | 5.1 | 4.4 | 7.7 | 10.9 |
| Bones | 4.4 | 3.9 | 3.4 | 2.9 | 4.6 | 4.0 | 6.3 | 8.9 |
| Dairy | 0.7 | 0.6 | 0.3 | 0.3 | 0.7 | 0.6 | 0.4 | 0.5 |
| Eggs (inc shells) | 1.5 | 1.4 | 1.4 | 1.2 | 1.3 | 1.2 | 0.4 | 0.6 |
| Tea bags / coffee granules | 10.0 | 9.0 | 10.3 | 9.0 | 12.0 | 10.4 | 4.4 | 6.2 |
| Snacks / sweets / desserts | 0.3 | 0.3 | 0.5 | 0.4 | 0.6 | 0.5 | 0.1 | 0.1 |
| Mixed meals | - | - | - | - | - | - | - | - |
| Other food materials | 0.4 | 0.3 | 2.6 | 2.3 | 0.4 | 0.3 | 0.7 | 1.0 |
| Biodegradable bags | 2.3 | 2.1 | 2.4 | 2.1 | 2.2 | 1.9 | 2.1 | 3.0 |
| Contamination | 0.4 | 0.4 | 0.3 | 0.2 | 0.4 | 0.3 | 0.0 | 0.0 |
| Non-food biodegradable | 1.8 | 1.6 | 0.9 | 0.8 | 1.5 | 1.3 | 0.6 | 0.8 |
| Total | 111.5 | 100.0 | 115.4 | 100.0 | 115.8 | 100.0 | 70.6 | 100.0 |

**Table B6**. Waste categorisation for 4 UK sites (food waste only)

| | Ludlow | Craven | Church | Flintshire |
|---|---|---|---|---|
| | 3-week ave | 3-week ave | 3-week ave | 1 day |
| | % | % | % | % |
| Fruit & Veg waste | 51.9 | 54.4 | 55.8 | 50.0 |
| Fruit & Veg whole | 12.8 | 10.2 | 9.5 | 7.4 |
| Seeds and stones | 0.0 | 0.0 | 0.0 | 0.0 |
| Pasta / rice | 1.1 | 1.1 | 1.6 | 0.3 |
| Cereal | 0.3 | 0.3 | 0.5 | 0.4 |
| Bread & bakery | 12.8 | 13.7 | 10.4 | 12.5 |
| Meat & fish | 4.9 | 3.7 | 4.6 | 11.3 |
| Bones | 4.1 | 3.0 | 4.1 | 9.3 |
| Dairy | 0.6 | 0.3 | 0.6 | 0.5 |
| Eggs (inc shells) | 1.4 | 1.3 | 1.2 | 0.6 |
| Tea bags / coffee granules | 9.4 | 9.2 | 10.8 | 6.5 |
| Snacks / sweets / desserts | 0.3 | 0.4 | 0.6 | 0.1 |
| Mixed meals | 0.0 | 0.0 | 0.0 | 0.0 |
| Other food materials | 0.4 | 2.3 | 0.3 | 1.0 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

**Table B7**. Waste categorisation for 4 UK sites (merged categories for comparison)

| | Ludlow | Craven Arms | Church Stretton | Flintshire |
|---|---|---|---|---|
| | % | % | % | % |
| Fruit and vegetable waste | 64.6 | 64.6 | 65.3 | 57.4 |
| Pasta/rice/flour/cereals | 1.4 | 1.4 | 2.1 | 0.7 |
| Bread and bakery | 12.8 | 13.7 | 10.4 | 12.5 |
| Meat and fish | 9.0 | 6.7 | 8.7 | 20.6 |
| Dairy | 2.0 | 1.5 | 1.8 | 1.1 |
| Drinks | 9.4 | 9.2 | 10.8 | 6.5 |
| Confectionery, snacks and de | 0.3 | 0.4 | 0.6 | 0.1 |
| Mixed meals | 0.0 | 0.0 | 0.0 | 0.0 |
| Other food | 0.4 | 2.3 | 0.3 | 1.0 |
| Total (%) | 100.0 | 100.0 | 100.0 | 100.0 |

**Table B8**. Waste categorisation for Craven Arms (all, no 'Mixed meals' or 'Seeds and stones')

| Craven Arms | Week 1 06.05.10 | | Week 2 12.05.10 | | Week 3 19.05.10 | | 3-week ave | |
|---|---|---|---|---|---|---|---|---|
| | kg | % | kg | % | kg | % | kg | % |
| Fruit & Veg waste | 67.6 | 55.7 | 65.2 | 52.1 | 49.7 | 49.8 | 60.8 | 52.5 |
| Fruit & Veg whole | 10.1 | 8.3 | 14.0 | 11.2 | 10.3 | 10.3 | 11.4 | 9.9 |
| Seeds and stones | - | - | - | - | - | - | - | - |
| Pasta / rice | 2.5 | 2.0 | 0.5 | 0.4 | 0.8 | 0.8 | 1.2 | 1.0 |
| Cereal | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 | 0.3 | 0.3 |
| Bread & bakery | 15.0 | 12.3 | 14.1 | 11.2 | 17.0 | 17.0 | 15.3 | 13.5 |
| Meat & fish | 5.0 | 4.1 | 4.4 | 3.5 | 3.0 | 3.0 | 4.1 | 3.6 |
| Bones | 4.1 | 3.4 | 3.6 | 2.9 | 2.5 | 2.5 | 3.4 | 2.9 |
| Dairy | 0.4 | 0.3 | 0.3 | 0.2 | 0.4 | 0.4 | 0.3 | 0.3 |
| Eggs (inc shells) | 1.6 | 1.3 | 1.5 | 1.2 | 1.1 | 1.1 | 1.4 | 1.2 |
| Tea bags / coffee granules | 10.8 | 8.9 | 11.4 | 9.1 | 8.8 | 8.8 | 10.3 | 8.9 |
| Snacks / sweets / desserts | 0.6 | 0.5 | 0.0 | 0.0 | 1.0 | 1.0 | 0.5 | 0.5 |
| Mixed meals | - | - | - | - | - | - | - | - |
| Other food materials | 0.0 | 0.0 | 6.0 | 4.8 | 1.8 | 1.8 | 2.6 | 2.2 |
| Biodegradable bags | 2.6 | 2.1 | 2.5 | 2.0 | 2.2 | 2.2 | 2.4 | 2.1 |
| Contamination | 0.2 | 0.2 | 0.4 | 0.3 | 0.2 | 0.2 | 0.3 | 0.2 |
| Non-food biodegradable | 1.2 | 1.0 | 1.4 | 1.1 | 0.2 | 0.2 | 0.9 | 0.7 |
| Total waste sorted | 121.4 | 100.0 | 125.1 | 100.0 | 99.6 | 100.0 | 115.4 | 100.0 |
| No of bags sorted | 100 | | 100 | | 100 | | | |

**Table B9**. Waste categorisation for Church Stretton (all, no 'Mixed meals' or 'Seeds and stones')

| Church Stretton | 04.05.10 | | 05.05.10 | | 10.05.10 | | 11.05.10 | | 17.05.10 | | 18.05.10 | | 1-week ave | 2-week ave | 3-week ave | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | kg | % | kg | % | kg | % | kg | % | kg | % | kg | % | % | % | kg | % |
| Fruit & Veg waste | 68.2 | 56.7 | 67.5 | 49.6 | 53.6 | 52.1 | 57.0 | 50.5 | 48.7 | 59.7 | 79.1 | 55.8 | 53.15 | 52.24 | 62.32 | 54.09 |
| Fruit & Veg whole | 11.5 | 9.6 | 17.5 | 12.8 | 7.5 | 7.3 | 11.2 | 9.9 | 6.1 | 7.5 | 10.0 | 7.0 | 11.19 | 9.89 | 10.61 | 9.02 |
| Seeds and stones | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Pasta / rice | 1.0 | 0.8 | 4.5 | 3.3 | 1.2 | 1.1 | 1.4 | 1.2 | 0.8 | 1.0 | 2.0 | 1.4 | 2.05 | 1.60 | 1.79 | 1.47 |
| Cereal | 0.0 | 0.0 | 0.3 | 0.2 | 0.8 | 0.7 | 1.0 | 0.8 | 0.2 | 0.2 | 1.0 | 0.7 | 0.09 | 0.44 | 0.52 | 0.45 |
| Bread & bakery | 8.6 | 7.1 | 11.8 | 8.7 | 15.3 | 14.9 | 12.8 | 11.4 | 9.4 | 11.5 | 12.0 | 8.5 | 7.91 | 10.52 | 11.64 | 10.34 |
| Meat & fish | 6.5 | 5.4 | 6.8 | 5.0 | 4.5 | 4.4 | 5.9 | 5.3 | 2.2 | 2.7 | 4.6 | 3.2 | 5.21 | 5.02 | 5.09 | 4.34 |
| Bones | 5.3 | 4.4 | 5.5 | 4.0 | 3.7 | 3.6 | 4.9 | 4.3 | 1.6 | 1.9 | 6.8 | 4.8 | 4.24 | 4.09 | 4.61 | 3.84 |
| Dairy | 0.6 | 0.5 | 0.4 | 0.3 | 0.5 | 0.5 | 1.6 | 1.4 | 0.3 | 0.3 | 0.7 | 0.5 | 0.36 | 0.64 | 0.65 | 0.56 |
| Eggs (inc shells) | 1.4 | 1.2 | 1.4 | 1.0 | 1.0 | 1.0 | 1.3 | 1.1 | 0.9 | 1.1 | 2.2 | 1.5 | 1.08 | 1.06 | 1.34 | 1.14 |
| Tea bags / coffee granules | 11.6 | 9.6 | 14.7 | 10.8 | 9.5 | 9.2 | 11.6 | 10.2 | 8.0 | 9.8 | 17.1 | 12.0 | 10.20 | 9.96 | 12.04 | 10.28 |
| Snacks / sweets / desserts | 0.0 | 0.0 | 0.7 | 0.5 | 0.3 | 0.2 | 0.5 | 0.4 | 2.0 | 2.5 | 0.3 | 0.2 | 0.24 | 0.29 | 0.62 | 0.64 |
| Mixed meals | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Other food materials | 0.0 | 0.0 | 0.9 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 1.0 | 0.31 | 0.16 | 0.38 | 0.27 |
| Biodegradable bags | 2.6 | 2.1 | 2.7 | 2.0 | 2.9 | 2.8 | 2.2 | 2.0 | 0.7 | 0.8 | 2.5 | 1.8 | 2.05 | 2.21 | 2.24 | 1.90 |
| Contamination | 1.2 | 1.0 | 0.2 | 0.1 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.4 | 0.2 | 0.55 | 0.41 | 0.40 | 0.34 |
| Non-food biodegradable | 2.1 | 1.7 | 1.4 | 1.0 | 1.9 | 1.9 | 1.4 | 1.2 | 0.7 | 0.8 | 1.9 | 1.3 | 1.37 | 1.46 | 1.54 | 1.32 |
| Total weight of food sorted | 120.4 | | 136.0 | | 102.7 | | 112.7 | | 81.4 | | 141.6 | | 100.0 | 100.0 | 115.8 | 100.0 |
| Total No of bags sorted | 100 | | 100 | | 100 | | 100 | | 100 | | 100 | | 100 | 100 | 100 | 100 |

**Table B10**. Waste categorisation for Presteigne (all, no 'Mixed meals' or 'Seeds and stones')

| **Presteigne** | **Week 1 12.07.10** | | **Week 2 27.05.10** | | **2-week ave** | |
|---|---|---|---|---|---|---|
| | kg | % | kg | % | kg | % |
| Fruit & Veg waste | 50.8 | 39.8 | 49.9 | 37.2 | 50.4 | 38.5 |
| Fruit & Veg whole | 13.0 | 10.2 | 11.6 | 8.7 | 12.3 | 9.4 |
| Seeds and stones | 1.5 | 1.2 | 2.4 | 1.8 | 2.0 | 1.5 |
| Pasta / rice | 0.6 | 0.4 | 0.0 | 0.0 | 0.3 | 0.2 |
| Cereal | 0.0 | 0.0 | 1.0 | 0.7 | 0.5 | 0.4 |
| Bread & bakery | 17.0 | 13.3 | 19.2 | 14.3 | 18.1 | 13.8 |
| Meat & fish | 7.4 | 5.8 | 5.8 | 4.3 | 6.6 | 5.0 |
| Bones | 3.8 | 3.0 | 4.2 | 3.1 | 4.0 | 3.1 |
| Dairy | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 |
| Eggs (inc shells) | 1.3 | 1.0 | 1.8 | 1.3 | 1.5 | 1.1 |
| Tea bags / coffee granules | 14.4 | 11.3 | 15.0 | 11.2 | 14.7 | 11.2 |
| Snacks / sweets / desserts | 0.4 | 0.3 | 0.1 | 0.1 | 0.2 | 0.2 |
| Mixed meals | 11.4 | 8.9 | 15.4 | 11.5 | 13.4 | 10.2 |
| Other food materials | 0.1 | 0.0 | 1.0 | 0.7 | 0.5 | 0.4 |
| Biodegradable bags | 5.8 | 4.5 | 6.4 | 4.8 | 6.1 | 4.7 |
| Contamination | 0.1 | 0.1 | 0.3 | 0.2 | 0.2 | 0.1 |
| Non-food biodegradable | 0.1 | 0.1 | 0.5 | 0.3 | 0.3 | 0.2 |
| Total waste sorted | 127.5 | 100.0 | 134.0 | 100.0 | 130.8 | 100.0 |
| No of bags sorted | 100 | | 100 | | 100 | |

**Table B11**. Waste categorisation for Ceredigion (all, no 'Mixed meals' or 'Seeds and stones')

| **Ceredigion** | **Week 1 04.06.10** | | **Week 2 18.06.10** | | **2-week ave** | |
|---|---|---|---|---|---|---|
| | kg | % | kg | % | kg | % |
| Fruit & Veg waste | 100.0 | 51.4 | 100.8 | 53.9 | 100.4 | 52.7 |
| Fruit & Veg whole | 15.3 | 7.9 | 16.2 | 8.7 | 15.8 | 8.3 |
| Seeds and stones | 0.2 | 0.1 | 0.9 | 0.5 | 0.6 | 0.3 |
| Pasta / rice | 1.7 | 0.8 | 0.9 | 0.5 | 1.3 | 0.7 |
| Cereal | 0.5 | 0.3 | 0.3 | 0.2 | 0.4 | 0.2 |
| Bread & bakery | 21.5 | 11.0 | 18.6 | 10.0 | 20.1 | 10.5 |
| Meat & fish | 10.7 | 5.5 | 9.0 | 4.8 | 9.8 | 5.1 |
| Bones | 4.7 | 2.4 | 5.6 | 3.0 | 5.1 | 2.7 |
| Dairy | 0.5 | 0.2 | 1.0 | 0.5 | 0.7 | 0.4 |
| Eggs (inc shells) | 2.0 | 1.0 | 1.9 | 1.0 | 2.0 | 1.0 |
| Tea bags / coffee granules | 21.0 | 10.8 | 12.7 | 6.8 | 16.8 | 8.8 |
| Snacks / sweets / desserts | 0.7 | 0.3 | 0.2 | 0.1 | 0.4 | 0.2 |
| Mixed meals | 10.7 | 5.5 | 11.6 | 6.2 | 11.1 | 5.9 |
| Other food materials | 0.7 | 0.3 | 1.0 | 0.5 | 0.8 | 0.4 |
| Biodegradable bags | 3.1 | 1.6 | 4.5 | 2.4 | 3.8 | 2.0 |
| Contamination | 0.7 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 |
| Non-food biodegradable | 1.0 | 0.5 | 1.0 | 0.5 | 1.0 | 0.5 |
| Total waste sorted | 194.6 | 100.0 | 186.8 | 100.0 | 190.7 | 100.0 |
| No of bags sorted | 100 | | 100 | | 100 | 100 |

**Table B12**. Waste categorisation for Ludlow (all, no 'Mixed meals' or 'Seeds and stones')

| Ludlow | Mon 04.05.10 | Mon 10.05.10 | Mon 17.05.10 | Tue 05.05.10 | Tue 11.05.10 | Tue 18.05.10 | Wed 06.05.10 | Wed 12.05.10 | Wed 19.05.10 | Thur 13.05.10 | Thur 20.05.10 | Thur 07.05.10 | Fri 14.05.10 | Fri 21.05.10 | Fri 28.05.10 | 3-week ave |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % | % | % | % | % | % | % | % | % |
| Fruit & Veg waste | 56.4 | 43.4 | 53.2 | 52.2 | 39.7 | 52.5 | 52.9 | 51.1 | 54.1 | 53.0 | 63.4 | 40.6 | 54.4 | 47.3 | 60.3 | 51.9 |
| Fruit & Veg whole | 12.1 | 25.8 | 11.3 | 10.9 | 13.7 | 9.0 | 9.3 | 12.3 | 10.2 | 11.3 | 9.4 | 16.6 | 10.4 | 16.6 | 10.7 | 12.8 |
| Pasta / rice | 1.2 | 0.4 | 0.6 | 1.6 | 0.7 | 0.2 | 0.3 | 0.7 | 1.8 | 2.8 | 2.4 | 1.5 | 1.5 | 0.3 | 0.3 | 1.1 |
| Cereal | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.3 | 0.0 | 1.1 | 0.1 | 0.0 | 1.5 | 0.1 | 0.4 | 0.0 | 0.3 |
| Bread & bakery | 9.6 | 7.9 | 9.0 | 12.2 | 16.4 | 15.8 | 15.7 | 14.4 | 12.7 | 13.2 | 8.7 | 12.9 | 16.8 | 18.6 | 14.3 | 12.8 |
| Meat & fish | 5.8 | 6.3 | 6.0 | 5.5 | 6.0 | 4.6 | 4.1 | 3.9 | 3.1 | 4.5 | 2.9 | 9.4 | 3.9 | 5.2 | 1.6 | 4.9 |
| Bones | 4.7 | 5.1 | 5.2 | 4.5 | 4.8 | 4.2 | 3.4 | 3.2 | 0.0 | 3.1 | 4.4 | 7.7 | 3.3 | 2.7 | 3.4 | 4.1 |
| Dairy | 0.4 | 0.3 | 0.1 | 0.6 | 0.8 | 1.2 | 0.0 | 0.4 | 1.6 | 0.6 | 0.0 | 1.2 | 0.5 | 1.7 | 0.7 | 0.6 |
| Eggs (inc shells) | 1.0 | 1.5 | 1.0 | 1.3 | 1.7 | 1.6 | 2.1 | 2.7 | 1.6 | 1.1 | 1.4 | 1.6 | 0.9 | 0.9 | 1.3 | 1.4 |
| Tea bags / coffee granules | 7.9 | 9.3 | 13.0 | 10.1 | 14.3 | 9.2 | 11.4 | 9.9 | 10.6 | 10.0 | 7.2 | 6.5 | 8.2 | 6.3 | 7.2 | 9.4 |
| Snacks / sweets / desserts | 0.2 | 0.0 | 0.2 | 0.6 | 0.7 | 0.2 | 0.5 | 0.1 | 1.4 | 0.3 | 0.3 | 0.5 | 0.0 | 0.0 | 0.2 | 0.3 |
| Other food materials | 0.2 | 0.0 | 0.3 | 0.5 | 1.2 | 0.3 | 0.0 | 1.2 | 1.7 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.4 |
| Total (%) | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |