Compositional analysis of food waste from study sites in Greek municipalities

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Abstract

Biowaste of household origin is mostly food waste and, in less percentage, green waste. In recent years qualitative and quantitative data concerning household food waste composition are limited with the exception of some countries. The current paper focuses on the presentation of the methodology developed and applied for conducting compositional analysis on source separated household biowaste originating from the Municipalities of Athens and Kifissia of the Attica Region (Greece). The performance of the methodology in the two different municipalities revealed similarities in obtained results, since fruit and vegetable waste constituted the main household biowaste stream in both municipalities. However, it also showed differentiations between municipalities mainly considering bread and bakery waste, paper and green waste which can be attributed to the most urbanised character of Athens Municipality. In line with data derived from other countries, in Greece 'Fruit and Vegetable' waste constitutes the main part of biowaste household waste. Waste compositional analysis can, between others, provide useful information regarding the degree of the success of a source separation scheme, the appropriateness of the specific feedstock as a substrate in a biological treatment process and the determination of a typical national composition of household biowaste. The high proportions of 'Rest waste' indicate that compositional analysis should be performed to fresh and non-compacted waste in order to be able to distinguish between different waste components, thus increasing accuracy and precision and minimising uncertainty.

Keywords: Household food waste, biowaste, compositional analysis, waste analysis composition, Greece

Introduction

According to the Directive 2008/98/EC, the term '*biowaste'* includes green biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants [1]. At household level, the greatest amount of biowaste constitutes the Household Food Waste (HFW), while especially in the large urban centres the fraction of green waste is considerably small. Food waste has been recognized as a major environmental and social issue to be addressed worldwide. At European level, the largest quantity of food waste is generated from households (42%) [2].

In recent years there is a tendency towards quantification and recording of qualitative characteristics of biowaste originated from households, since such data are too limited [3] except for some countries, e.g. United Kingdom (UK). Such information is of interest to a range of stakeholders, such as national and local authorities, waste management companies, researchers and the public in order to: (a) define current situation of waste composition, (b) prioritize waste management needs, (c) determine preventing measures at national, regional and local level and benchmarking the progress towards their implantation, (d) determine the degree and nature of the presence of impurities in source separation, (e) inform food-waste reduction activities and (f) plan waste collections and treatment [4]. Moreover, in any waste treatment process, feedstock characteristics are of considerable significance and importance in order to define some design and operational parameters [5]. The composition of household waste can be acquired through compositional analysis. However, since there is no international standard methodology and no consistency in the definitions used, the analysis can be done through different methods including: (a) waste analysis campaigns (WAC) undertaken by the interested party, (b) kitchen diaries kept by the consumers, (c) estimations from statistical data on food supply and nutrition and (d) questionnaire surveys etc [4].

In Greece, there is almost a complete knowledge gap of compositional characteristics of food waste given that the legislation encouraging biowaste separate collection and treatment has been recently put into practice [6]. This study aims at presenting the ensued methodology for conducting the compositional analysis through conduction of waste analysis campaigns. Furthermore, it is in the scope of the present study to illustrate the results derived from the performance of household biowaste composition campaigns on samples from the Municipalities of Athens and Kifissia of Attica Region (Greece) as well as to compare the results to those from other countries.

Materials and Methods

The development of the compositional analysis methodology was conducted in the framework of the LIFE+ ATHENS-BIOWASTE project which aims at establishing a separate biowaste collection scheme in the *Municipalities of Athens and Kifissia* (Greece) and treating the collected biowaste in the Mechanical and Biological Treatment (MBT) facility of the Association of Municipalities of Attica (EDSNA) in order to produce high quality compost [7]. In the *Municipality of Kifissia* the project was implemented in six (4) pilot areas - neighbourhoods: *Kato Kifisia, Ano Kifisia, Kastri, Ekali, Strofuli and Kefalari*, *while i*n the *Municipality of Athens* in two (2) neighbourhoods: *Kypriadou* and *Gazi* [7, 8].

In order to determine the methodology for conducting the compositional analysis different technical reports, standards and scientific papers [4, 9, 10, 11, 12, 13] given that a standardised methodology for household biowaste separated at source is missing from the literature. The compositional analysis was executed through waste analysis campaigns (WACs) to the MBT facilities by appropriately trained personnel and for each municipality separately. Although special attention was given in order to ensure that the collected material from the served areas was fresh enough, since food spoiling can imped the procedure, it was not always achievable. In total, six (6) WACs (three (3) WACs for each municipality) were implemented, in a year period.

The methodology developed included procedures for the collection of a representative sample of unprocessed waste, manual sorting of the waste into individual waste components, data recording, and reporting of the results. Initially, on the day of waste analysis campaign, the load of the designated vehicles from each municipality (*Athens or Kifissia*) was weighed and recorded. The collected load was discharged from the collection vehicle in a clean surface at the MBT facility (**Figure 1**). Each time and for each municipality, the working group was selecting a quantity between 300 to 500kg depending on the biowaste load received. Following, opening of all bags (plastic and biodegradable) and emptying of the contents to a prepared area was implemented. Afterwards, mixing, coning and quartering procedure of the material was executed (**Figure 2**). Unprocessed HFW is a highly heterogeneous mixture. Thus, care must be taken for the purpose of eliminating or minimizing biasing of the sample and in order to obtain a representative sample [9]. After performing mixing, about 5kg of representative sample was collected and stored for laboratory analysis. The remaining mixture was weighed and transferred to the sorting table where the compositional analysis was conducted (**Figure 3**). The methodology employed manual sorting of the mixture into specified waste components until the maximum particle size of remaining waste particles was about 13mm. The primary waste components which were selected are presented in **Table 1**.

Table 1: Selected waste component categories for compositional analysis in household biowaste

No.	Waste component category
1	Vegetables and Salads
2	Fruits
3	Bread and Bakery
4	Meals (homemade and preprepared)
5	Spaghetti /Rice/Flour/Cereals
6	Meat and Fish
7	Dairy and Eggs
8	Cake, Desserts, Confectionery and Snacks
9	Drinks (Coffee and tea bags)
10	Paper
11	Garden Waste
12	Rest biowaste: *organic material which do not fit into another category because (a) it is not possible to be integrated in a category and / or (b) have a size less than 13mm*
13	Impurities: *i.e. plastics, metals, glass, plastic bags etc.*

These specific categories (waste components) were deliberately used in order that the current estimates can be legitimately compared with data from other countries. After sorting, weighing of the sorted material into categories was employed. Each weighing was executed twice and the resulting values were recorded. Finally, the load discharge area, the sorting site and the sorting table of all waste materials were cleaned. The mass fraction of each component in the sorting sample was calculated from the mass of the component. In particular, the mass fraction of component i, mf_i, is defined and computed as follows: $mf_i = \frac{w_i}{\sum_{i=1}^{j} w_i}$, w $_i$= weight of component i and j = number of waste components, while the percent of component i, Pi, is defined as: $P_i = mf_i \times 100$ [9]. An outline of the methodology is illustrated in **Figure 4**.

(a) **(b)**

Figure 1: Weighing the collected load (a) and unloading waste from collection vehicles (b)

Figure 2: Coning and quartering procedure for selecting representative unprocessed waste samples

Figure 3: Conducting compositional analysis

1. Weight and record the mass of the total collected load of household from each municipality.
2. Prepare: (a) a swept clean load-discharge area at the MBT facility for unloading the collected biowaste by vehicles (*Step 3*), (b) a clean surface for opening bags (*Steps 4 and 5*) and (c) the sorting table (or area) (*Step 6*). Use tarp *(if needed)* prior to any discharge.
3. Unload waste from collection vechicle to the load discharge area at the MBT facility.
4. Select between 300 -500kg, then open all bags and empty the contents to the prepared area.
5. Mix, cone and quarter biowaste and then select about 5kg of representative sample for laboratory analysis.
6. Weight the remaing biowaste and transfer it to the sorting table.
7. Mannualy sort to predefined waste components *(see Table 1).* Continue sorting until the maximum particle size of the remaining waste is approximately 13mm
8. Weight and record the waste category. Re-weight is ncessary.
9. Clean the load-discharge area, the surface for mixing and the sorting table.
10. Calculate mass fraction and percentage of waste component.

Figure 4: Outline of the methodology used for conducting compositional analysis in household biowaste

Results and Discussion

Figure 5 illustrates composition results of household biowaste from the Municipality of Kifissia from two out of three WACs, without considering the impurities. Results from the 3rd WAC were not considered representative due to bad weather conditions during collection from vehicles and, thus, are not presented.

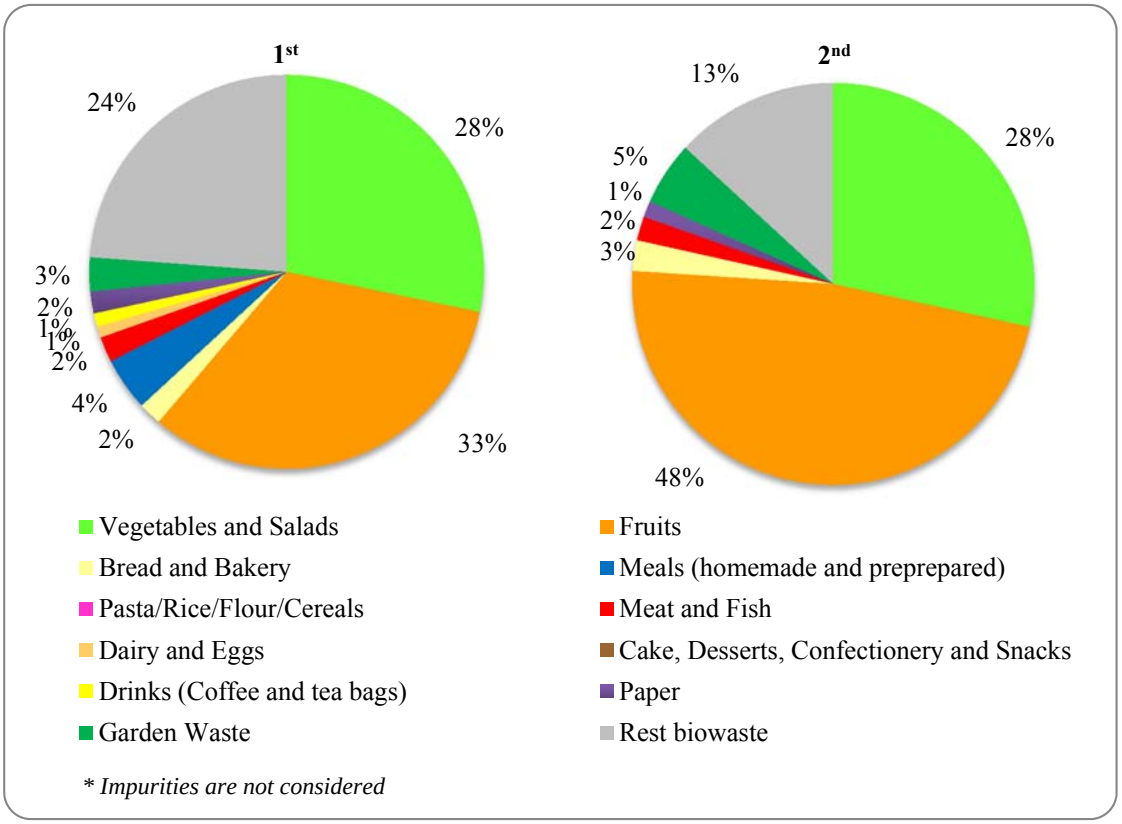

Figure 5: Pie charts depicting compositional analysis results from Kifissia, Greece

The charts clearly show that the largest amounts of household biowaste of Kifissia are '*Fruit*' waste (33% and 48 % from 1st WAC and 2nd WAC, respectively) followed by waste from '*vegetables and salads*' (28 % in both WAC). Percentages of '*Rest biowaste'* recorded high values especially during the 1st WAC (24 %), while during the 2nd the percentage fell to 13 %. The figures for '*Meat and Fish*' and '*Bread and Bakery*' food waste categories remained constant at around 2 %, both for the 1st & 2nd WAC in Kifissia.

Low enough was the percentages of '*Paper*' (2% and 1 % from 1st WAC and 2nd WAC, respectively) and of '*Garden Waste*' (3% and 5% from 1st WAC and 2nd WAC, respectively) in Kifissia.

Figure 6 depict the results derived from the execution of the three WACs of household biowaste originated the Municipality of Athens.

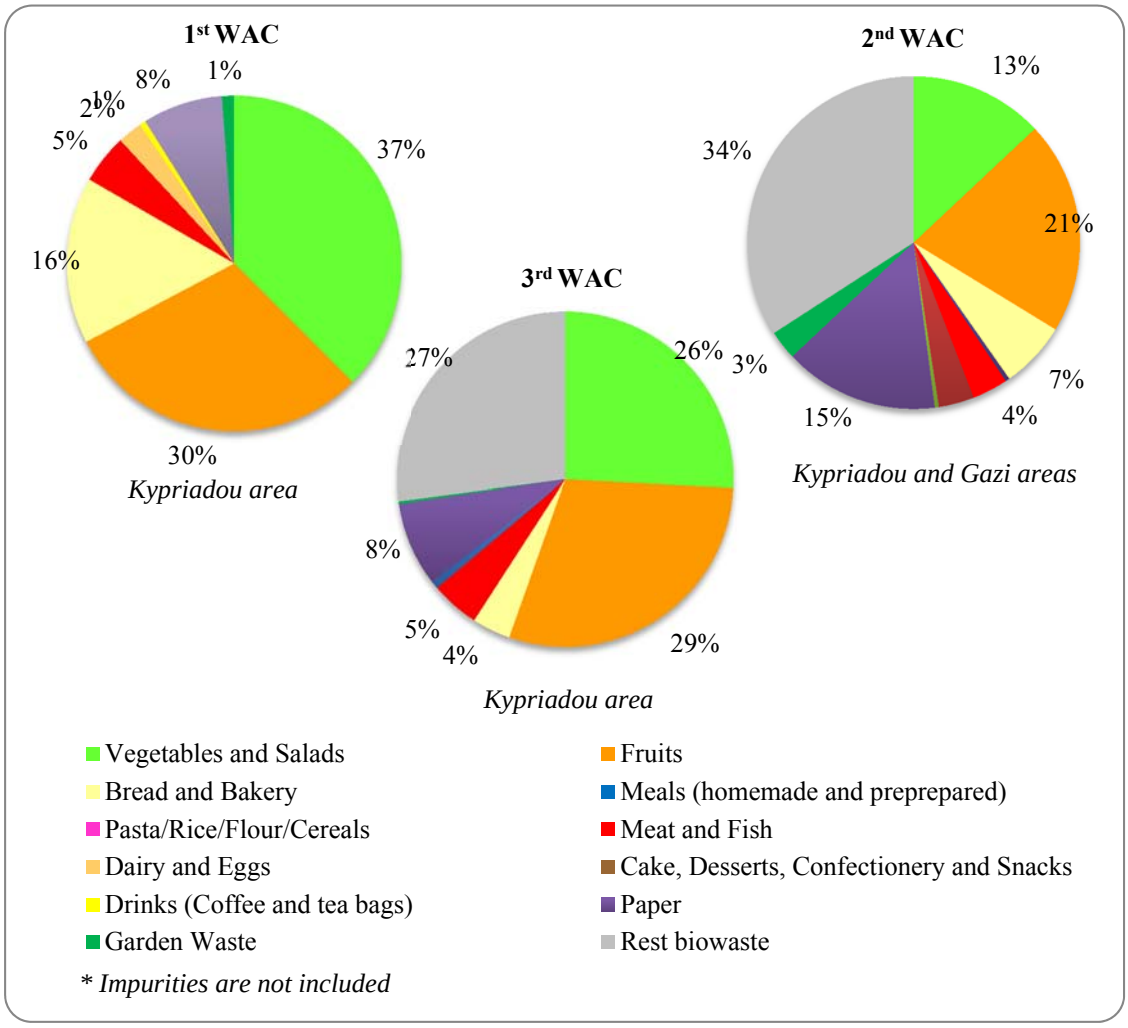

Figure 6: Pie charts illustrating compositional analysis results from Athens Municipality, Greece

Figure 6 shows variations in composition of biowaste derived from the three different WACs. As exemplified below, this outcome is inextricably linked to the origin of biowaste each time. Despite that, as in the case of Kifissia, '*Fruits*', *Vegetable and Salads*' and '*Rest Biowaste'* represented the greatest amounts in each WAC for the Municipality of Athens. The figures for '*Meat and Fish*' are slightly higher (4%, 3% and 5 % from 1st WAC, 2nd WAC and 3rd WAC, respectively) than those recorded for Kifissia; albeit the increase is rather small. Remarkable differentiations comparing to those of Kifissia were recorded for the categories of '*Bread and Bakery'* and '*Paper*'. During the 2nd WAC, a percentage of 15% was observed for the '*Paper*', which can be attributed to the fact that during this campaign biowaste originated from Gazi area was also sorted. Gazi is a place in Athens where numerous bars, cafeterias and restaurants are located. Finally, low enough is the contribution of '*Green waste*' to overall waste composition (1%, 3% and <1 % from 1st WAC, 2nd WAC and 3rd WAC, respectively), which is in line with the fact that the Municipality of Athens is more urbanised that Municipality of Kifissia. In **Figure 7** the percentage of impurities in the samples is presented.

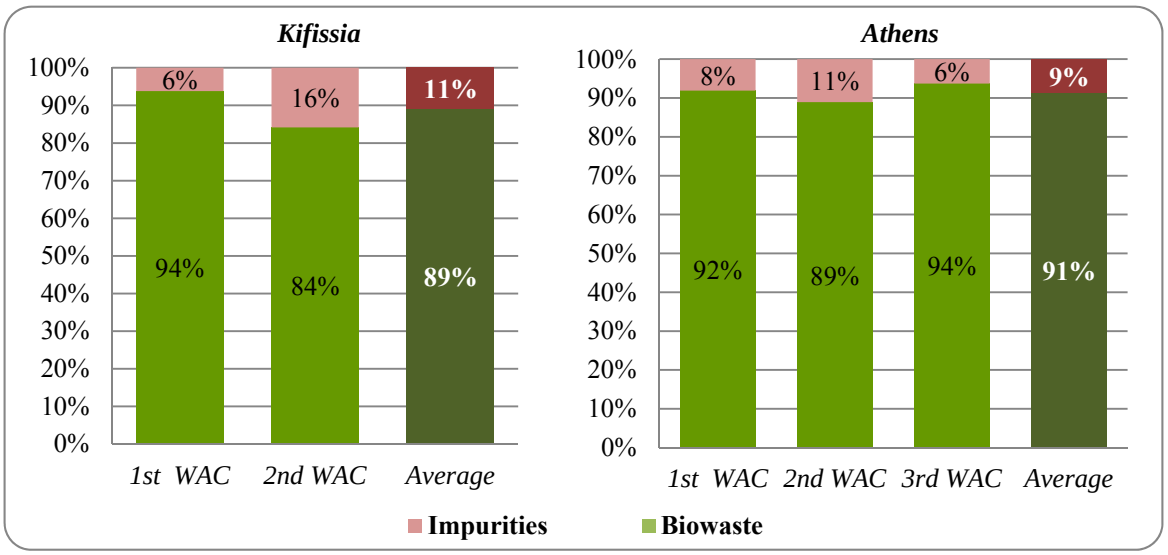

Figure 7: Impurities found in the household biowaste in Kifissia and Athens

Table 2 summarises the average percentages per waste category per Municipality of Greece and the average from the two Municipalities of Greece while presenting the compositional analysis for the food waste component of samples from UK, Finland, Portugal, Italy and those from WRAP (2008) study [12].

Table 2: Compositional analysis for sorted biowaste for Kifissia & Attica Municipalities (Greece), average values for Greece and for other countries

Type	***Average Kifissia (1)***	***Average Athens (1)***	**Greece *(2)***	**Finland**	**UK**	**Portugal**	**Italy**
Fruits & Vegetables	*72,3%*	*54,8%*	60,2%	44,5%	60,9%	59,2%	69,0%
Bread & Bakery	*2,3%*	*8,9%*	5,1%	3,8%	9%	3,1%	2,8%
Meals	*2,4%*	*0,0%*	1,2%	6,3%	12,3%	29,0%	1,4%
Spaghetti/rice/flour/cereals	*0,0%*	*0,0%*	0,0%	0,4%	1,5%	0,2%	12,4%
Meat & Fish	*2,1%*	*4,6%*	3,1%	4,3%	6,1%	7,3%	6,2%
Dairy & Eggs	*0,5%*	*1,0%*	0,5%	2,0%	1,7%	0,7%	1,4%
Cake, Desserts, Confectionery & Snacks	*0,0%*	*1,2%*	0,6%	3,2%	0,7%	0,3%	0,0%
Drinks (Coffee, tea bags)	*0,6%*	*0,4%*	0,5%	27,5%	7,1%	0,2%	0,0%
Rest food *(3)*	*19,9%*	*29,2%*	28,8%	8,0%	0,2%	0,0%	6,9%

(1) Data are normalised average values from the respective WACs. During the normalisation paper, green waste and impurities were excluded.

(2) Data are average values of the average values of Kifissia and the average values of Athens.

(3) Rest food is the former Rest biowaste

Based on **Table 2,** the percentages of food waste components are in line with those observed in other countries except for the '*Rest food'* which shows considerable higher values to those observed from other countries. This can be attributed to the condition of the raw material delivered to the MBT facility which was in some cases spoiled up to the point in which it was not easy to distinguish between different waste components. Moreover, it can also be attributed to the mixing that it had undergone during transport to the vehicles. Despite the aforementioned differentiation, the Greek compositional data agreed with the general observation from compositional analysis from other countries that '*Fruit and vegetable'* waste constitutes the largest proportion (60%). The percentage of *'Bread and bakery'* products was in the same

range with those from other countries, while the proportion of '*Meat & Fish*' was a little lower from other countries. In all other categories the recorded percentages for Greece were slightly lower than those of other countries.

Conclusions

The developed methodology for executing biowaste household compositional analysis provided useful information concerning the composition of waste in specific waste categories including: vegetables and Salads, Fruits, Bread and Bakery, Meals, Spaghetti and Rice, Meat and Fish, Dairy and Eggs, Confectionery and Snacks, Drinks (Coffee and tea bags), Paper, Garden Waste and Rest biowaste. The results obtained from the performance of the methodology in two different municipalities of Greece revealed similarities, since fruit and vegetable waste constitute the main household biowaste stream in both municipalities. However, it also showed differentiations between municipalities mainly considering bread and bakery waste, paper and green waste which can be attributed to the most urbanised character of Athens Municipality. In line with data derived from other countries, in Greece 'Fruit and Vegetable' waste constitutes the main part of biowaste household waste. The proportion of 'Rest waste' was relevantly high, which indicates that in order to improve the procedure of compositional analysis and to obtain more representative results, the waste load for sorting should be fresh and to be transported with waste collection vehicles without compacting. Results from compositional analysis can also be considered as a promising technique for recording the degree and nature of contamination on the performance of a source segregated schemes. Despite that, the revealed information from a waste analysis campaign can be utilized so as to determine the appropriateness of household biowaste or household food waste as a feedstock for biological processes, such as anaerobic digestion, composting or ethanol production.

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