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ORIGINAL PAPER

Door-to-Door Collection of Food and Kitchen Waste in City Centers Under the Framework of Multimunicipal Waste Management Systems in Portugal: The Case Study of Aveiro

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Abstract Separate collection of biowaste represents in Portugal only 2 % of total collected biowaste. Even though higher quality compost can be obtained through the separate collection of biowaste, this is generally regarded as more expensive and discarded as an option. In this work we assessed the viability of implementing the separate collection of biowaste targeting restaurants and canteens in city centers, using Aveiro as a case study. The current situation (no separate collection for biowaste) was compared with an alternative scenario in which biowaste was separately collected and valorized. The costs, constrains and the producers' attitude towards such a collection scheme are presented and discussed. On average 0.46 kg of biowaste were produced per meal served. The acceptance of separate biowaste collection was high (67 %) among producers, and it could be increased further through informative campaigns and economic incentives such as pay-as-you-throw tariffs. Door-to-door collection of biowaste could reduce the cost per ton as much as 37 %, when compared to collection as unsorted waste. The major constrains for the implementation of separate collection of biowaste were the selection of alternative legal destinations to the MBT unit (which has the exclusivity to treat collected waste) and the lack of dedicated infrastructures at multimunicipal waste management facilities to handle separately collected biowaste.

Keywords Food waste · Kitchen waste · Biowaste · Source segregation · Municipal solid waste · Compost quality

Introduction

In the European Union (EU) up to 138 Mt of biowaste are produced each year [1]. Biowaste includes biodegradable garden and park waste, food and kitchen waste (from households, restaurants, caterers and retail premises) and comparable waste from food processing plants [2]. Aiming at limiting greenhouse gas emissions, proper management of biowaste is necessary. The European Directive on the landfill of wastes (1999/31/EC) establishes that in 2016 landfilled biodegradable waste should not exceed 35 % of the amount of biodegradable waste produced in 1995. The deadline is postponed until 2020 for countries that strongly depended on landfilling in 1995, as is the case with Portugal. European countries have used different approaches to divert biodegradable wastes from landfills and achieve the goals set in the Landfill Directive (1999/31/EC). For instance Austria set a legal obligation to separately collect biodegradable waste, while in Denmark all municipal waste that can be incinerated must be sent to incineration [1].

Waste management strategies in Portugal lead to the installation in the last two decades of mechanical and biological treatment (MBT) facilities of regional influence, in which organic materials are recovered from unsorted waste. Recovered biowaste is then either composted or anaerobically digested. In case of anaerobic digestion the digestates are afterwards composted [3]. Even though MBT facilities

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exist throughout Portugal, the fact remains that currently 59 % of biodegradable municipal solid waste (MSW) is still being landfilled [4], showing the need for other measures that favor using waste as a resource. For this it is important to minimize contaminants (such as heavy metals and organic compounds) and macroscopic impurities. Source-segregation of biowaste is most suitable for obtaining a high quality organic fraction and in the EU the implementation of compost quality standards is currently under discussion [1, 5]. The quality standards can take the form of (1) criteria on compost quality or (2) restrictions to the input materials that can be used to produce compost. In the later there is a strong possibility that only source-separated biowaste could be used to produce compost. In Portugal only 2 % of biowaste is separately collected, and given this low value any future European legislation restricting input materials to composting would mean that MBT compost would have very limited applications, ending up in landfills. Implementation of separate collection of biowaste is generally seen as more expensive by local authorities and therefore disregarded as a viable option. A recent study in Greece shows that the operational costs with biowaste collection is higher for door-to-door than for road containers, as it requires additional routes for serving a specific area [6]. In city centers the spatial density of biowaste producers such as restaurants and canteens is higher, rendering collection more cost effective. However, so far the economic sustainability of collecting biowaste from such producers in city centers has not been accessed, hence remains unclear.

In this work the technical and economic analysis of the implementation of the separated collection of biowaste in medium sized city centers in Portugal is presented, using Aveiro City as a case study. The aims are to provide insight on the feasibility of a collection scheme targeting specific producers of food and kitchen waste and to discuss constrains and solutions that can be adopted by municipalities throughout Portugal.

Materials and Methods

Case Study

Aveiro municipality (pop. 78,000) is located in the Centro Region of Portugal, approximately 70 km South of Oporto and 230 km North of Lisbon (GPS 40,640,384; −8,653,632). The study area comprises the city center, characterized in Table 1, representing 23 % of the municipality area and 24 % of its population.

Collection of unsorted MSW is the responsibility of local authorities (Aveiro City Council) and collected waste is delivered at The Integrated Center for Treatment and Recovery of MSW of Aveiro. This facility is managed by ERSUC, S.A. and comprises an MBT unit for the treatment of unsorted MSW; an Automated Screening Station for treatment of recyclable waste from separate collection; a Unit for the preparation of refuse derived fuel (RDF) for the fraction with calorific value recovered at the MBT; a Unit for Energy Recovery from the biogas produced at the MBT; and a refuse landfill. The organic fraction currently separated at the MBT is first treated by anaerobic digestion, and then either composted to produce an organic amendment ("FERTISUC") or landfilled. The company ERSUC, S.A. has the concession in exclusivity until 2030 to valorize and dispose unsorted MSW from the multi-municipal system "Litoral Centro" (to which the municipality of Aveiro belongs), comprising 36 municipalities and approximately one million inhabitants [7]. ERSUC, S.A. is also responsible for the separate collection of packaging waste (paper and cardboard, plastic and metal). ERSUC, S.A. is a partnership between the municipalities (42.5 % of the capital) and a state company (EGF—Empresa Geral do Fomento; 51.5 %), currently on the verge of privatization, with the remaining 6.0 % hold by two private companies [7].

Table 1 Characterization of the study area (adapted from [7, 8])

Parish	UF Gloria e Vera Cruz (Aveiro, Portugal)
Inhabitants	18,756
Area (km^2)	45.32
Generation of MSW	
Unsorted MSW (t $year^{-1}$)	9808
Unsorted MSW per capita (kg $person^{-1}$ $year^{-1}$)	523
Collection of unsorted MSW	
800 L containers	493
Collection vehicles	2
Collection frequency	Daily (except Sundays and holidays)
Treatment/elimination at MBT Facilities of ERSUC, S.A. for the Centro Region (in Aveiro and Coimbra)	
Unsorted waste recovered for material recycling and valorization (% of total received)	5 %
RDF (refuse derived fuel) potential (% of total received)	28.9 %
Refuse waste to landfill (% of total received)	45.7 %

Identification of Biowaste Producers in the Study Area

This work targeted food and kitchen waste from services and commercial units that are currently collected by the municipality together with household waste. It excluded

residential producers but included local restaurants, hotel restaurants, public schools and university, nurseries and kinder gardens, rest homes (including day care, house support), military barrack and prison. Snack-bars and coffee shops were excluded due to the smaller amount of biowaste produced. Food markets and large companies having their own arrangements for waste management were also excluded, such as large food chains and the central hospital. A comprehensive list of target producers in the study area was put up, divided by types:

- Public schools (identified from the Municipal Registry);
- Restaurants (list supplied by the Trade Association);
- Public and private kinder gardens, nurseries and rest homes (identified from Social Charter [9]);
- Other specific producers were identified through field knowledge and previous waste services contracts with City Council.

Waste Collection Potential

From the biowaste producers identified in the study area approximately 1/3 were selected to participate in a door-to-door survey, ensuring that all types of producers were represented. Surveys were carried out in April 2014, and consisted of a set of 11 questions, aiming at an interview time of 15–20 min per producer. The survey was designed to assess (a) the daily amount of biowaste per producer (b) the biowaste generated per meal (c) management options in place at the producer (d) the willingness of producers to participate in a future biowaste collection scheme, and (e) the preferred collection frequency and time of day for the future biowaste collection. The volume of biowaste at each producer was estimated based on a direct answer to the survey questions and on field data obtained from the observation of the bin volume available at each facility and the frequency of disposal reported by the producer. The volume was converted into mass using an average volumetric mass for the biowastes of 291 kg m^{-3}, taken from the ranges reported in [10].

Collection, Treatment and Disposal Scenarios

Two scenarios were considered:

1. Baseline scenario: biowaste is placed in road containers, together with unsorted waste. After collection by the municipality, the waste is delivered at MBT unit (run by ERSUC, S.A.) and anaerobic digestion (with biogas production) takes place (this is the current destination to all unsorted MSW collected in the study area);
2. Alternative scenario: door-to-door collection of biowaste is implemented among selected producers. Producers included those who during the enquiry stated their willingness to join such a collection scheme. After collection, biowaste is sent to a private licensed waste operator and composted.

Biowaste-Dedicated Collection Routes

The collection points corresponded to the addresses of the selected biowaste producers. The starting point for the collection route was the City Council's garage, located approximately 6 km from the city center. We have considered that after disposal the vehicle returns to the City Council garage. The routes were planned using the software MyRouteOnline, an on-line application suitable for multiple addresses [11]. The following parameters were set: (1) service time of 5 min; (2) route optimization to minimize distance; (3) no limitation were imposed on time or on maximum number of stops per route. In addition to the route definition, MyRouteOnline calculated the total distance of the collection circuit and the time required to complete it. Intermediate journeys to the disposal site were added to the total distance and to the total time of the collection circuit.

Cost Estimates

The costs were calculated per ton and per month, based on the amount of biowaste that producers can divert from the unsorted fraction. In case the biowaste is not separated (baseline scenario) the cost per tone was the same as that of unsorted waste currently practiced, and the values are presented in Sect. "Costs".

For the alternative scenario, in which a biowaste-dedicate circuit was implemented, the cost comprised the following categories: (1) collection vehicle, (2) waste containers, (3) personnel, (4) fuel and (5) treatment/disposal. Each parameter is detailed next.

(1) Waste collection vehicle: the selected collection vehicle must be suitable to drive in the narrow streets characteristic of city center. So a compact, leak-proof, five cubic meter model was selected, with a tipping body and a rear mounted bin lift. To avoid large investment costs (not compatible with current constrains on municipal funding) a market consultation was carried out for the rental of such a vehicle, and the rental and maintenance value of 1845 € $month^{-1}$ (inclusive 23 % VAT) quoted by the supplier was used. To this value the insurance cost of 170 € $year^{-1}$ (equivalent to 14.17 € $month^{-1}$) was added. The cost with the rental of the collection vehicle added up to 1860 € $month^{-1}$.

(2) Waste containers: for the biowaste circuit new containers need to be acquired and distributed among producers, according to the amount of biowaste they produced. The containers selected were the 120 L (or 240 L), two-wheeled, high-density polyethylene (HDPE) bins with handler for small and medium sized producers and the 800 L, four-wheeled HDPE containers for the larger producers. The number and volume of containers were based on the amount of biowaste generated at each producer obtained in the survey results. The costs, based on market consultation, were 47.74 € for 120 L bins, 59.85 € for 240 L bins and 463 € for 800 L container, to which 23 %VAT was added. To account for losses and maintenance 15 % extra was added to the base price. A 5-year lifetime for containers was considered. The investment cost with containers was divided by 60 months, to obtain the cost per month.

(3) Personnel: a team of two people (driver and garbage collector) was required daily to carry out collection. The annual cost for one person was 16,303 €, comprising the base salary (750 €) multiplied by 14 months/year, a supplement of 20 % for working shifts, social security contributions (23.75 % of base salary), lunch allowance (4.27 € day^{-1} and 220 working days) and insurance (1.25 % of base salary plus lunch allowance), which represented the hiring costs for the institution for one person. The monthly cost for one person was 1358.64 € and was obtained by dividing the annual cost by 12. The number of equivalent workers required to carry out the collection service was calculated considering the circuit time, the number of workers in the collection team, the frequency of collection and the average annual hours actually worked per worker in Portugal, which in 2013 was 1712 h [12]. The labor cost per ton was calculated by multiplying the monthly cost for one person by the equivalent number of workers to obtain the total labor cost per month and then dividing the result by the tons of biowaste collected per month.

(4) Fuel: cost was computed considering an average fuel consumption of 15 L/100 km, current fuel price (1.29 € L^{-1}) and the total number of kilometers driven by month (calculated by multiplying the distance of the daily collection route by the number of days in one month for which collection was considered.

(5) Treatment and disposal: following a market consultation, the lowest gate fee price charged by a private composting company for this biowaste was 21.2 € t^{-1} (inclusive 6 % VAT). In this situation there was no landfill tax, as the waste was transformed into compost.

Sensitivity Analysis

Sensitivity analysis was carried out for a selected range of relevant parameters. The parameters considered were biowaste density, amount of biowaste collected, distance to disposal and treatment facility, fuel cost, vehicle rental, base salary and gate fee.

The variation (%) in the cost per ton (output) was calculated as a function of the variation of each input parameter in the range (−10, +10 %) and the ratio output/input was determined for each parameter. When |output/input| was higher than 0.1 the system response was considered to be highly dependent on that specific parameter, whereas an |output/input| <0.1 indicated that the system was stable.

Results and Discussion

Characterization of Biowaste Producers and Amount of Biowaste Separated

A total of 132 producers were inventoried in the study area (Table 2), of which local restaurants were by far the most frequent type, representing practically 80 %. Producers comprised organizations providing social and public services (as is the case with schools and rest homes for the elderly) as well as profit-oriented private entities, as is the case with restaurants. In total 49 inquiries were carried out, corresponding to 37 % of the producers. According to the average number of meals served per day, biowaste producers were divided into three groups (Fig. 1a): small-scale units (≤50 meals day^{-1}), medium sized units (50 < meals day^{-1} ≤ 200) and large units (>200 meals day^{-1}). All restaurants were in the small and medium scale group, whereas the social and public entities were all classified as large units with the exception of the military barrack, which according to the classification was a small-scale unit.

Total biowaste generated by the producers surveyed accrues 4061 kg day^{-1}. The largest producer was by far the University (Table 2), with its three canteens producing 2793 kg day^{-1} (almost 70 % of the total biowaste). The remaining units produced between 3 kg day^{-1} (hotel) and 76 kg day^{-1} (schools with canteens).

Biowaste produced per meal is shown in Fig. 1b for each unit. For restaurants the average biowaste per meal was 0.46 kg (±0.42) and for the canteens 0.43 kg (±0.39). According to the Sustainable Restaurants Association the average restaurant in the UK accrues around 0.48 kg $meal^{-1}$ [13] and in another study the value of 0.61 kg $meal^{-1}$ is referred (2.31 L $meal^{-1}$ and 0.263 kg L^{-1}, in [14]). These average values reported are similar to the one obtained in the current work. Individual values per

Table 2 Kitchen and food waste producers in the study area and average biowaste produced at each type of unit

Type of producer	Notes	Total number of units	Units surveyed	Biowaste produced per unit (kg/day)
Schools (with their own canteen and kitchen)	4 primary schools (6–9 years-old); 1 preparatory school (10–11 years old); 2 high-schools (12–17 years old);	7	1 (14.3 %)	76
Kindergarden/nursery	<6 years-old	8	1 (12.5 %)	73
Rest homes	Rest homes (full pension), day care (lunch) and home assistance (lunch and dinner)	5	1 (20.0 %)	58
Local restaurants	Snack-bars and coffee-shops not included	105	40 (38.1 %)	24 (±19)
Military barrack	Canteen serving meals to 50 military guards	1	1 (100 %)	29
Prison ward	Approximately 270 meals per day	1	1 (100 %)	70
University canteen	Approx. 2500 meals per day (3 canteens)	3	3 (100 %)	931
Hotel	Only hotels with restaurants	2	1 (50 %)	3
Total		132	49 (37 %)	–

establishment varied widely, ranging from 0.05 to 1.89 kg per meal, even though the activity was similar (food preparation). This difference of more than ten times can be due to several factors. The first are the procedures in food preparation, as these are necessarily different at a small unit and a large one. However, the size of the unit is not by itself the only explanatory factor, as plotting the waste generated per meal versus the number of meal served showed no clusters nor any linear relation between the two parameters ($R^2 = 0.03956$). Hence other factors other than the unit size were relevant. Waste minimization and separation measures are expected to strongly influence the volume of biowaste and the level of contamination. For instance the paper towels (covering the tables) might be included in the biowaste fraction in some cases and not in others. Additional uncertainties arise as restaurants consider the number of meals served to be part of the business' secret, so it was difficult to get accurate data on this parameter.

Producers' Attitude Towards a Biowaste Collection Scheme

According to the inquiry results (shown in Fig. 2), 67 % of the units would be willing to join a separate collection scheme for biowaste. Producers not willing to join such a circuit are all private restaurants, and two reasons were put forward: not having enough space for biowaste containers (4 %) and employees take biowaste home by at the end of the day to feed farm animals (29 %). According to Regulation (EC) No 1069/2009 [15], biowaste containing animal-derived waste (as is the case with food and kitchen waste) should not be used in feed for farmed animals. However this is a deep-rooted practice in Portugal, and even though the study area is markedly urban, some neighboring parishes in the municipality have a strong rural character. Nevertheless, a 67 % acceptance level is encouraging considering that no previous environmental campaign was carried out and that no economic incentive is involved. Acceptance levels could most likely be increased through a specifically designed campaign or by implementing a pay-as-you-throw (PAYT) charging system. In this last case the producer would pay according to the amount of unsorted waste produced, so there would be an economic incentive to divert the organic fraction.

Regarding the frequency of biowaste collection 87 % of the units preferred daily collection, Monday to Saturday (Fig. 2b). This is in line with the collection of unsorted waste practiced by the local authority. This high collection frequency brings high collection costs, but is nevertheless a common practice in southern European countries, as opposed to central and northern European ones, where a once-a-week collection (or every other week) is normal.

The preferred collection time was the period between 14 and 22 h afternoon and evening (Fig. 2c).

Final Destination

Two different options were considered for the biowaste. In the baseline scenario unsorted biowaste was delivered at the regional MBT, where it was recovered from unsorted waste through mechanical sorting and then treated by anaerobic digestion for biogas production. This compost should not be used in agriculture for food production due to the risk of contamination hence in this scenario the potential to produce high quality compost with market value is lost, as it is also lost the possibility to recycle nitrogen and phosphorus. Even though ERSUC, S.A. detains the exclusivity to handle source-separated materials this is only valid from the date this entity can maximize the

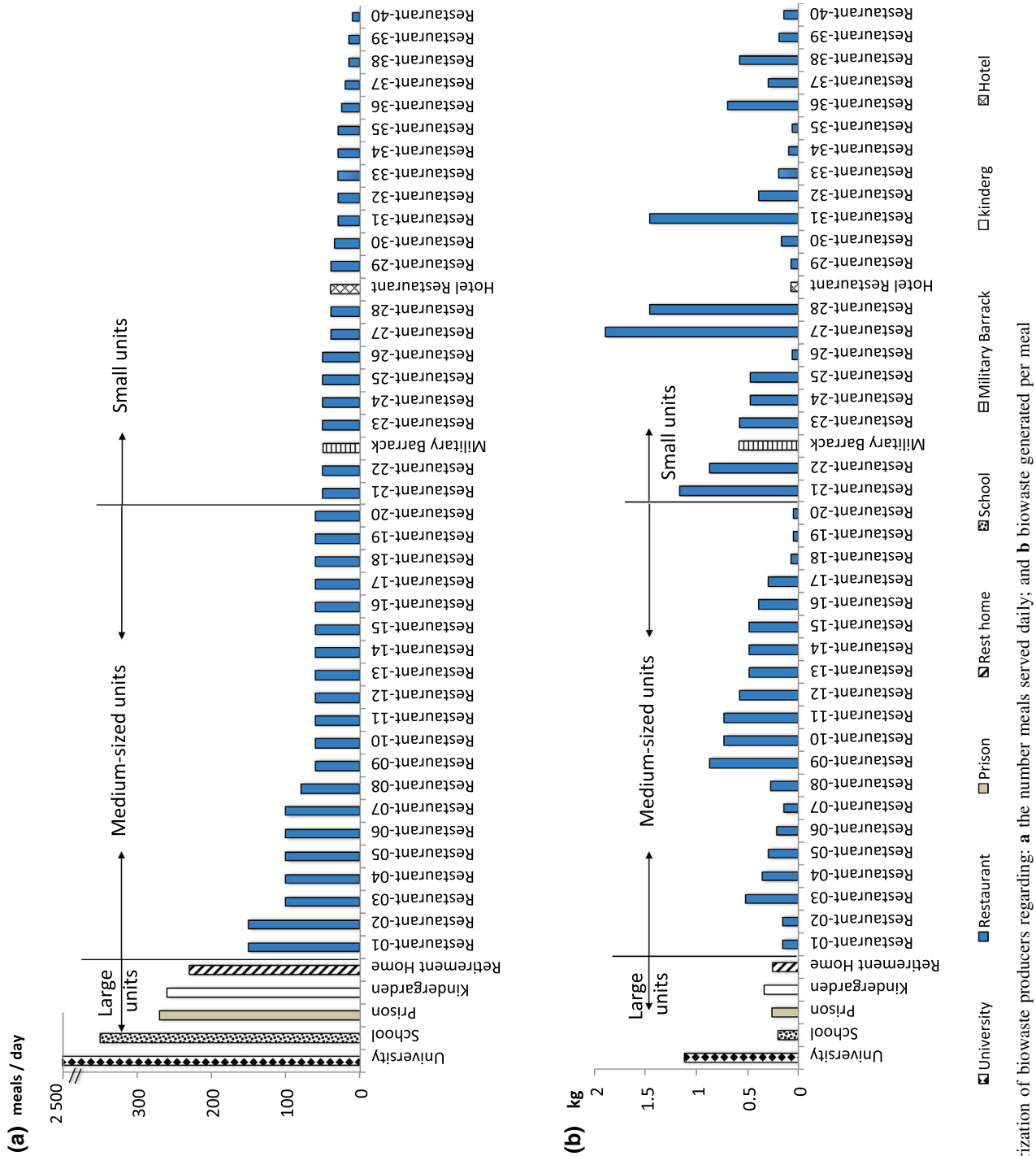

Fig. 1 Characterization of biowaste producers regarding: **a** the number meals served daily; and **b** biowaste generated per meal

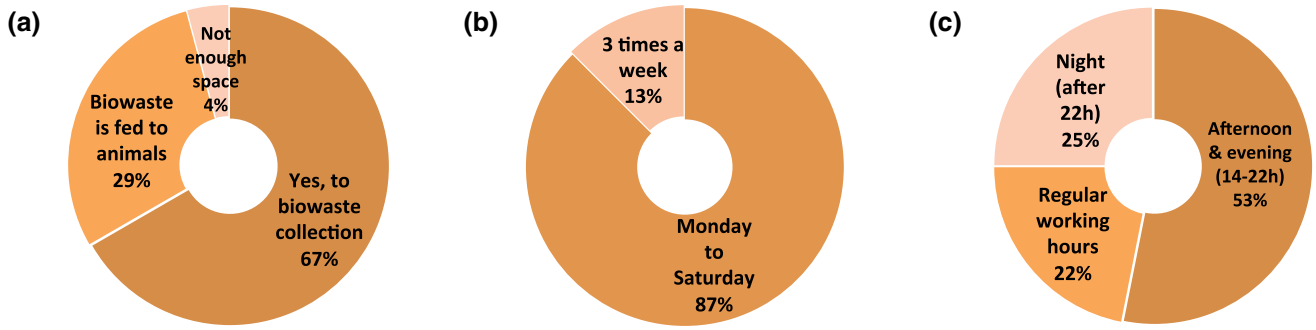

Fig. 2 Biowaste producers' answers to the enquiry: **a** interest in participating in source-separated biowaste collection; **b** preference of frequency of collection; and **c** preferences for collection time

valorization potential of MSW according to the best practice for waste management, as stated in the contract between ERSUC, S.A. and the Portuguese State. At this moment ERSUC, S.A. is focused on energy recovery, not material valorization, and no intentions to implement source-separated biowaste collection and treatment are put forward in the "future perspectives" chapter of their annual report [7]. This opens the legal possibility for local authorities to implement source-separated collection of biowaste. So an alternative scenario was envisaged, in which source-segregated biowaste was sent to a private licensed waste operator to produce compost. Compliance with the specific provisions of EC Regulation Nr 1069/2009 [15] with regard to hygienisation, transport and use of compost containing animal by-products was required. It was also considered advisable the waste operator being located within 50 km from the producers to prevent high transportation costs and to reduce transport-related environmental impacts. Based on these requirements one private company was identified (in case of future implementation a thorough benchmarking is required, as other companies may also comply with requirements). This company receives mainly forest waste for composting, which can be mixed with food and kitchen waste to adjust relevant operational composting parameters. For instance food waste is rich in N and water, and if co-composted with forestry waste it would accelerate the decomposition of that carbon-rich waste. The selected private company is also licensed to handle animal by-products, guaranteeing the specific provisions of Regulation (EC) No 1069/2009.

Biowaste Collection Routes

A new biowaste collection route was set covering the 32 producers that stated they would be willing to join this collection scheme. As the capacity of the collection vehicle is 5 m^3, two intermediate journeys were required to the disposal site. Collection is to be carried out daily (Monday to Saturday, except holidays), from 14 to 22 h, in line with producers' preferences (Fig. 2b, c) and following current service levels for unsorted waste. The separately collected biowaste was delivered at a private waste operator for composting. The route characteristics are summarized in Table 3.

Table 3 Summary of parameters for the biowaste collection circuit

Collection frequency	Monday to Saturday
Collection days per month (average)	25.71
Origin	Garage of the municipality
Number of collection points	32
Containers	18 bins 120 L + 12 bins 240 L + 12 containers 800 L
Amount of biowaste collected	4 t day^{-1} (14 m^3 day^{-1})
Final destination	Private waste operator
Total distance	165 km
Distance to final destination	21 km
Distance between collection points (% of total)	16 %
Total time	6 h:38 m
Collection time (service and between collection points), as % of total	66 %
Journeys to disposal site	3
Number of equivalent workers	2.4

Even with disposal site closely located to waste generators (as is the case) a significant amount of the distance travelled (>75 %) was back and forth to the disposal site, and not between the collection points, as these were located closely together in the city center.

Costs

This section shows the costs associated with biowaste collection, transport, treatment and disposal for the current situation (unsorted waste collection) and for an alternative scenario in which biowaste was separately collected. These costs are summarized in Table 4.

Table 4 Collection costs (€ t^{-1} of collected waste, including VAT) and cost distribution (% of total) for each scenario

	Baseline scenario	Alternative scenario
Collection scheme	Unsorted waste	Door-to-door collection of biowaste
Final destination	MBT unit	Private waste operator
Collection and transport		
Vehicle	–	17.76
Labor	–	31.03
Fuel	–	7.9
Containers	–	1.61
Subtotal	50.12 (62 %)	58.26 (73 %)
Treatment and disposal		
Gate fee	28.62	21.20
Landfill tax (equivalent)	2.38	–
Subtotal	31.00 (38 %)	21.20 (27 %)
Total cost (€ t^{-1})	81.12	79.46

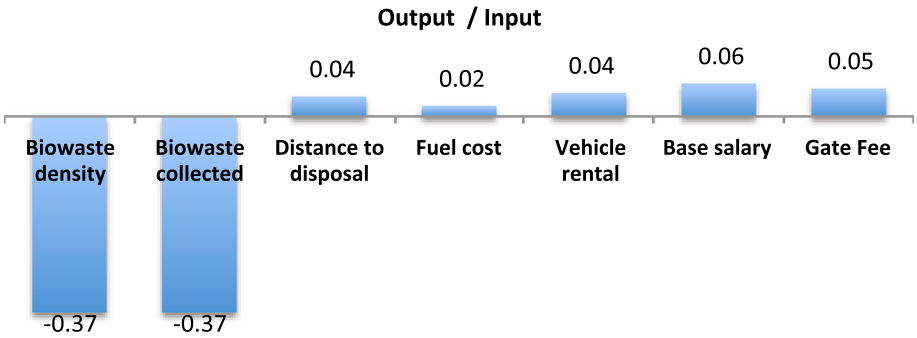

Fig. 3 Variation in the cost per ton of collected biowaste as a result of the variation in input parameters

Currently unsorted waste collection in Aveiro is outsourced to a private company. The service (including container rental) costs 47.28 € t^{-1} plus 6 % VAT, which totals 50.12 € t^{-1}. Unsorted waste is delivered at the MBT unit (run by ERSUC, S.A.) with a gate fee of 28.62 € t^{-1}. In addition, a landfill tax of 4.29 € t^{1} (plus 6 % VAT) is due when the waste is landfilled. The percentage of waste received at the MBT that is landfilled corresponds to 52.42 %, so an equivalent landfill tax of 2.38 € t^{-1} was considered for all waste delivered at the MBT. These values added up to 81.12 € t^{-1} (inclusive VAT), which represent the cost per ton of unsorted MSW paid by the Aveiro City Council (Table 4). In case the biowastes are separately collected this cost is avoided, and the cost incurred instead is the one presented for the alternative scenario in Table 4 (detailed in the methodology section).

The cost in the alternative scenario was distributed between collection/transport (73 %) and treatment/disposal (27 %). Labor and gate fees contributed the most to the total cost, whereas the acquisition of containers represented the lowest value (<2 %). Even though the costs with door-to-door collection of biowastes were higher than those for unsorted waste (58.26 vs 50.12 € t^{-1}), the total cost was slightly lower. This derives from the lower treatment/disposal costs of the composting unit when compared to the MBT facility. Implementing a separate biowaste collection for the city center of Aveiro (study area) would not represent any added cost for the City Council, being in fact slightly cheaper than the current waste management solution.

A market survey showed that biowaste collection for this specific circuit would cost from 30 to 100 € t^{-1}. In the alternative scenario, collection by the municipality added up to 58.26 € t^{-1}, while treatment and disposal amounted to 21.20 € t^{-1}. If the collection operation in the alternative scenario were outsourced, than the total cost for the alternative scenario could be as low as 51.20 € t^{-1} (30.00 + 21.20 € t^{-1}), making the separate collection and treatment of biowaste highly competitive when compared to the current value for unsorted waste (81.12 € t^{-1}).

The sensitivity analysis carried out showed the system is sensitive ($|output/input| > 0.1$) to the biowaste density and to the amount of biowaste collected (Fig. 3). An increase of 1 % in these parameters results in a decrease of 0.37 % in the final cost per ton. On the opposite, the system is stable ($|output/input| < 0.1$) to variations of the remaining parameters, namely distance to the disposal facility, fuel cost,

vehicle rental, base salary, and gate fee charge. For these later parameters an increase of the input brings also an increase to the output, whereas for the former parameters the relation is inverse.

Conclusion

This works show that source-separated collection of biowaste targeting canteens and restaurants in the center of Aveiro city can be implemented by local authorities without additional costs, and even with economical gains for the municipality. The study area comprises the city center, where biowaste producers are concentrated, and door-to-door collection includes a small number of waste producers. Even so, it was found economically possible to implement the source-separated collection of biowaste, and the advantages are clear compared to the current situation: gate fee is reduced and the additional landfilling tax is also avoided. If collection is outsourced then the total price per ton of biowaste could be almost 30 € t^{-1} lower than it is now for unsorted waste, which means a 37 % reduction in the cost of each ton of diverted biowaste. Due to the small number of producers participating in the study the overall impact at the municipality level is small. However, the results are encouraging and open the possibility of expanding the collection circuit to the whole city center.

The major constrain to the implementation of a separate biowaste collection is to where this biowaste can be directed to. The regional MBT unit run by ERSUC, S.A. is the most obvious entity to receive source-separated biowaste, as it has the concession (in exclusivity) to collect and valorize both source separated as well as unsorted waste in the study area. However, its focus is on energetic valorization (biogas production) and it has not so far put forward any plans to implement the material valorization of source-separated biowaste. EGF, the state company holding more than 51 % of the ERSUC, S.A.'s shares is currently being privatized, so there are a lot of uncertainties about what will happen in general. The MBT unit is not prepared to handle and valorize the separately collected biowaste, and adaptation of facilities would mean additional costs which will mostly likely only happen as a result of external pressures (incentives or regulations).

As an alternative biowaste can end up in a private composting company (alternative scenario). The compost would be of higher quality since source-separation reduces the level of contaminants, making the recycling of valuable nitrogen and phosphorus possible. The drawback is that it would no longer be possible to valorize the waste energetically (production of biogas). For small cities, composting food and kitchen wastes with garden and park organic waste can probably be a good alternative, especially if other big producers also join in, such as wholesale markets or vegetable markets. However, for larger cities, due to the larger amounts and concentration of organic waste other larger-scale solutions must be found, necessarily involving inter and multimunicipal waste management systems. Though the conversion of existing infrastructures to comprise separate treatment for biowaste is not interesting for such systems due to the investments required, these changes must necessarily happen in the near future, driven by a need for increased sustainability of the waste sector.

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