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Abstract

Food waste is a global problem. In Australia alone, it is estimated that households throw away AU\$5.2 billion worth of food (AU\$616 per household) each year. Developed countries have formal waste management systems that provide measures of food waste. However, much remains unknown about informal food waste disposal routes and volumes outside of the formal system. This article provides indicative metrics of informal food waste by identifying, in detail, five of the dominant informal food waste disposal routes used by Australian households: home composting, feeding scraps to pets, sewer disposal, giving to charity, and dumping or incineration. Informal waste generation rates are then calculated from three primary data sources, in addition to data from previous Australian and UK surveys, using a weighted average method in conjunction with a Monte-Carlo simulation. We find that the average Australian household disposes of 2.6 kgs of food waste per week through informal routes (1.7 kgs via household composting, 0.2 kgs via animals, and 0.6 kgs via sewage). This represents 20% of Australian household food waste flows. Our results highlight that informal food waste is a sizable food waste flow from Australian homes, deserving of greater research and government attention. Our examination of the full extent of food waste by disposal mode provides waste managers and policy makers with clear disposal routes to target for behaviour change and positive environmental outcomes.

Keywords

Informal, domestic, food waste, household, sustainability, waste management

Introduction

Food waste is a global problem with estimates of between 30% to 50% of food produced never reaching a human stomach (Institution of Mechanical Engineers, 2013). In Australia, the majority of food waste is sent to landfill, representing an inefficient use of scarce natural resources (water, electricity, etc.), a waste of money (Baker, et al. 2009), and an environmental problem through its associated generation of greenhouse gasses (GHG) (Productivity Commission, 2006). The quantity of waste generated by households is measured as part of government environmental accounting (European Commission, 2012). However, governments can only capture waste data that is disposed of via organised (formal) waste treatment processes. This omission in waste management accounting leads to an underestimation of the total volume of waste, as well as the associated economic and environmental impacts of the waste.

‘Informal’ disposal of domestic food takes many forms and is traditionally thought to be less prevalent in developed countries, with the few studies available focused upon developing countries (Seng et al., 2011; The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2011). While there have been studies that estimate the level of informal food waste in the UK (WRAP,

2009a; WRAP, 2009b; WRAP, 2011), no other developed country has conducted such an estimation. This quantification is needed so that government and industry can implement proper policy in regards to both formal and informal food waste practices.

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This article aims to quantify the scale of informal domestic food waste disposal in Australia, a developed country outside of the EU, to contribute to understanding of the scale and disposal paths of informal food waste globally. This article starts by providing an introduction to both formal and informal food waste disposal methods commonly found in developed countries, and discusses the limited availability of informal food waste data. In 'Method' we introduce the data sets used to explore informal waste disposal in Australia and discuss our method for estimating mean household informal disposal weights and participation rates using a weighted average Monte-Carlo simulation. 'Result' discusses the environmental, social, and economic impacts of informal food waste disposal in Australia. We conclude by noting the similarity in volumes of domestic informal food waste between Australia and the UK, and discuss avenues for future research. Accompanying this short report is an online appendix that provides a more detailed review of the various informal household food waste disposal avenues in Australia (home composting, feeding scraps to pets, sewer disposal, charity, dumping, and incineration).

Australian food waste disposal

In Australia, waste can be disposed of formally through waste disposal systems established by waste disposal businesses and local government (LG), or through alternate informal routes (DEWHA, 2010). When households select an informal waste disposal method, that waste is not captured in official waste statistics and its scale is thus difficult to estimate. This is true for all developed country waste systems.

In Australia, formal disposal of household food waste occurs through kerbside LG collections and treatment by landfilling or municipal composting. The present municipal composting system places the onus on the householder to dispose of their food waste in the appropriate municipal bin – specifically a 'green organics' bin that includes food waste – from which it is collected and transferred to a landfill or composting facility (Hyder Consulting, 2012). However, there is no standardisation of practice for food waste collection. While some LGs have introduced their own municipal composting systems, others do not provide any municipally organised food waste disposal other than collection with other residual waste sent to landfill.

The lack of accessibility by the entire population to formal non-landfill disposal options has been compounded as the majority of LGs do not provide (or make their residents aware of) municipal composting; and in the choice between informal disposal and landfill, in many households informal disposal is believed to be the better option (Adhikari et al., 2010; Zschokke et al., 2012; ZWSA, 2010). Furthermore, informal food waste disposal can alter the volume of food waste formally disposed of, with one programme finding that 24% of participants used informal disposal systems in preference to (or as a supplement for) the supplied municipally organised food waste disposal system (ZWSA, 2010).

Method

As this article is a first step towards estimating (Australian) informal waste, we have drawn data from three complimentary Australian studies.

1. A state-wide telephone survey of households from South Australia covering on a broad range of topics related to household food waste. A total of 401 householders with some responsibility for either household food shopping or preparation, were interviewed about their attitudes, beliefs, and behaviours surrounding food shopping, preparation, disposal, and waste. This survey also asked about the amount of food discarded per household (Sharp and Høj, 2009).
2. An anthropological study of 14 metropolitan-based households in South Australia, with 96 observations and semi-structured interviews with these households and the people residing in them, observing their food-related behaviour, with particular emphasis on food waste behaviours (Mavrakis, 2012).
3. Interviews with 25 South Australian householders covering both rural and urban areas exploring their behaviours and beliefs relating to food management. These householders also completed a written questionnaire. Types of food disposed of and the methods of disposal were also identified (Davison, 2012).

The generalisability of the latter two studies is limited by their small sample size, but have the strengths of detail and quality in the data obtained. Additionally, the state of South Australia is considered to be an environmentally progressive state (Moore, 2009; United Nations Human Settlements Programme (UN-HABITAT), 2010), as demonstrated by actions such as a plastic bag ban (Sharp, 2009) and a Bio Basket food waste disposal trial in 10 LG areas (ZWSA, 2010). This predisposition for pro-environmental behaviours may lead to skewed results. Therefore, to ensure that our estimation is an accurate representation of the whole of Australia, additional data has been sourced from other Australian studies, such as the Australian Bureau of Statistic's report *Environmental Issues: Waste Management And Transport Use* (ABS, 2009), and Baptiste's *People & Food Waste* project (Hyder Consulting, 2010).

Comparable UK literature (WRAP, 2009a; WRAP, 2009b; WRAP, 2011) has been used as proxy data when Australian data is unavailable. We are confident in using WRAP data to inform our estimates, because similar behaviours, values, and social norms are found in UK and Australia. In the current context, this can be demonstrated by the successful translation and implementation WRAPs *Love Food Hate Waste* consumer food waste behaviour change campaign in the state of New South Wales (WRAP, 2013).

To combine the various data sources, we used a weighted average operation. As per the methodology described by Bolaane and Ali (2004), weighting is given by sample size. Additionally, as

Table 1. Main assumptions for informal food waste disposal calculation, provided for participating and average Australian households. Note 'totals' do not necessarily sum with the above single categories, as all were separate Monte-Carlo simulations.

Disposal route	Adjusted average disposed of per participating household kg w ⁻¹	Adjusted S	Proportion of households participating	S	Average for all households kg w ⁻¹	S	Adjusted average for average household kg y ⁻¹	S	Adjusted average per all Australian household t y ⁻¹	S
Composting	3.88	1.15	0.41	0.11	1.71	2.11	80.70	11.49	681,307.54	7331.20
Animal disposal	0.38	0.21	0.37	0.11	0.21	0.41	14.87	2.17	125,563.13	1150.26
Sewage and macerator	1.44	0.78	0.45	0.22	0.63	0.88	38.93	5.01	328,634.93	3662.94
Charity	-	-	-	-	-	-	-	-	-	-
Illegal dumping	-	-	-	-	-	-	-	-	-	-
Total	5.71	1.41	-	-	2.55	2.34	141.30	14.94	1,192,890.88	8964.68

many samples provide no standard deviation, we assumed normal distribution and a coefficient of variation of 0.5 for all data sets, from which we calculate standard deviations (S) as shown in:

$$0.5 = \frac{S}{\bar{X}} \quad (1)$$

As the mean weights of waste disposed cannot go below 0, we followed Pollard's (1979) method of calculating adjusted means and deviations using a truncated normal distribution using the iterative equations (2) to (4). The suffix n denotes the n th approximation to the maximum likelihood estimate, and the symbols \emptyset and θ refer to the ordinate and cumulative areas of the unit normal curve, \bar{X} is supplied from the data, while S^2 is estimated from equation (1). We found that after 3–5 iterations, a stable μ_n and σ_n was reached:

$$\alpha_n = (0 - \mu_n) / \sigma_n \quad (2)$$

$$\mu_{n+1} = \bar{X} + \sigma_n ((-\emptyset(\alpha_n)) / (1 - \theta(\alpha_n))) \quad (3)$$

$$\sigma_{n+1}^2 = S^2 + (\bar{X} - \mu_{n+1})^2 + \sigma_n^2 ((-\alpha_n \emptyset(\alpha_n)) / (1 - \theta(\alpha_n))) \quad (4)$$

To further simulate uncertainty in the data, we ran a Monte-Carlo-type simulation (Tian, et al. 2007) of this adjusted weighted average operation 2000 times, with input parameters randomly drawn from their respective ranges, in order to find a final mean and standard deviation of each disposal route's diversion weight and participation rate. These weighted mean weights were also truncated to be above 0.

Results

Shown in Table 1 and Figure 1, we estimate that Australian households disposed an average of 2.6 kg of food waste per week via informal methods. The standard deviation of 2.3 kg, means that the average household disposed of at least 0.2 kg of food waste per week by the various informal methods. Participating Australian households disposed an average of 5.7 kg of food

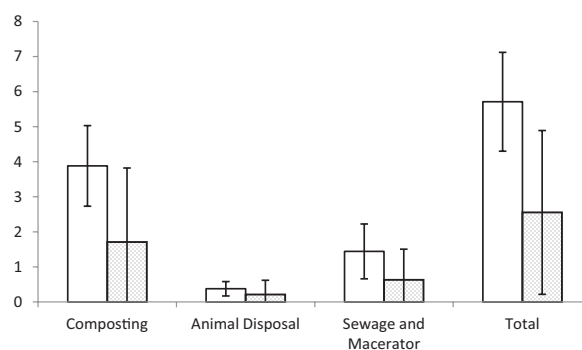


Figure 1. Adjusted average disposed of per participating, and average (shaded) Australian households (kg) per week, with bars for adjusted S .

waste per week via informal methods, with participating households disposing between 4.3 and 7.1 kg of food waste per week by informal methods.

In 2006, Australia had over 8.4 million households (ABS, 2012), which formally disposed of 4.4 million tonnes of food waste (DEWHA, 2010). The majority of this food waste was disposed of to landfill, with only 79,000 tonnes municipally composted (DEWHA, 2010; Recycled Organics Unit, 2007).

Over the same time period we estimate that Australia informally disposed of over 1.2 million tonnes of food waste; 20% of the total household food waste produced in Australia, 13% of the total food waste produced in Australia, or 2% of the total Australian waste stream. This is somewhat similar to the UK, where between 30% to 36% of household food waste is disposed of informally (WRAP, 2011). This result indicates that there is, in both countries, a sizable volume of food waste informally disposed of that is not captured through formal quantification.

The results shown in Figure 2 indicate that informal disposal conceals a substantial amount of food waste generated by Australian households. It is worth considering that half of the respondents of Sharp and Høj's (2009) survey claimed that 10% or less of their food waste was formally disposed of and so our estimated volume could be considerably larger still.

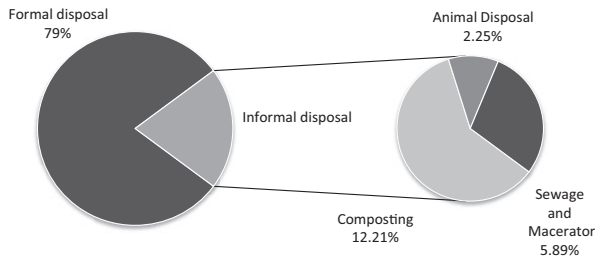


Figure 2. The estimated average share of formal (79%) and informal (20%) household disposal methods in Australia, 2006.

In 2006, Australia municipally composted 79,000 tonnes of formally disposed food waste (DEWHA, 2010; Recycled Organics Unit, 2007). Our results indicate that Australian households informally treated 15 times more food waste than formally treated by municipal composting. This could imply that there is currently a greater environmental benefit (i.e. a reduction of GHG) from informal treatment than from formal diversion from landfill (Colón et al., 2010; Martínez-Blanco et al., 2010). It should also be noted that our results could indicate a lack of awareness of formal disposal systems, as well as limitations in their actual existence and standardisation at that time of data collection. It also indicates (potentially) that people think informal means are better, though further investigation upon this point is required.

Conclusions, limitations, and further study

From our three complimentary investigations (with additional proxy data sets from Australia and overseas) we have estimated the volume of informal food waste generated by Australian households. Using 2006 as a proxy year (owing to formal food disposal data availability), we found that 1.2 million tonnes of food waste was disposed of informally by households. Additionally, we have identified and quantified five of the dominant informal food waste strategies in Australia. To our knowledge, this is the first article to quantify or categorise (Australian) domestic informal food waste in this detail.

This informal food waste represents a sizable proportion (20%) of total household food waste that has been 'invisible' to policy makers and researchers because it was not formally reported – a considerable problem when addressing material flows or environmental or economic impacts. This percentage bears similarity to informal disposal rates in the UK (30%–36%), indicating that informal food waste disposal is a generalisable phenomenon that is important to capture in developed countries.

The results suggest that Australian households divert 15 times more food waste from landfill via informal methods, than via formal municipal composting. This highlights that, when considering household food waste interventions, greater attention must be given to informal disposal and raising

awareness of formal food waste disposal options and improving infrastructure to encourage adoption (e.g. the use of kitchen caddies). Future investigation and consideration should be given to the relative environmental benefits of informal routes versus municipal composting, and to investigate potential knock-on effects to informal disposal if the use of municipal composting were to proliferate.

Given the issue of representativeness and regional specificity in our estimation, and to further increase accuracy of home compost, sewage, animal, illegal, and charitable, food waste disposal routes, additional data collection is needed. This will reduce the need for future estimations to rely on UK proxy data. The value system behind the informal waste disposal hierarchy also merits further investigation, including the relationship between informal disposal and waste prevention behaviour. Finally, the GHG emission rates of the various informal disposal options needs to be examined in greater detail.

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Declaration of conflicting interests

The authors declare that there is no conflict of interest.

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