ARTICLE IN PRESS

Waste Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

# Carbon footprint and energy use of food waste management options for fresh fruit and vegetables from supermarkets

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ARTICLE INFO

*Article history:*
Received 30 March 2016
Revised 22 November 2016
Accepted 4 January 2017
Available online xxxx

*Keywords:*
Greenhouse gas emissions
Food waste valorisation
Conversion
Donation
Anaerobic digestion
Incineration
Chutney

ABSTRACT

Food waste is a problem with economic, environmental and social implications, making it both important and complex. Previous studies have addressed food waste management options at the less prioritised end of the waste hierarchy, but information on more prioritised levels is also needed when selecting the best available waste management options. Investigating the global warming potential and primary energy use of different waste management options offers a limited perspective, but is still important for validating impacts from the waste hierarchy in a local context. This study compared the effect on greenhouse gas emissions and primary energy use of different food waste management scenarios in the city of Växjö, Sweden. A life cycle assessment was performed for four waste management scenarios (incineration, anaerobic digestion, conversion and donation), using five food products (bananas, tomatoes, apples, oranges and sweet peppers) from the fresh fruit and vegetables department in two supermarkets as examples when treated as individual waste streams. For all five waste streams, the established waste hierarchy was a useful tool for prioritising the various options, since the re-use options (conversion and donation) reduced the greenhouse gas emissions and the primary energy use to a significantly higher degree than the energy recovery options (incineration and anaerobic digestion). The substitution of other products and services had a major impact on the results in all scenarios. Re-use scenarios where food was replaced therefore had much higher potential to reduce environmental impact than the energy recovery scenarios where fossil fuel was replaced. This is due to the high level of resources needed to produce food compared with production of fossil fuels, but also to fresh fruit and vegetables having a high water content, making them inefficient as energy carriers. Waste valorisation measures should therefore focus on directing each type of food to the waste management system that can substitute the most resource-demanding products or services, even when the whole waste flow cannot be treated with the same method.



## 1. Introduction

Food wastage is a problem of increasing severity, with rising awareness of the extent of the problem in recent years (FAO, 2011, 2012, 2013). Although food losses are just one of many problems that have to be addressed in creating a sustainable food supply chain that can feed a growing population (Godfray et al., 2010; Garnett, 2011), concerns about food waste in Sweden have prompted the Swedish government to suggest goals to reduce the amount of waste and increase biological treatment of food waste (SEPA, 2013). These efforts comply well with the European Waste Framework Directive (WFD), which ranks waste prevention and management options in order of priority in a waste hierarchy (EC, 2008). The WFD also obliges member states to encourage options that deliver the best overall environmental outcome from a life cycle perspective, even when this differs from the waste hierarchy. However, since the environmental outcome is not defined in the WFD, this goal can be achieved in many ways. Addressing the global warming potential (GWP) and primary energy use (PEU) alone offers a very limited version of the overall environmental outcome, but is no more or less appropriate than targeting any other environmental impact category.

In the case of food waste, the environmental choice of waste management system from a life cycle perspective follows the hierarchy closely in many cases (Laurent et al., 2013a). However, since each waste management system is dependent on a local context, the waste hierarchy must still be seen as a rough generalisation (Eriksson et al., 2015). An actual investigation of each local context is necessary to fulfil the obligation in the WFD.

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http://dx.doi.org/10.1016/j.wasman.2017.01.008
0956-053X/

Please cite this article in press as: Eriksson, M., Spångberg, J. Carbon footprint and energy use of food waste management options for fresh fruit and vegetables from supermarkets. Waste Management (2017), http://dx.doi.org/10.1016/j.wasman.2017.01.008

Early versions of the waste hierarchy have been part of European policy since the 1970s (EC, 1975). While it has since been developed and amended (EC, 2008), the EU waste hierarchy still provides only very general guidelines for all waste. National guidelines relating specifically to food waste have therefore been devised. Examples of such systems are the Moerman ladder in the Netherlands (Dutch Ministry of Economic Affairs, Agriculture and Innovation, 2016), the Food Recovery Hierarchy in the United States (USEPA, 2016), and the Food Waste Pyramid in the United Kingdom (Feeding the 5000, 2014). All these systems prioritise prevention, since the waste management options include downcycling and loss of the intended product. Despite the order of priority in the waste hierarchy, only a few studies measure waste prevention in the context of waste management (Laurent et al., 2013a). This omission may be due to the methodical difficulties involved in measuring something that is not there (Zorpas and Lasaridi, 2013) or, as discussed by van Ewijk and Stagemann (2016), to prevention being fundamentally different from waste management.

Priority is also given to donations to people in need, although this is limited by the fact that food waste can only be donated to charity if it is surplus food still fit for human consumption (Papargyropoulou et al., 2014). Since a higher level in the waste hierarchy increases the requirements on food hygiene or biosecurity, there is a decreasing likelihood that the whole waste flow will be suitable for the same type of waste management. This creates a need for more complex systems where a food waste flow is developed and used for higher priority waste treatments, while the rest is treated with a lower priority, more general method (Vandermeersch et al., 2014; Eriksson, 2015). To analyse the potential of subdividing the food waste stream, instead of treating it in its entirety, an approach with individual waste streams can be used (Vandermeersch et al., 2014).

Most previous studies on waste management methods for food waste, or organic waste including food waste, describe and sometimes compare landfill, incineration, composting and anaerobic digestion (Bernstad and la Cour Jansen, 2012; Laurent et al., 2013a, 2013b). However, all these options are found in the less prioritised part of the waste hierarchy. Some studies also include animal feed in the comparison (*e.g.* Lee et al., 2007; Menikpura et al., 2013; Vandermeersch et al., 2014), but only a few include comparisons with the highest levels in the food waste hierarchy, such as conversion, donation and prevention, where surplus food is still used as food. However, some studies describe the environmental benefits of preventing food waste. For example, Gentil et al. (2011) concluded that there could be a 20% reduction in a food waste stream, but did not specify how this reduction could be achieved or the cost of doing so. Another prevention study, by Salhofer et al. (2008), regarded prevention as being equal to donation, but did not quantify the actual potential in this measure. Eriksson et al. (2015) compared donation with other waste management methods and found that it reduced greenhouse gas emissions to a similar level as anaerobic digestion. According to Eriksson (2015), this is largely dependent on the products or services that are replaced in a system expansion and, since their study assumed that donated food replaced bread production, many of the emissions associated with the donated food could not be reduced. However, if the reduced emissions associated with donated food are valued as emissions during production, instead of the produce that could be replaced, donations appear a much more favourable option (Schneider, 2013).

Donating food has long been a well-used way to prevent surplus food from becoming waste (Schneider, 2013). Converting surplus food to new products is also a well-used option which may open new markets or extend the shelf life, and thereby make the food sellable (Eriksson, 2015). One way to convert food and extend shelf life is to produce marmalade, jam or chutney from surplus fresh fruit and vegetables. While it is difficult to find scientific literature evaluating this option, there are several current initiatives developing its potential (e.g. Rubies in the Rubble, 2015; Confitures Re-Belles, 2015; Rescued fruits, 2015). Even if these waste valorisation options are more favourable in the waste hierarchy than less favourable waste management options like incineration and anaerobic digestion, they still need to be complemented with a general waste management option with larger capacity and acceptance of food unfit for human consumption (Eriksson, 2015). Since there is a need for parallel waste management systems, it is important to know the benefits of each system in order to prioritise the waste flows in the current local infrastructure. The main objective of this study was therefore to compare the outcome, with regard to greenhouse gas emissions and primary energy use, of different food waste management scenarios available to supermarkets in Växjö in Sweden. The overall aim was to provide more detailed knowledge about the quantity of emissions avoided when applying a more prioritised step in the waste hierarchy for waste management of surplus fruit and vegetables from supermarkets.

## 2. Materials and methods

Life cycle assessment (LCA) (ISO, 2006a, 2006b) was used to calculate the environmental impact from four different waste management scenarios concerning the impact categories global warming potential (GWP) and the primary energy use (PEU). In order to include both a waste management perspective and a resource management perspective, two different functional units (FU) were used. One of these was the use of 1 kg of wasted food in a waste management scenario and the other was the removal of 1 kg of food waste from a supermarket. The first FU illustrates the potential outcome in each waste management option if all waste could be treated with the selected method. The second was used (only in Section 3.3) to illustrate that when a waste management option is limited to certain categories of food or a special quality, there will still be waste that needs to be handled with a general method that can treat everything in the selected waste flow.

### *2.1. Study area*

Four scenarios were designed based on waste management methods already in use by supermarkets in the municipality of Växjö in Sweden (an incineration plant in Ljungby, a biogas plant at Sundet, the charity organisation Diakonicentrum and a kitchen staffed by unemployed jobseekers in Växjö where chutney was made). Therefore site-specific data were used and assumptions were made to reflect the actual circumstances of the infrastructure in use. Moreover, transport distances from two supermarkets in Växjö to the incineration plant, biogas plant, charity and kitchen were used, respectively, in the four scenarios. All waste management facilities were established prior to this investigation except for chutney production, which was established as part of this study. Therefore chutney production just operated at pilot scale, while the other scenarios were based on more long-term management options.

Two supermarkets, one large and one smaller, participated in the study. The large supermarket was part of the retailer ICA and represented its largest concept, ICA Maxi, which could be described as a hypermarket selling more than just food. This ICA outlet has an out-of-town location and is run as an individual company using the concept of the company group. The smaller supermarket was located in central Växjö and is run as a franchise within the retailer COOP, using its traditional concept COOP Konsum, which means an average-sized supermarket.