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Greenhouse gas emissions of food waste disposal options for UK retailers

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ABSTRACT

Food retailers are under increasing political and social pressure to reduce both the amount of food that they waste and the amount of greenhouse gases (GHGs) that their food retailing activities incur. For completeness, when assessing the 'carbon footprint" of their business activities, food retailers should also included the greenhouse gas emissions caused by their disposal of waste food, which will vary with the waste disposal option used. However, there is lack of quantitative guidance for food retailers on the net GHG emissions that are incurred in the disposal of specific food types by the various disposal options available. Here, we calculate the net GHG emissions of eight different waste disposal options for five core food types using life cycle assessment, accounting for both emissions incurred in transport and processing, and those mitigated by the creation of useful products. We also assess the extent to which the embodied emissions in waste foods at the retail checkout can be mitigated by each disposal option. In addition to food specific results, we calculate mass-weighted averages using data from a mid-sized retail chain. We find a strong correlation between net emissions and the energy density of foods, and the following mass weighted disposal hierarchy (from best to worst, with respect to greenhouse gas emissions): donation of edible food to food banks; anaerobic digestion; conversion to animal feed; incineration with energy recovery; aerobic composting; landfill with gas collection and utilisation; landfill with gas collection and flaring; landfill without gas collection. If waste food from retailers is unfit for human consumption, to minimise greenhouse gas emissions it should be disposed of by conversion to animal feed or anaerobic digestion. For all food types, landfill is the worst disposal option.

1. Introduction

Food waste is major global problem with social, economic and environmental implications. Reducing food waste is a challenge faced by governments, charitable organisations, corporations and individuals alike, with the United Nations aiming to halve global food waste per capita at the retail and consumer level by 2030 (UN, 2015). Despite innovations in consumer demand modelling, storage, packaging and the use of price-cutting to reduce waste, some retail food waste is inevitable, leaving food retailers with decisions as to how to best dispose of this waste.

The disposal options available to a food retailer for any given food depend on several factors: the food's condition; whether the food's expiry date has passed; and whether the food is plant-derived or contains components of animal origin. Where it is safe to do so, unsold foods can be donated for human consumption; however in Europe at least, foods that have spoiled or passed their 'use-by' date cannot be donated or redistributed for human consumption (European Commission, No 1169/2011). Foods unsuitable for human consumption can be used for animal feed, providing they do not present any health risks (European Commission, No 68/2013). The recycling of 'vegetal' foods (fruits, vegetables and cereal grains) as animal feed is generally encouraged (Wadhwa & Bakshi, 2013), providing the foodstuff has not contacted animal products during its lifetime or spoiled (Lancashire County Council, 2016). The use and disposal of animal by-products (ABPs; foods no longer intended for human consumption consisting of or containing animal products) from food retailers is strictly regulated (European Commission, No 142/2011; European Commission, No 1069/2009), with only 'lower risk' ABPs (vegetarian bakery and confectionery products, milk and products, eggs and products, animal fats and fish oils) eligible for use as feed (DEFRA & APHA, 2014b). Greater risk ABPs ('medium' risk foods containing cooked or fully pre-cooked meat or fish products; and 'higher' risk foods containing raw, cured or partially cooked meat or fish products) can be sent to landfill (with a 20 kg/week limit applying to higher risk ABPs) (European Commission, No 142/2011). Other disposal options for food waste by retailers

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include conversion to pet food (except for higher risk ABPs) (DEFRA & APHA, 2014c); rendering (ReFood, 2014); ensiling of fish wastes, incineration; anaerobic digestion; composting; land application (direct for egg and shellfish shells, after heat-treatment for all other ABPs) and conversion to fertilizer or soil approver (DEFRA & APHA, 2014a).

Anaerobic digestion (controlled anoxic microbial degradation of organic matter) of commercial food waste is increasingly popular (Ariunbaatar, et al., 2016; Carlsson, et al., 2015). It is now generally favoured over composting as a means of processing commercial food waste (DEFRA, 2011a; ReFood, 2014), producing methane-rich biogas and nutrient rich digestate. Incineration is also growing in popularity (DEFRA, 2014) as a means of deriving energy from high-energy foodstuffs (San Martin, et al., 2016), particularly high risk ABPs (ReFood, 2014). Landfill remains a major end-destination for food waste from retail despite taxation (currently £84.40/tonne in the UK) (HM Revenue & Customs, 2016a) and incurring substantial methane emissions.

Annual food wastages by the UK retail sector are estimated at 250 kt (WRAP, 2017). Of this, ~2% is redistributed (donated) to people, ~10% is converted to animal feed, and ~30% is managed through each of recycling (anaerobic digestion and composting), recovery (incineration and landfill with energy recovery) and disposal (sewer and landfill without energy recovery) routes (WRAP, 2015). Such proportions are contrary to the objectives of food waste management hierarchies published by US and European government agencies (EPA, 2017; European Commission, 2008/98/EC) which encourage donation and conversion to animal feed whilst discouraging disposal to landfill and incineration.

Environmental impact is an integral factor influencing food waste management decisions made by retailers. These impacts can include GHG emissions, water use and pollution of water, air and soil systems. However, for this study we focus on GHG emissions only. The carbon footprint of any given food waste management pathway is inherently dependant on the composition of the food being disposed of and of the disposal pathway used. However, there is currently little information on food-type specific waste management emissions for food retailers, with most published food waste management hierarchies being based on a heterogeneous mix of food waste.

In prior work, the food wastage from a mid-sized food retail chain in the UK was investigated (Fig. 1). Bakery goods, dairy, fruit & vegetables, meats and fish collectively accounted for 82% of waste by weight. Similar results were reported by a major food retailer, with bakery, fresh fruit and vegetable produce, dairy, meat and fish making up 74% by weight of the chain's food waste in 2014 (Tesco, 2014).

In this study, we evaluate the net greenhouse gas emissions resulting from the individual disposal of unsold bread, cheese, fruit and vegetables (F&V), fish and meat from the point of potential sale in a supermarket through eight disposal options: donation of edible food to a food bank or redistribution charity for human consumption ('donation'); conversion to wet animal feed at a feed processing facility ('animal feed' or 'conversion to feed'); anaerobic digestion; composting; large modern UK landfill capturing 70% of produced methane (Gregory, et al., 2014); and global average landfill with 20% methane capture (IPCC, 2006); landfill with no gas collection infrastructure. Some of these disposal options are hypothetical for certain foods, such as conversion to raw meat and fish to animal feed, due to the aforementioned regulations in the UK, but are included for completeness of GHG emissions.

2. Methods and data

We employ a life cycle assessment (LCA) approach to evaluating net GHG emissions from each disposal option. We do not consider food-carbon returned to the atmosphere as carbon dioxide, since it was originally sequestered though photosynthesis, but do consider other emissions both incurred and mitigated at all stages of each disposal option, from transportation to processing facility or end of life destination. Our system boundaries are shown in Fig. 2 and the assumptions used are listed in Table 1. GHG emissions are evaluated in terms of carbon dioxide equivalents per tonne of food waste (kg CO_2e/t FW). We use a global warming potential (GWP) of 25 for methane emissions (IPCC, 2007). Nutritional content/profile/chemical composition data and embodied carbon (E_{store}) values for each food type are shown in Table 2. E_{store} values include all major life cycle stages up to the checkout: production, processing, transport, packaging and supermarket operations, and were obtained from previous work (Hoolohan et al., 2013). The emissions factors used to generate these values are detailed elsewhere (Berners-Lee & Hoolohan, 2012). Emissions factors used in this analysis are detailed in Table 3.

2.1. Transport modelling

We assume that waste food is transported from the retail outlet to the nearest appropriate facility for each disposal option. Emissions are based on round trips of distance approximate to the square root of the average land area served per site, calculated by dividing the number of each site type in the UK (Table 4) by the total UK land area (see *S.I. Transport*). Resulting distances compared favourably to the data used in the Waste and Resources Assessment Tool for the Environment (WRATE) on average journey distances to landfills and incinerators (BEIS, 2017a). Vehicle type and emissions data were taken from the

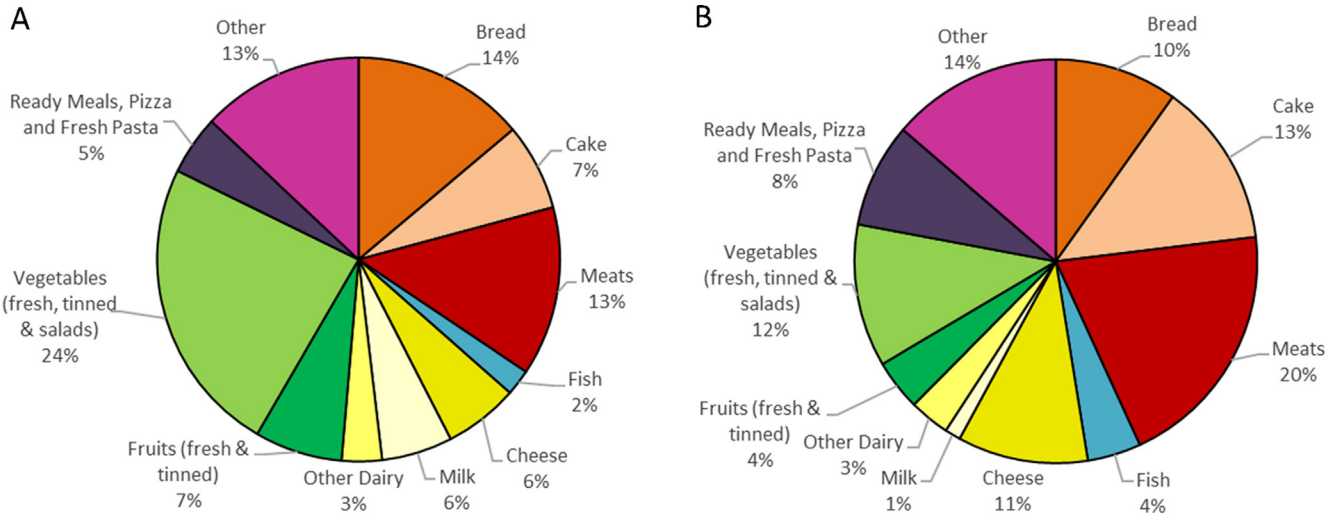

Fig. 1. Annual food retail waste from a mid-sized (~28 outlets) supermarket chain in the UK, proportioned: (a) by mass (kg) (b) by value (£).

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