Science of the Total Environment 628–629 (2018) 979–989

Contents lists available at ScienceDirect

Science of the Total Environment

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

Improving the environmental sustainability of reusable food containers in Europe

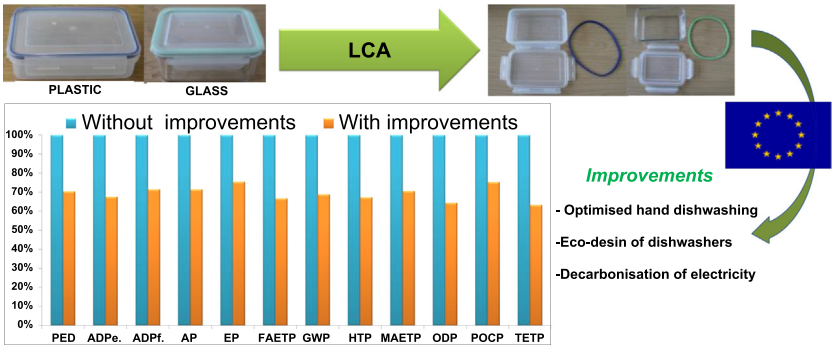
Alejandro Gallego-Schmid *, Joan Manuel F. Mendoza, Adisa Azapagic

Sustainable Industrial Systems, School of Chemical Engineering and Analytical Science, The University of Manchester, The Mill, Sackville Street, Manchester M13 9PL, UK

HIGHLIGHTS

- Over 275 M food savers are used annually in the EU with a GWP of 653 kt CO_2 eq.
- The use stage is the main hotspot for all the impacts (>40%).
- Lifespan of glass containers must be up to 3.5 times longer to match plastic savers.
- The dishwasher eco-design regulation can reduce EU impacts by 6%–20% by 2020.
- Implementation of best hand dishwashing techniques can decrease impacts by 12%–27%.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 10 January 2018
Received in revised form 8 February 2018
Accepted 11 February 2018
Available online xxxx

Editor: D. Barcelo

Keywords:
Life cycle assessment (LCA)
Eco-design
Energy efficiency
Global warming
Food containers
Environmental impacts

ABSTRACT

Modern lifestyles have popularised the use of food containers, also known as food savers or Tupperware. However, their environmental impacts are currently unknown. To fill this knowledge gap, this paper presents the first comprehensive assessment of the life cycle environmental sustainability of reusable plastic and glass food savers and evaluates different options for improvements, focusing on European conditions. Taking a cradle-to-grave approach, the paper considers twelve environmental impacts, including global warming potential (GWP), acidification, eutrophication, human and ecotoxicities. The results suggest that, for example, the total GWP of using both types of food saver in the European Union (EU) amounts to 653 kt CO_2 eq./year, equivalent to the annual greenhouse gas emissions of Bermuda. The use stage is the main contributor to the impacts (>40%), related to the washing of containers. Glass food savers have 12%–64% higher impacts than the plastic and should have up to 3.5 times greater lifespan to match the environmental footprint of plastic containers. Three improvement scenarios have been considered at the EU level for the year 2020: low-carbon electricity mix; implementation of the EU eco-design regulation for dishwashers; and adoption of more resource-efficient hand dishwashing techniques. The results suggest that the implementation of all three improvement options would reduce the impacts by 12%–47%. The option with the greatest potential for reducing the impacts (12%–27%) is improved hand dishwashing to reduce the amount of water, energy and detergents used. Thus, policy makers and manufacturers should devise strategies to raise awareness and guide consumers in adopting these

Abbreviations: ADP_e, abiotic depletion potential of elements; ADP_f, abiotic depletion potential of fossil resources; AP, acidification potential; BAT, best available technology; DCB, dichlorobenzene; EP, eutrophication potential; EU, European Union; FAETP, freshwater aquatic ecotoxicity potential; GWP, global warming potential; HTP, human toxicity potential; LCA, life cycle assessment; MAETP, marine aquatic ecotoxicity potential; ODP, ozone depletion potential; PE, polyethylene; PED, primary energy demand; PET, polyethylene terephthalate; PLA, polylactic acid; POCP, photochemical oxidants creation potential; PP, polypropylene; PS, polystyrene; TETP, terrestrial ecotoxicity potential.

* Corresponding author.
E-mail address: alejandro.gallegoschmid@manchester.ac.uk (A. Gallego-Schmid).

https://doi.org/10.1016/j.scitotenv.2018.02.128

techniques with the aim of reducing the environmental impacts associated with reusable food savers used by millions of people worldwide.

1. Introduction

Reusable food savers, also known as food containers, lunch boxes or Tupperware, are used worldwide and their popularity is growing. This is due to the increasing out-of-home consumption of food as a result of changing work and recreational habits (Razza et al., 2009). Reusable food savers are used for temporary food storage, preserving food quality and safety through mechanical and physico-chemical protection in a practical and cost-effective way (Marsh and Bugusu, 2007). One of the main manufacturers of food savers, Tupperware, reported net sales of $2.35 billion and an active sales workforce of more than 530,000 in 2013 (Tupperware, 2014). In the European Union (EU),[1] 42% of meals consumed by employees at work are brought from home (FOOD Programme, 2015). Given that 144.4 million employees work full time in the EU (Teichgraber, 2015), the number of food savers used annually in the EU could be substantial. Therefore, the environmental impacts related to the production, use and disposal of these products could be significant.

However, so far, research on the life cycle environmental sustainability of reusable food savers has been scarce. Only two life cycle assessment (LCA) studies have been found in the literature, both limited in scope. One of these (Harnoto, 2013) considered three environmental burdens – greenhouse gas emissions, energy consumption and waste generation – associated with reusable polypropylene (PP) containers. These were compared with the containers made of compostable bagasse used in the main canteen of the University of Berkley. The study found that the reusable PP containers required 15 uses to equal the burdens of the equivalent number of compostable containers. The second study (Accorsi et al., 2014) considered global warming potential of four food containers used in the catering industry in Italy. The authors concluded that the use of PP reusable containers had a lower impact than the non-reusable alternatives made of cardboard, plastic and wood.

The other LCA studies related to food containers focused on various non-reusable options. For instance, Kuo et al. (2005) considered food boxes used for take-away food in Taiwan, made from paper, PP and polystyrene (PS). They estimated the environmental burdens and costs of pollution control associated with the production of the boxes. The PP box had the highest cost for air pollution control and the paper for waste and water pollution control. Another study (Suwanmanee et al., 2013) compared the environmental performance of three non-reusable thermoform boxes made from polystyrene (PS) and polylactic acid (PLA) produced from corn and cassava starch. This cradle-to-gate study considered three impacts: global warming, acidification and photochemical oxidants formation. The results suggested that the impacts were higher for the PLA than the PS container, especially for global warming, because of the indirect land-use change related to cultivation of corn and cassava. Madival et al. (2009) also considered PLA and PS thermoforms (used for strawberry packaging) and compared them with polyethylene terephthalate (PET) packaging, concluding that the last had the highest impacts.

Plastic food savers have the greatest share of the market owing to their low cost, light weight and functional advantages, such as microwavability, optical properties and availability of various sizes and shapes (Duraccio et al., 2013). However, some organisations have suggested that these types of food saver could have negative effects on health because of the potential leaching into the food of toxic chemicals, such bisphenols A, S and F (NRDC, 2011; Earth Talk, 2008). Scientific studies, on the other hand, claim that these concerns are unfounded (EFSA, 2015; Harvard Health, 2015; Marsh and Bugusu, 2007). As a consequence of this debate, glass food savers have emerged as an alternative to plastic containers, particularly for people concerned about health (Girling, 2003). In addition to being chemically inert, they are resistant to staining, easy to recycle and give an impression of a 'higher quality' product. Therefore, this paper focuses on plastic and glass reusable food savers to evaluate their life cycle environmental sustainability and identify opportunities for improvements by the means of LCA.

As the focus is on reusable food savers, their use could have significant contribution to environmental impacts at the EU level because they need to be cleaned after each use, either manually or in a dishwasher, requiring water, energy and detergents. This is particularly important as dishwashing contributes considerably towards global warming, human toxicity and fossil fuel depletion (Arendorf et al., 2014a, 2014b). Furthermore, dishwashers consume around 1% of the electricity used annually in the EU (ECEEE, 2013; ENTSO-E, 2011), equivalent to the electricity produced by ten gas power plants (DECC, 2015). To improve the environmental performance of household dishwashers, the European Commission (2010) has developed an eco-design regulation (No. 1016/2010) for these appliances. In the case of hand dishwashing, several studies at the EU level have demonstrated the importance of consumer behaviour for reducing the amount of energy, water and soap used (Stamminger et al., 2007; Fuss and Stamminger, 2010; Fuss et al., 2011) but no specific EU policy has been developed so far to address this issue. Therefore, it is important to consider the effects on the environmental impacts of food savers of both manual and machine dishwashing to identify opportunities for improvements. For this reason, two scenarios related to this are considered in the paper: i) the implementation of the eco-design regulation for dishwashers; and ii) use of best available techniques (BAT) for hand washing up. These are compared with a third scenario related to the expected decarbonisation trend of the electricity mix in the EU. All three scenarios refer to the year 2020 and are evaluated against the present situation for the reusable food savers. To our knowledge, this is the first study of its kind internationally.

2. Materials and methods

The study has been carried out according to the ISO 14040/44 methodological guidelines for LCA (ISO, 2006a, 2006b). The goal and scope of the study is described in the next section. This is followed first by the inventory data for the individual plastic and glass food savers and then by the assumptions for the food savers used at the EU level. The impact assessment method used to estimate the impacts is described in Section 2.3.

2.1. Goal and scope of the study

The main goals of the study are:

i) to evaluate and compare the life cycle environmental sustainability of reusable plastic and glass food savers;
ii) to identify environmental hotspots and evaluate opportunities for improvements at the EU level.

The functional unit of the study is defined as "50 uses of plastic (polypropylene) and glass food savers over their lifetime". The number of uses is based on the data for plastic containers found in the literature (Accorsi et al., 2014). The same lifespan has been considered for the

[1] The term "EU" used throughout the paper refers to the union of 28 member countries (EU28).