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# Is the reusable tableware the best option? Analysis of the aviation catering sector with a life cycle approach

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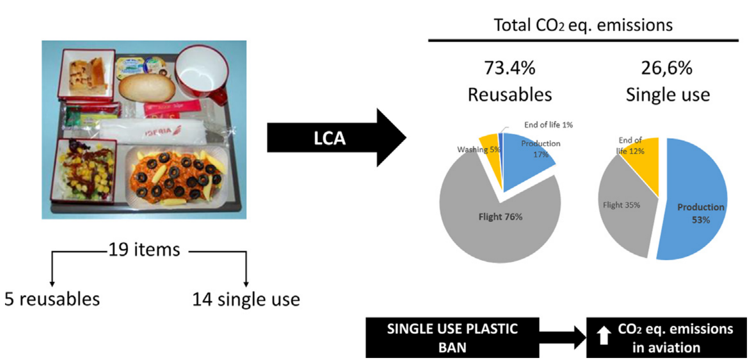
## GRAPHICAL ABSTRACT

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## ABSTRACT

Annually, around 7.7 billion passengers travel by plane. The menus served during the flight are quite similar between different airlines and are composed of the food itself, packaging (paper envelopes, film, etc.) and tableware (mainly trays, plates, glasses, cups and cutlery). In 2016, 1522 tonnes of tourist class menus were served in Iberia aircrafts landing at Madrid Barajas airport in Spain. From this amount, 51% by weight was packaging and tableware, and the remaining 49% food. As changes in the food has little room for maneuver, since the same amount would be delivered regardless how it is served, this study focus on the possibilities of packaging and tableware to reduce GHG emissions. The assessment has been done using life cycle assessment methodology (LCA) in order to identify the hotspots along the whole life cycle of packaging and tableware items. The case study chosen was the catering service of Iberia, the national airline of Spain. The functional unit used was "the service of 1,000 tourist class menus on Iberia flights that landed in Madrid in 2016".

The results show that the impacts of reusable and single use items take place at different stages of their life cycles. For reusable ones, 76% of the impact is produced during the flight phase, meanwhile, for single use ones, 53% of the impact comes from the production stage.

Variables such as material, weight and the number of reuses can greatly influence greenhouse gas (GHG) emissions. From the results of the analysis some eco-design strategies has been proposed and

*Abbreviations:* ABS, Acrylonitrile butadiene styrene; ACARE, Advisory Council for Aviation Research and innovation in Europe; ATAG, Air Transport Action Group; $CO_2$ eq., $CO_2$ equivalent; CORSIA, Carbon Offsetting and Reduction Scheme for International Aviation; EU, European Union; FU, Functional Unit; GHG, Green House Gasses; GG, Gate Gourmet; IATA, International Air Transport Association; ICAO, International Civil Aviation Organization; ICW, International Catering Waste; LCA, Life Cycle Assessment; LDPE, Low-density polyethylene; PEF, Product Environmental Footprint; PP, Polypropylene; PS, Polystyrene.

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analysed. The paper reveals that the lighter single-use packaging and tableware for airline catering are less harmful under a life cycle perspective become.



## 1. Introduction

The study presented in this paper is based on the LIFE + Zero Cabin Waste project. The main objective of the project is the reduction, reuse, and recycling of the waste generated in aircrafts coming from the catering service. In addition, it aims to reduce the carbon footprint of all processes, implementing improvements in all stages of waste management, where the catering service is included (Blanca-Alcubilla et al., 2018).

This founded project is the only one, to our knowledge, that takes into account every stage of the cabin catering waste. Since the flight phase, through the separate collection in flight till the proper waste management in its end of life.

Related to this, in Europe, two important policy issues are being highly debated: climate change and plastic pollution (European Commission, 2018).

### 1.1. Aviation and climate change

The Paris Agreement (United Nations, 2015) aims to reinforce the global response to the threat of climate change. A decision to mitigate the global annual emissions of greenhouse gases (GHG) by 2020 was established in order to manage that the increase in the global average temperature was kept below 2 °C above preindustrial levels, while trying to keep it below 1.5 °C.

Transport produces almost a quarter of Europe's GHG emissions and is the main cause of air pollution in cities. Europe's answer to the emissions reduction challenge in the transport sector means an irreversible shift to low-emission mobility. By midcentury, GHG emissions from transport will need to be at least 60% lower than in 1990 (European Commission, 2016).

Air transport is responsible for 12% of the emissions by the transport sector (ATAG, 2017). Europe is committed to increase aviation sustainability. For instance, the Strategic Research and Innovation Agenda (SRIA) provides the strategic roadmap for aviation research, development and innovation developed by ACARE (Advisory Council for Aviation Research and Innovation in Europe) that accounts for both evolutionary and revolutionary technology. Regarding to environment and energy goals for 2050, 75% reduction in $CO_2$ emissions per passenger kilometer and a 90% reduction in NOx emissions are set (ACARE, 2017). In addition, since 2012, aviation is contributing to the emissions reduction within the EU through the EU emissions trading system (the European Parliament and the Council of the European Union, 2008). Furthermore, the International Civil Aviation Organization (ICAO), with the implementation of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), aims to improve $CO_2$ efficiency by an average of 1.5 per cent per annum from 2009 until 2020, to achieve carbon neutral growth from 2020 and to reduce its carbon emissions by 50 per cent by 2050 compared to 2005 levels (ICAO, 2013).

On the other hand, it can be stated that emissions from the aviation sector are directly related to the transported weight (IATA, 2018). In fact, the life cycle assessment of an airplane shows that the stage of greatest impact is that of use, due to the flying time, during which the burning of kerosene emits GHG (Horvath and Chester, 2008; Lopes, 2010; Howe et al., 2013). To reduce this impact of air transport, several proposals have been published suggesting the use of lighter materials in aircraft components to save fuel, such as carbon fiber (Timmis et al., 2015), and the use of biofuels (Cox et al., 2014; de Jong et al., 2017).

### 1.2. Aviation and plastics

Tonnes of plastic packaging and other items are arriving to our seas, affecting the marine ecosystem (Eriksen et al., 2014). Therefore, the European Commission is currently developing measures in order to ban certain single use plastics by 2021. The ban will apply to single use plastic items such as cotton buds, cutlery, plates, straws, drink stirrers and sticks for balloons (European Commission, 2018).

As can be noted, most of the listed items are used in the catering sector. This prohibition will result in the use of other materials for the manufacture of the above mentioned items. The materials commonly used in reusable items (e.g. glass and metals) tends to be heavier than the single-use ones (Garrido and Alvarez del Castillo, 2007). As can be easily deducted, in the case that those prohibited single-use items are used in aviation catering services, not only the production or end of life stages should be considered, but also the use stage, since this phase could be a high contributor to the overall GHG emissions.

The authors are convinced that this European proposal is going to affect the environmental impact of the aviation catering sector. Single use items will probably be substituted by reusable ones, increasing the transported weight (other single use alternatives, such as bamboo and bioplastics have other environmental issues, such as eutrophication (Wu et al., 2009), land use (Piemonte and Gironi, 2012) and ecosystem destruction (Liu et al., 2011). Therefore, GHG emissions related to catering will increase in the sector, a fact against the international goals to fight climate change.

In 2016, 1522 tonnes of tourist class menus (776 tonnes of packaging and tableware, and 746 tonnes of food) were transported by the Iberia aircrafts landing at Madrid Barajas airport in Spain, having a direct effect on the overall GHG emissions of flights.

In addition to the flight stage, the production of food (Mattsson, 1999), packaging (Ligthart and Ansems, 2007; Madival et al., 2009; Poovarodom et al., 2012) and tableware (Postacchini et al., 2016), as well as their management as waste (Cherubini et al., 2009) (Guo et al., 2014), also generate GHG emissions along their life cycle (Hanssen et al., 2017).

### 1.3. Aviation and food waste

One way to reduce the impact of catering services is by reducing the amount of food waste (Bogner et al., 2008; Williams and Wikström, 2011; Hoehn et al., 2019; Garcia-Herrero et al., 2018). EU-28 produces about 100 Megatonnes of food waste every year (FUSIONS, 2015). If we consider that every tonne of food waste emits 2.27 t $CO_2$ eq., this results in 227 Mt of $CO_2$ eq. emitted per year, taking into account the full life cycle for the food (Timmermans, 2015), representing ~5% of total EU28 GHG emissions (European Environment Agency, 2018). In this sense, efforts are already being made within the Zero Cabin Waste project (Zero Cabin Waste, 2016) to analyze what type of food is most often found in the leftovers of airplane catering to replace it with another, thus reducing the organic matter waste. Another way to

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reduce the food carbon footprint would be to modify the type of food offered in the menus (Stehfest et al., 2009; Batlle-Bayer et al., 2019a,b). It is true that the food production phase has the greatest impact on the food life cycle and that a diet with less meat products has a lower carbon footprint (Scarborough et al., 2014; Clune et al., 2017), although it is very important to compare products including their nutritional value as well (Batlle-Bayer et al., 2019a,b). However, due to commercial reasons inherent to the airline, apart from measures such as a fully vegetarian menu, many changes in the food amount served in the menus are not possible. On the other hand, the substitution of heavy packaging materials for lighter ones, such as glass for plastic, could reduce emissions during the transport phase (Humbert et al., 2009).

Taking into account that the amount of weight transported due to the packaging and the tableware is higher than that of the food itself, it certainly makes sense using the life cycle assessment methodology (LCA hereafter) to analyze and improve the system. LCA has been applied to know the impact of each catering element through their individual life cycle stages, as well as to identify which variables (such weight or number of uses) have the main contribution to the overall impact. Improvements in design can only be properly targeted if hotspots are well known.

## 2. Methodology and data

Gabi Professional software was used to model the systems. The selected characterization method employed was the one recommended by the Single Market for Green Products Initiative by the European Commission, for the so-called Product Environmental Footprint (PEF) (European Commission, 2012). Since climate change is the most relevant environmental impact category for the aviation sector, subjected to strong regulation targets, the results of this paper focus on this particular impact category. In relation to the other above mentioned issue which is most relevant to the European Commission, plastic pollution, no methodology of including marine littering into LCA has been developed yet, although some initiatives have started (Civancik-Uslu et al., 2019).


**Fig. 1.** Tourist menu.

### 2.1. Goal and scope

The objective of this study is to evaluate the GHG emissions of the existing catering service provided to IBERIA by the catering operator Gate Gourmet (GG) at Barajas airport (Madrid, Spain). This has been done from a life cycle perspective to be able to identify those stages where there is a potential GHG mitigation.

### 2.2. Functional unit

The functional unit (FU) of the study is "the service of 1,000 tourist class menus on Iberia flights that landed in Madrid in 2016". GG is the main catering service in Madrid airport, and its service to Iberia represents 76% of the total menus served by the company in that airport and year (Fig. 1).

### 2.3. System boundaries

The stages included in the analysis are: production and manufacturing of the different materials of which the packaging and the tableware are made of, transport up to GG facilities, transport up to the airplane, flight phase, catering discharge from the aircraft to GG facilities, washing of reusable items, and end of life treatment (landfilling). For reusable items an average number of 10 uses before its end of life has been used. The transport to the landfill as well as the credits due to energy recovery (for the paper fraction) have been also taken into account (see Fig. 2).

### 2.4. Inventory

The life cycle inventory was built by means of the information provided by GG.

Table 1 summarizes the material of each tableware item present in the menu, as well as its weight, its reusability or not, and the number of uses considered, whereas Table 2 summarizes the parameters used for the transport stages.

All data regarding truck types and transport distances were provided by the catering (GG) and the waste management operator (Ferrovial). The truck utilization rate used was the default one in the GaBi database except for the transport stage between GG facilities and the sorting plant, as there were foreground data available from Ferrovial. Payloads used were also the predefined ones in the GaBi database for each type of truck.

#### 2.4.1. Assumptions

The flight distance was set at 2500 km (outbound EU flight average distance served for tourist menus) and the chosen utilization rate of the aircraft was 82% for an A330 with payload capacity of 65 t (IBERIA, 2016).

All waste materials were considered to go to landfill. It is necessary to clarify that international catering waste (ICW) is not considered hazardous waste when the planes are traveling within EU territory only, and it is classified as Cat3 waste. However, in

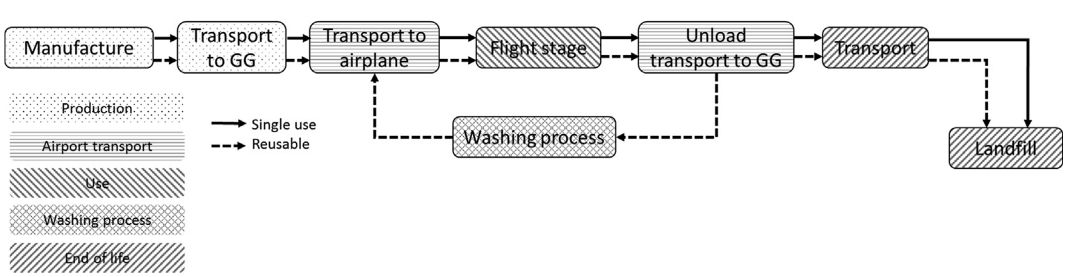


**Fig. 2.** Studied system.

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**Table 1**
Tableware characteristics.

| Item | Material | Weight | Reusable | Number of uses | Weight per functional unit (kg) |
|---|---|---|---|---|---|
| 1st course | ABS | 0.0280 | YES | 10 | 2.8 |
| 1st course lid | PS | 0.0042 | YES | 10 | 0.42 |
| 2nd course | Aluminum | 0.0079 | NO | 1 | 7.9 |
| 2nd course lid | Aluminum | 0.0043 | NO | 1 | 4.3 |
| Butter packaging | PP | 0.0007 | NO | 1 | 0.7 |
| Coffee creamer packaging | PP | 0.0007 | NO | 1 | 0.7 |
| Coffee cup | Paper | 0.0200 | YES | 10 | 2 |
| Condiments film | LDPE | 0.0005 | NO | 1 | 0.5 |
| Condiments packaging | Paper | 0.0003 | NO | 1 | 0.3 |
| Condiments washcloth | Cellulose | 0.0020 | NO | 1 | 2 |
| Condiments packaging 2 | Paper | 0.0002 | NO | 1 | 0.2 |
| Cutlery set film | LDPE | 0.0008 | NO | 1 | 0.8 |
| Cutlery set napkin | Cellulose | 0.0031 | NO | 1 | 3.1 |
| Cutlery set | Steel | 0.0713 | YES | 10 | 7.13 |
| Dessert course | ABS | 0.0280 | YES | 10 | 2.8 |
| Dessert lid | PS | 0.0042 | NO | 1 | 4.2 |
| Drink cup | ABS | 0.0254 | YES | 10 | 2.54 |
| Tablecloth | Paper | 0.0050 | NO | 1 | 5 |
| Tray | PP | 0.2000 | YES | 10 | 20 |

**Table 2**
Truck transport inventory.

| | Distance (km) | Utilization (%) | Payload (t) | Gross weight (t) |
|---|---|---|---|---|
| Manufacture-GG | 607 | 85 | 22 | From 28 to 34 |
| GG-Airplane | 8.3 | 85 | 3.3 | 7.5 |
| Airplane-GG | 8.3 | 85 | 3.3 | 7.5 |
| GG -landfill | 32 | 85 | 17.3 | From 20 to 26 |

flights from countries not included in EU territory, ICW is considered as animal by-product and, therefore, classified as high-risk Cat1 waste. It is assumed that a potential risk of the spread of animal diseases exists, being dangerous both to animal and human health, if not properly disposed of. The European Parliament regulates the way in which ICW can be disposed of, and waste classified as Cat1 must be disposed of by burial in an authorized landfill according to the EU 1069/2009 Regulation (European Parliament, 2009).

The type of landfill used includes landfill gas utilisation and leachate treatment and without collection, transport and pre-treatment.

## 3. Results

The GHG emission distribution to each of the studied stages are shown in Table 3.

For this menu composition, the flight stage is the one where most of the GHG gases are emitted.

The results of the $CO_2$ eq emissions from each analyzed item life cycle, for the chosen functional unit, are shown in Fig. 3. Clearly, the reusable items group is the one that generates most of the impact (73.4% in total). In addition, Tables 4 and 5 show how the impact of each item is distributed along their life cycle.

For reusable items, most of the $CO_2$ eq emissions take place in the flight stage while, for single-use items, the majority of the impact takes place in the production stage. In order to reduce the GHG emissions in different stages of the life cycle, several eco-design strategies were tested.

**Table 3**
GHG emission distribution.

| Production | Transport | Flight | Washing | End of life |
|---|---|---|---|---|
| 29.13% | 0.28% | 62.81% | 4.01% | 3.78% |

### 3.1. Ecodesing strategies

Steel cutlery was taken as an example, since it is the second item with the highest emissions during its life cycle and has different easily comparable design alternatives.

The effects on the results of some key variables were analyzed through a sensitivity analysis: number of uses, flight distance and weight.

Fig. 4 depicts how the number of reuses influences the GHG emissions in some of the life cycle stages.

Production stage is the one that is affected the most by an increase of reuses. GHG emissions in the production stage decrease as more reuses need less cutlery production.

For the transport stages (airport transport stage and flight) reusing the cutlery has no GHG reductions as the weight is the only factor that contributes in this case. Flight stage is the one that contributes the most to the global impact. Although the impact slightly increases in the washing phase, the overall impact decreases by 12.6%, if the reuses increase from 10 to 100 (Table 6). Being the flight stage the stage which contributes most to $CO_2$ eq. emissions, an asymptote near to 100 reuses occurs with no GHG improvements thereafter.

Another variable affecting the impact of reusable cutlery is the flight distance (Fig. 5). The results have been compared with those that would be obtained if metal cutlery was replaced by single-use plastic. Plastic cutlery is made of PS, with a weight of 6 g (compared to 71 g by the metal cutlery), and its end of life scenario is landfilling.

As can be expected, the greater the flight distance, the greater the emissions. It can be observed that, if the steel cutlery were replaced by others of PS of a single use, the environmental impact for its entire life cycle would be 80% lower in a 2.500 km long flight (the one assumed to be representative).

Two other eco-design measures were tested (Fig. 6). If weight reduction measures were taken for the metal cutlery, a proportional reduction in the environmental impact would be obtained.

In addition, an alternative solution to plastic was added to the analysis, single-use bamboo cutlery was added to the analysis too, with 26 g of weight, and considered to be landfilled at the end of life.

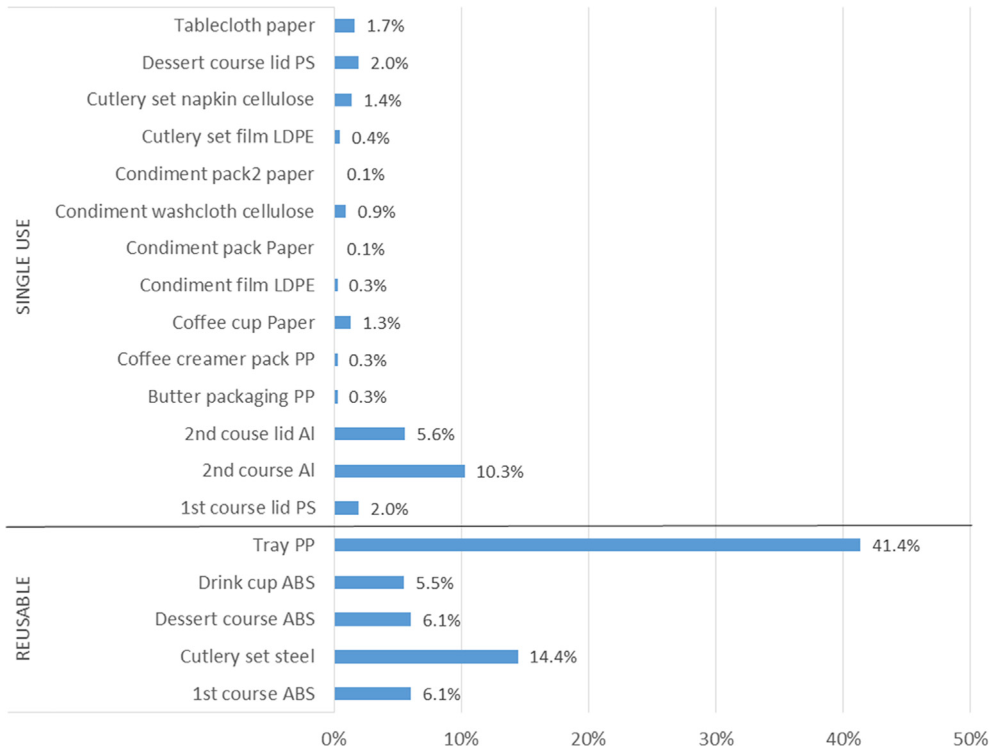


**Fig. 3.** Contribution to Global Warming Potential per item.

**Table 4**
Distribution of $CO_2$ eq. emitted by the reusable items in each stage.

| | Production | Airport transport | Flight | Washing | End of life | Total kg $CO_2$ eq. |
|---|---|---|---|---|---|---|
| 1st course ABS | 19.82% | 0.32% | 74.15% | 5.24% | 0.46% | 50.00 |
| Cutlery set steel | 14.33% | 0.35% | 79.37% | 5.61% | 0.34% | 119.46 |
| Dessert course ABS | 19.82% | 0.32% | 74.15% | 5.24% | 0.46% | 49.95 |
| Drink cup ABS | 19.82% | 0.32% | 74.15% | 5.24% | 0.46% | 45.31 |
| Tray PP | 11.12% | 0.34% | 77.77% | 5.50% | 5.28% | 341.45 |

**Table 5**
Distribution of $CO_2$ eq. emitted by the single use items in each stage.

| | Production | Airport transport | Flight | End of life | Total kg $CO_2$ eq. |
|---|---|---|---|---|---|
| 1st course lid PS | 63.23% | 0.15% | 34.49% | 2.13% | 14.91 |
| 2nd course Al | 87.05% | 0.05% | 12.37% | 0.53% | 78.22 |
| 2nd course lid Al | 87.05% | 0.05% | 12.37% | 0.53% | 42.58 |
| Butter packaging PP | 57.28% | 0.18% | 40.07% | 2.47% | 2.14 |
| Coffee creamer pack PP | 57.28% | 0.18% | 40.07% | 2.47% | 2.14 |
| Coffee cup Paper | 21.25% | 0.21% | 48.43% | 30.11% | 10.11 |
| Condiment film LDPE | 69.45% | 0.13% | 28.65% | 1.77% | 2.14 |
| Condiment pack Paper | 21.25% | 0.21% | 48.43% | 30.11% | 0.76 |
| Condiment washcloth cellulose | 50.56% | 0.15% | 35.24% | 14.05% | 6.95 |
| Condiment pack2 paper | 21.25% | 0.21% | 48.43% | 30.11% | 0.51 |
| Cutlery set film LDPE | 69.45% | 0.13% | 28.65% | 1.77% | 3.42 |
| Cutlery set napkin cellulose | 50.56% | 0.15% | 35.24% | 14.05% | 10.77 |
| Dessert course lid PS | 63.23% | 0.15% | 34.49% | 2.13% | 14.91 |
| Tablecloth paper | 21.25% | 0.21% | 48.43% | 30.11% | 12.64 |

Even with a 20% weight reduction, PS cutlery GHG emissions would still be 76% lower. Bamboo cutlery would be 56% better than reusable metal as well, and would have about double the emissions of the PS solution. Of course, other impact categories may point in different directions.

## 4. Discussion

The choice of the most environmentally sustainable catering material in the case of aviation will depend on the impact of manufacturing, weight, number of uses, and recyclability. Aluminum

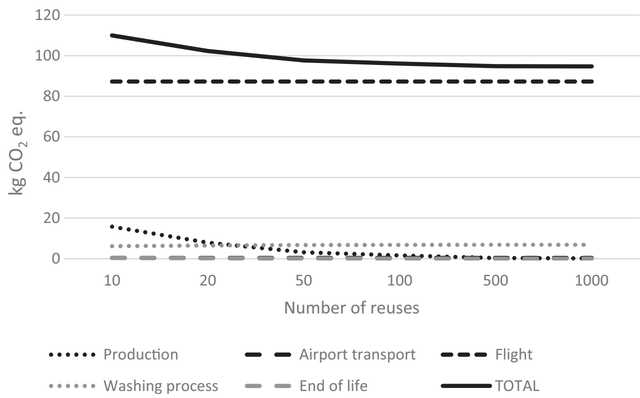


**Fig. 4.** Kg of $CO_2$ eq. for steel cutlery for different number of reuses.

**Table 6**
Total kg of $CO_2$ eq. for steel cutlery for different number of reuses.

| Reuses | Total kg $CO_2$ eq. |
|---|---|
| 10 | 110.0 |
| 20 | 102.3 |
| 50 | 97.6 |
| 100 | 96.1 |

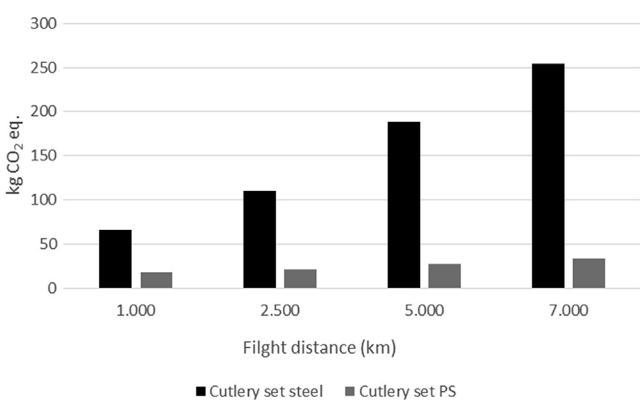


**Fig. 5.** Kg $CO_2$ eq. emitted for the steel and y PS cutlery according to different flight distances.

materials have a high manufacturing impact compared to other single-use materials. For example, the aluminum lid of the second plate has a similar weight (4.3 g) to the plastic lid PS of the first plate (4.2 g). However, the overall impact of the aluminum lid is almost three times higher than that of PS (42.59 and 14.91 respectively). Therefore for light single use packaging, when selecting the material, the focus should be made on the manufacturing stage impacts.

In this case, almost 63% of the total emissions are produced during the flight, this is why it is really important to have into consideration the weight when reducing the overall impact. Indeed 73% of the total impact is produced by reusable items (5 out of 19) which are heavier than the single use ones.

The number of uses has only a relevant effect on the manufacturing stage. Increasing the number of reuses will reduce manufacturing impacts but not flight stage impacts. Nevertheless, reusable items are normally heavier than single use ones so they are expected to generate more GHG emissions due to the flight stage.

Finally, it is worth to mention that the current Regulation for this cabin catering waste do not allow it to be recycled. Thus, a change of this European Regulation is needed, as this waste can be sterilized previously and be led to a recycling process reducing the overall impact.

## 5. Conclusions

For reusable items used in aviation catering services, ecodesign strategies should focus on minimizing the weight of the item while increasing the number of possible reuses up to 100. On the other hand, for single-use items, strategies should focus on the production stage (changing materials or decreasing their weight). To summarize, the best solution for the catering in the aviation sector, attending the climate change impact category, would be to use lightweight materials, allowing several uses, a controlled collection system (which would avoid littering), and an easy way to recycle. Nevertheless, further investigation, regarding PS and bamboo alternatives, is needed to add other impact categories to the analysis, such as land use, toxicity or eutrophication potential.

This analysis have been done taking into account the current ICW regulations, which only allow landfilling of catering waste coming from non-European countries. If some changes in this regulations occur, it would be interesting to consider into the analysis alternative end of life scenarios including incineration and recycling.

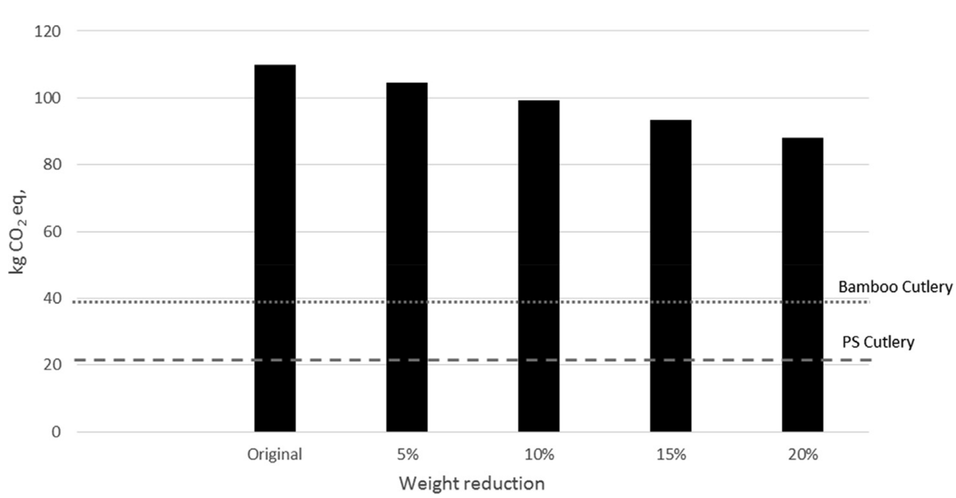


**Fig. 6.** Comparison of kg $CO_2$ eq. emitted by the steel cutlery with respect to the PS and bamboo, if the weight of the reusable solution was reduced.

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On the other hand, given the current intention to prohibit certain single-use plastics (including cutlery, plates, cups…) by the European Commission (European Commission, 2018), we recommend the use of the LCA methodology to know, in each case and for aviation in particular, if the use of these items is environmentally more beneficial or not. In cases where transport is the dominant stage, as in aviation, it can be observed that much lighter single-use items generate less greenhouse gases throughout their complete life cycle.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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