The Global Warming Potential analysis of beverage: Which is the best option?

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Abstract The main objectives of this study are to evaluate the Global Warming Potential of the most common packaging options for beverage products (juice, water and beer), and to evaluate the contribution of packaging to the environmental profile of a product's life cycle (beverage production, transport, packaging production and final disposal). The disposal methods considered are landfilling, incineration and recycling, and the packaging types are aseptic carton, glass, HDPE, aluminum can and PET, and their sizes are from 200 ml to 8 liters. Recycling was found to be the most environmentally friendly disposal option for all the packaging alternatives compared, and landfilling was considered the second best option. The packaging options with the lowest environmental impacts were aseptic carton and plastic packaging (for sizes greater than 1 liter). The influence of beverage production on the life cycle varies according to the type of beverage.

1 Introduction

The world population consumes ever-increasing amounts of all types of products, however the consumers have fewer opportunities to use products without generating packaging waste, leading to large amounts of solid waste. Also, the possibility to consume products without generating wastes is lower. Packaging has been the subject of intense public debate, as today most food, cleaning, health care and other products are offered to consumers in a wide range of packaging alternatives made from different materials and sizes. Because of that, it also takes up a growing percentage of municipal solid waste streams.

The main beverage contributions to the packaging fraction are juice, water and beer [1].

The environmental effect that a product has on the environment does not only include the process of manufacturing the product, but also the processes of packaging, distributing, use and disposing of the product after use [2].

If packaging is to be managed correctly, its environmental implications should also be taken into account. Therefore, it is important to inform the consumer about the environmental implications of the product's whole life cycle, including its packaging, in order to implement improvements that promote sustainability.

Life Cycle Assessment (LCA) is a tool that provides a quantified assessment of the environmental performance of goods, processes and services (collectively termed products). LCA has been used to assess alternative packaging for coffee and has shown that using polylaminate bags instead of metallic cans for small size packages would be an better alternative, even though this solution does not favor material recycling [3]. In the case of egg packaging, paper eggcups seem to have less environmental impact than polystyrene ones [1]. Comparing alternatives for baby food packaging shows that using plastic pots instead of glass jars has environmental benefits [4]. Recycling aluminum cans can reduce the consumption of natural resources and the generation of emissions resulting from their manufacture [5]. Consequently, it is a suitable tool for assessing food packaging production and packaging disposal options. Most of these studies are focused on evaluating the environmental impact of packaging, without considering the impact of the product. Though several LCA studies regarding product packaging have been published [6], only a few have specifically studied the different beverage packaging options, also including the product [7,8].

Because of that, this study is divided into two main parts:

1) Packaging assessment. In this section we evaluate the Global Warming Potential (GWP) of manufacturing and disposing of the most common packaging options for three beverage products: juice (packaged in aseptic carton, glass and HDPE), water (packaged in PET and glass) and beer (packaged in aluminum can, glass and HDPE). The disposal methods are landfilling, incineration and recycling. The packaging materials and sizes found in the market have been analyzed for each of the products and range from 200 ml to 8 liters.
2) Environmental profile assessment. In this section of this study we evaluate the contribution of packaging to the GWP of a product's life

cycle, including the beverage production, transport (local), packaging production and packaging disposal.

2 Methodology

2.1 Life cycle assessment

The goal of the LCA was to evaluate the GWP of producing and disposing of several types of beverage packaging, and to determine the GWP of each product's life cycle. The functional unit was the packaging required to contain 1 liter of beverage. The production of the beverage and the transport of the packaged product were not included in the first section. The system boundaries considered are detailed in each of the corresponding sections.

Beverage products were obtained from several local suppliers in order to get a wide brand range that was representative of the Spanish beverage packaging market. Empty packaging was weighed on precision scales and the material weights were averaged for the different brands found in the Spanish market (Table 1).

Environmental data regarding the consumption and emissions of each different material analyzed were obtained from the ecoinvent v2.1 database [9]. These data were adapted to the Spanish electricity mix and the European model for transport and water.

Global Warming Potential (GWP, kg CO2 eq) has been considered as the environmental indicator in this study.

2.2 Packaging assessment

The packaging options studied for each beverage type are detailed in Table 1, and include the type of the packaging materials, the beverage volume and the packaging weight for 1 liter of beverage and secondary materials (tops and straws).

The packaging options considered are the following: Aseptic carton (made of layers of cardboard (75%), aluminum and LDPE, from which the cardboard is the component that is mainly recycled), Aluminum cans (material 100% recyclable), Glass bottles, High density polyethylene (HDPE) and Polyethylene teraftalate (PET).

Tab.1: Beverage packaging types studied (Packaging weights correspond to 1 liter beverage)

Material	Size (L)	Mass (g/L)	Secondary material (g/L)
Aseptic carton	0.2	50.0	5.0 g/L PP straw
Aseptic carton	0.33	51.2	3.0 g/L PP straw
Aseptic carton	1.0	36.0	1.3 g/L HDPE top
Aseptic carton	1.5	35.2	1.4 g/L HDPE top
Aluminium can	0.33	67.9	-
Aluminium can	0.5	34.7	-
Glass (brown)	0.33	722.7	6.1 g/L Aluminium top
Glass (white)	0.33	722.7	6.1 g/L Aluminium top
Glass (white)	1.0	492.2	9.3 g/L Aluminium top
Glass (brown)	1.0	468.8	1.6 g/L Aluminium top
Plastic (HDPE)	0.2	91.1	1.7 g/L Aluminium top
Plastic (HDPE)	1.0	32.4	3.1 g/L PP top
Plastic (HDPE)	1.5	32.7	3.4 g/L PP top
Plastic (PET)	0.33	42.4	5.4 g/L HDPE top
Plastic (PET)	1.5	19.3	0.9 g/L HDPE top
Plastic (PET)	5.0	20.0	2.8 g/L HDPE top
Plastic (PET)	8.0	17.5	1.8 g/L HDPE top

The final disposal assessment assumed that 100% of the packaging was disposed in one of the following three packaging disposal options:

- Landfill: includes the dump infrastructure, the use of land, the effect of landfilled waste, and the emissions to the soil, air and groundwater released by waste disposed of in landfills.
- Incineration: covers the incineration plant infrastructure, the incineration process, the electricity generated and the disposal of residual ashes (to landfill). Electrical energy recovery was considered as an avoided environmental load.
- Recycling: takes into account the recycling plant infrastructure, the sorting and recycling processes, the products obtained and the wastes generated. The products obtained from the recycling process are considered to displace virgin raw materials and are thus an avoided load.

2.3 Environmental profile assessment

One packaging option was selected for each of the beverages, from the first part of this study. The packaging options (material and size) selected, from the first part of this study, were a compendium between the option with the lowest environmental impacts and the ones widely present in the market.

The environmental profile assessment considers the whole life cycle product, taking into account the following aspects: Beverage production (estimated using data from the ecoinvent v2.1 and LCAfood databases and information from the bibliography), Transport (considering a local transport, with a distance of 100 and the use of small trucks), Packaging production (selected from the results of the previous part of the study), Packaging disposal (recycling was chosen as the disposal scenario with the lowest environmental impact for all the types and sizes of beverage and packaging material).

3 Results and Discussion

3.1 Packaging assessment

The GWP results for each material when used to package juice (Table 2) show that aseptic cartons have the lowest environmental impact, followed by HDPE and glass bottles in that order. For water (Table 3), as with the other two beverages, the highest GWP comes from glass bottles and the lowest comes from PET. For beer the lowest GWP results (Table 4) come from HDPE packaging and the highest come from glass and aluminum cans.

The highest GWP for the three beverages is due to the glass bottle. When comparing different packaging sizes for the same material, it was found that the higher the volume content of the packaging, the lower the GWP for the same amount of beverage (1 liter). This was due to the reduction in packaging material needed per unit of product.

The final environmental impacts of the different disposal options depend not only on how the waste is treated but also on any possible avoided loads. In the case of recycling, these are the materials recovered, and in the case of incineration, these are the energy generated. For the GWP indicator, recycling has the lowest

environmental impact for all the packaging alternatives, followed by landfilling and finally incineration.

Tab.2: GWP (Kg CO2 eq/L) indicator for different juice packaging alternatives.

JUICE	Landfill	Incineration	Recycling
Aseptic Carton 200 ml	0,091	0,113	0,074
Aseptic Carton 330 ml	0,086	0,105	0,072
Aseptic Carton 1 L	0,058	0,070	0,049
Aseptic Carton 1.5 L	0,057	0,069	0,048
Glass White 330 ml	0,727	0,975	0,513
Glass White 1 L	0,557	0,729	0,352
HDPE 200 ml	0,321	0,510	0,155
HDPE 1 L	0,117	0,189	0,059
HDPE 1.5 L	0,119	0,193	0,061

Tab.3: GWP (Kg CO2 eq/L) indicator for different water packaging alternatives.

WATER	Landfill	Incineration	Recycling
PET 330 ml	0,224	0,311	0,101
PET 500 ml	0,160	0,222	0,073
PET 1.5 L	0,084	0,116	0,038
PET 5 L	0,093	0,130	0,042
PET 8 L	0,079	0,110	0,036
Glass White 330 ml	0,727	0,975	0,513
Glass White 1 L	0,557	0,729	0,352

Tab.4: GWP (Kg CO2 eq/L) indicator for different beer packaging alternatives.

BEER	Landfill	Incineration	Recycling
Aluminium Can 330 ml	0,859	0,895	0,077
Aluminium Can 500 ml	0,439	0,458	0,039
Glass Brown 330 ml	0,727	0,975	0,513
Glass Brown 1 L	0,442	0,601	0,330
HDPE 1 L	0,117	0,189	0,059

3.2 Environmental profile assessment

In order to evaluate how packaging contributes to the environmental impact of a beverage's entire life cycle, one packaging type for each beverage was chosen and compared its production and final disposal with the overall production and transport of the packaged beverage. The packaging types chosen are those that are most widely represented in the Spanish market within those that also have low values in the GWP.

Consequently, on the basis of the results obtained in the previous section, the packaging option for the whole profile was selected, taking into account the following considerations:

For juice packaging, the 1.0 liter aseptic carton is considered as the most representative packaging type for juice, as many juice brands provide it in this size. It also has one of the lowest GWP results.

For water packaging, the 1.5 liter PET bottle was chosen as representative and recommended according to the consumer preferences. Also PET has a lower GWP than glass for all the sizes compared.

For beer packaging, although aluminum can does not have the lowest GWP impact, it was chosen as the most representative beer packaging option (330 ml), as it is one of the options usually found for most commercial beer. It is also the best option if it is recycled.

In Fig. 1 the different stages of the beverages' life cycle are compared; that is, beverage production, packaging production, product transport and packaging disposal.

For juice packed in 1.0 liter aseptic cartons, it can be seen that packaging production is the stage with the highest environmental impact, whereas juice production and local transport of the packaged product have a lower and similar impact. The transport stage (100 km) is very important given that it represents more than 20% of the total environmental impact when local juice transport is considered.

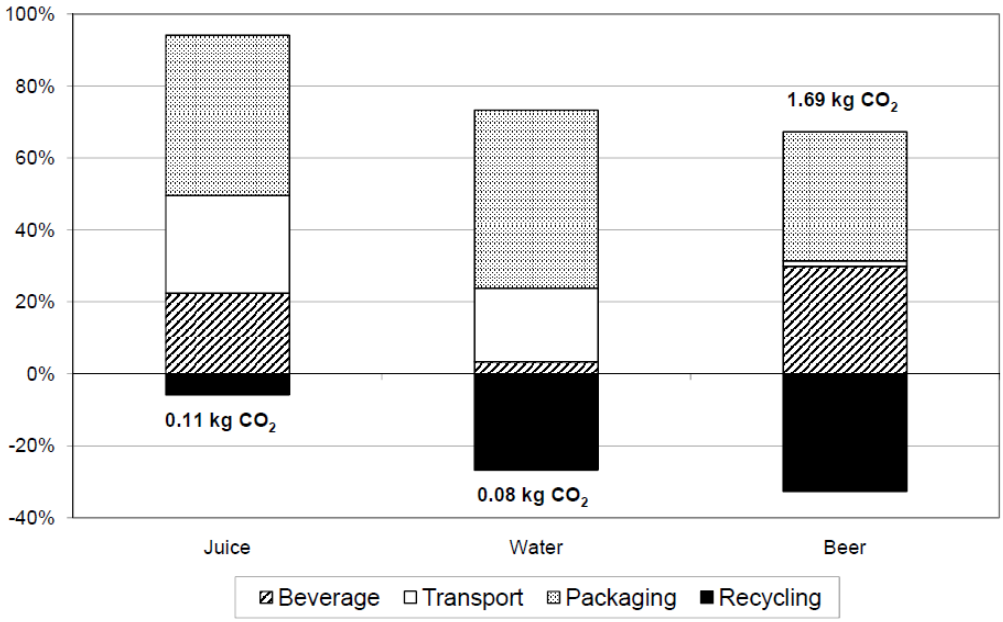

Fig.1: GWP for the different stages of the beverages' life cycles.

In the case of the water packed in 1.5 liter PET bottles, it can be seen that while PET bottle production has the highest impact, this can be reduced by more than 50% if the PET is recycled. The water production stage has almost no influence on the total life cycle, even when the most intensive (energy consuming) water treatment is used. If water is collected from natural streams with no further treatment, the impact of water production is limited to the water bottling process.

In the case of beer packed in 330 ml aluminum cans, it can be seen that the beer production and the can production and recycling stages have the greatest effect on the final impact of the beer's life cycle. The high impact of beer production is mainly due to barley production. The high impact of the packaging production is mainly due to the production of the aluminum.

4 Conclusions

This paper estimates, according to the GWP, the best packaging options (size and materials) for three beverages: juice, water and beer.

All the beverage packaging materials and sizes have a lower environmental impact if they are recycled rather than disposed of in landfills or incineration plants, because of the energy and raw material savings it entails.

Larger packages always have a lower environmental impact than smaller packages, and optimal packaging sizes guarantee minimum product losses and maximum ease of use for consumers.

Aseptic cartons and plastic packaging (for sizes greater than 1 liter) present the lowest GWP for the three disposal methods.

The influence of beverage production on the life cycle varies according to the type of beverage. Thus, the production of beer contributes significantly to the environmental impact of the product's life cycle, whereas the environmental impact of producing water for bottling is insignificant.

The stage of the life cycle that contributes more to the environmental impact for juice and water is the packaging stage.

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