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Environmental assessment of Food Packaging: some case studies carried out by CIPACK Center

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Summary

- ***Introduction***
- ***Goal and scope definition***
- ***Processes description***
- ***Impact assessment***
- ***Sensitivity analysis***
- ***Conclusions***

Introduction

- The main rules for applying the LCA method are:
  - ***ISO 14040***. Environmental Management – Life Cycle Assessment. Principles and Framework.
  - ***ISO 14044***. Environmental Management – Life Cycle Assessment. Requirements and Guidelines.
- The first one is of a more general nature and it outlines the principles and describes the structure of an LCA; the second one reports the requirements and guidelines, and it is the main support for the practical application of a lifecycle study.

Introduction

- To perform an environmental assessment of products, especially in the food sector, an increased attention is attributed to certification and to defining standard methods for the food product evaluation.

  - **Environmental Product Declaration (EPD)**: based on this standard it is possible to certify for example a Food Product by evaluating the impact associated to all its phases along its supply chain

EPD VERIFIED

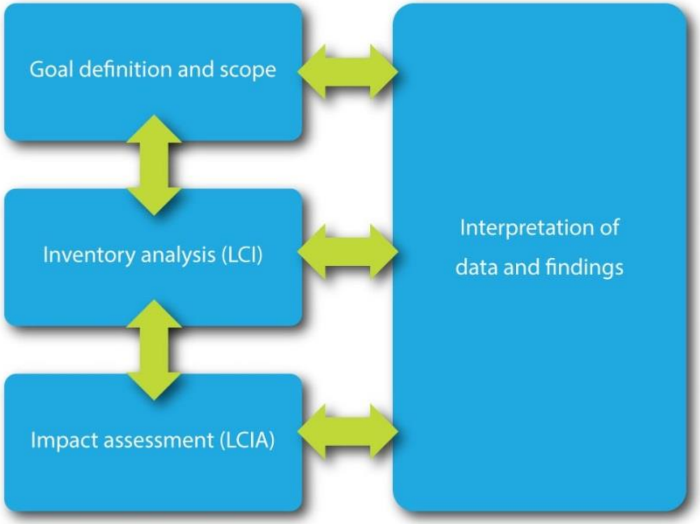
- For each category of products there is a specific Product Category Rule (PCR), which has to compliant to the EPD standard. Nowadays there are 41 PCR's in "Food & Agricultural Products", which are frequently updated and available on the website www.environdec.com/PCR .

LCA: Life Cycle Assessment

- ✓ LCA is a technique to assess and quantify the **potential environmental impacts** of a product, process or activity.
- ✓ It considers the **entire life cycle** of a product, from raw material extraction to disposal.

The method is composed by the following steps:

1. Goal and scope definition;
2. Inventory analysis;
3. Impact assessment;
4. Interpretation and conclusion.



Goal and scope definition of the Coffee capsules case study

- **Aim of the study:**
  - The aim of this work is to compare the environmental impact of three different packaging systems for coffee capsules, which can be used in the same coffee machine.
  - A comparative Life Cycle Assessment has been performed considering the following three types of coffee capsules:
    - ✓ 1. Compostable coffee capsules packaged into a multi-chamber PET tray.
    - ✓ 2. Capsules made of aluminium and packaged into cardboard boxes.
    - ✓ 3. Capsules made of polypropylene with an aluminium top lid, singularly packaged in modified atmosphere into a bag made of multilayer film of aluminium and polypropylene.

Goal and scope definition

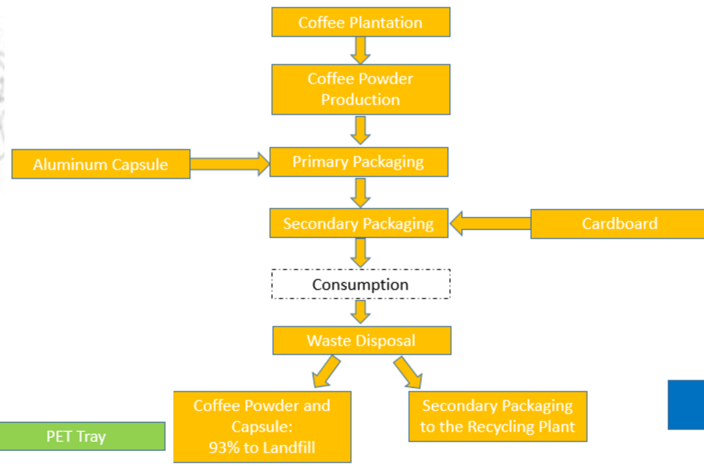
- ✓ **Adopted approach:**
  - The environmental impact of a coffee capsules has been assessed by means of the LCA methodology following the EPD standard;
  - The environmental impact has been analyzed through a sensitivity analysis;

- ✓ **Functional Unit**
  - The functional unit considered is a coffee capsule.

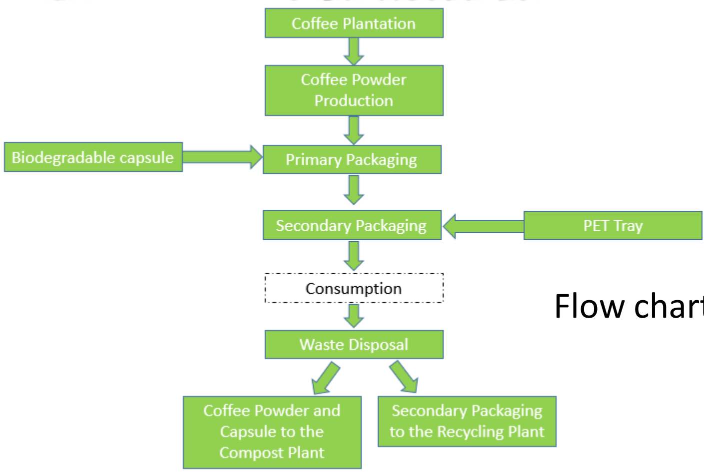
Goal and scope definition

System Boundaries

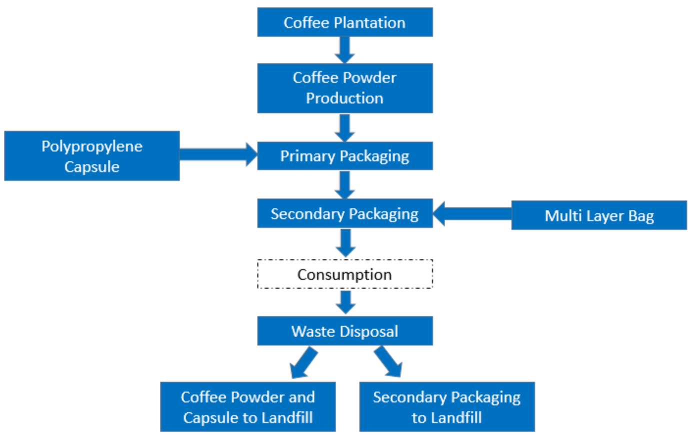
✓ In order to quantify the impact of the analyzed product, the system boundaries shall be determined.



Flow chart of the aluminium capsule life cy



Flow chart of biodegradable capsule life cycle



Flow chart of the polypropylene capsule life cycle.

LCIA

- **Source of data for the Inventory**
  - Primary data was collected by a coffee capsule production company
  - Secondary data relating to Italian or European processes are taken from Ecoinvent 3.2, other databases available in SimaPro 8.2 software and database and from scientific literature
- **Software used**
  - The LCA analysis was performed using the SimaPro 8.2. software.
- **Impact Method used**
  - The impact analysis was carried out using the EPD (2013) method.
- **Impact Categories analyzed (7)**
  - Impact values were calculated at midpoint level for 7 impact categories: (i) Acidification (fate not incl.), (ii) Eutrophication, (iii) Global warming (GWP100a), (iv) Photochemical oxidation, (vi) Ozone layer depletion (ODP), and (v) Abiotic depletion, Abiotic depletion, fossil fuels

Processes description

The three analysed capsules present the same life cycle main phases:

1. *Coffee Plantation, which includes the cultivation of coffee and all the processes made at the plantation site necessary to obtain coffee beans ready to be transformed in coffee powder.*

2. *Coffee Powder Production, which includes the energy and resources consumption of all the processes done to obtain the coffee powder starting from the green bean. It also includes the energy consumption for the filling of coffee powder.*

3. *Packaging, it includes all the packaging materials used and the energy for their production, starting from row materials extraction. For what concerns the transports of packaging materials from the producer plant to the coffee capsules factory, an average distance is considered, calculated through Ecoinvent Database.*

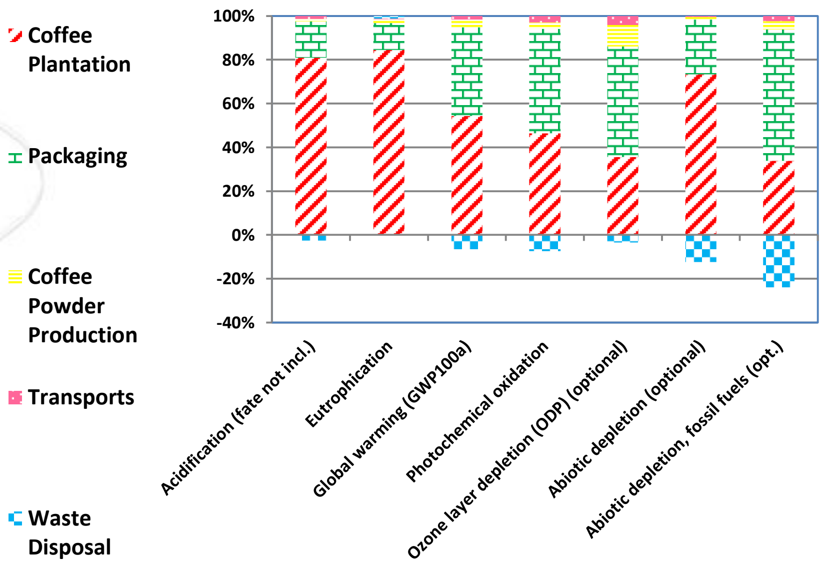
4. *Waste disposal, which varies according to the packaging materials used.*

Impact assessment

- ✓ Environmental impact produced by the biodegradable capsule in PET tray
- ✓ Table and figure show the total impacts for all the considered categories and the relative impacts of each of the considered phases.

Impact Category	Unit	Total	Coffee Plantation	Packaging	Coffee Powder Production	Transports	Waste Disposal
Acidification (fate not incl.)	kg SO2 eq	6,22E-04	5,17E-04	1,06E-04	7,87E-06	8,24E-06	-1,69E-05
Eutrophication	kg PO4--- eq	4,34E-04	3,67E-04	5,34E-05	7,80E-06	1,24E-06	5,33E-06
Global warming (GWP100a)	kg CO2 eq	4,61E-02	2,68E-02	1,99E-02	1,74E-03	8,27E-04	-3,26E-03
Photochemical oxidation	kg C2H4 eq	1,15E-05	5,77E-06	5,93E-06	3,60E-07	3,65E-07	-9,21E-07
Ozone layer depletion (ODP) (optional)	kg CFC-11 eq	3,66E-09	1,35E-09	1,91E-09	3,71E-10	1,56E-10	-1,30E-10
Abiotic depletion (optional)	kg Sb eq	2,13E-07	1,78E-07	6,08E-08	2,84E-09	1,30E-09	-3,00E-08
Abiotic depletion, fossil fuels (opt.)	MJ	4,17E-01	1,86E-01	3,29E-01	2,11E-02	1,28E-02	-1,32E-01

Environmental impact produced by a biodegradable capsule packaged in PET tray



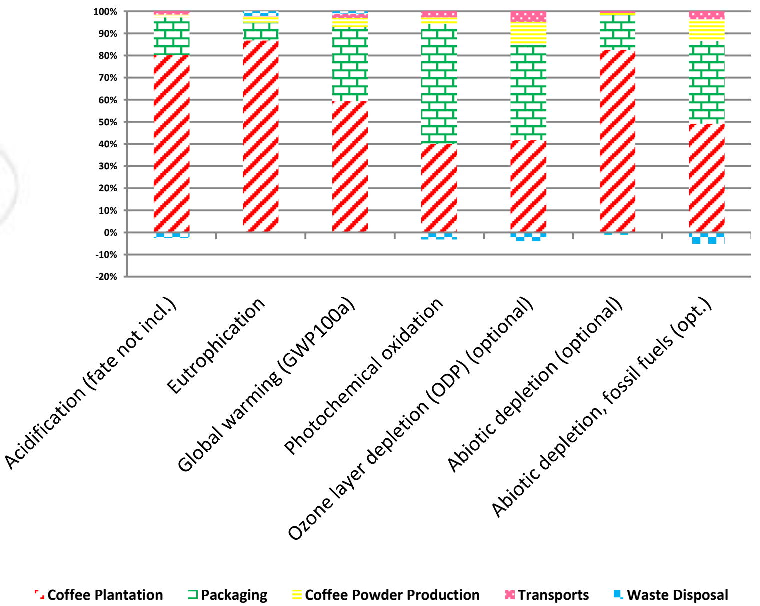
Relative environmental impact of the biodegradable capsule life cycle.

Impact assessment

- ✓ Environmental impact produced by an aluminium capsule in cardboard box.
- ✓ Table and figure show the total impacts for all the considered categories and the relative impacts of each of the considered phases.

Impact Category	Unit	Total	Coffee Plantation	Packaging	Coffee powder Production	Transports	Waste disposal
Acidification (fate not incl.)	kg SO2 eq	6,3E-04	5,2E-04	1,1E-04	8,5E-06	9,4E-06	-1,7E-05
Eutrophication	kg PO4--- eq	4,2E-04	3,7E-04	3,4E-05	1,1E-05	1,5E-06	8,5E-06
Global warming (GWP100a)	kg CO2 eq	4,5E-02	2,7E-02	1,5E-02	1,9E-03	9,2E-04	4,6E-04
Photochemical oxidation	kg C2H4 eq	1,4E-05	5,8E-06	7,9E-06	4,1E-07	4,0E-07	-4,6E-07
Ozone layer depletion (ODP) (optional)	kg CFC-11 eq	3,1E-09	1,4E-09	1,4E-09	3,3E-10	1,6E-10	-1,3E-10
Abiotic depletion (optional)	kg Sb eq	2,1E-07	1,8E-07	3,4E-08	2,3E-09	1,4E-09	-2,4E-09
Abiotic depletion, fossil fuels (opt.)	MJ	3,6E-01	1,9E-01	1,4E-01	3,8E-02	1,3E-02	-2,0E-02

Environmental impacts produced by an aluminium capsule packaged in cardboard box.



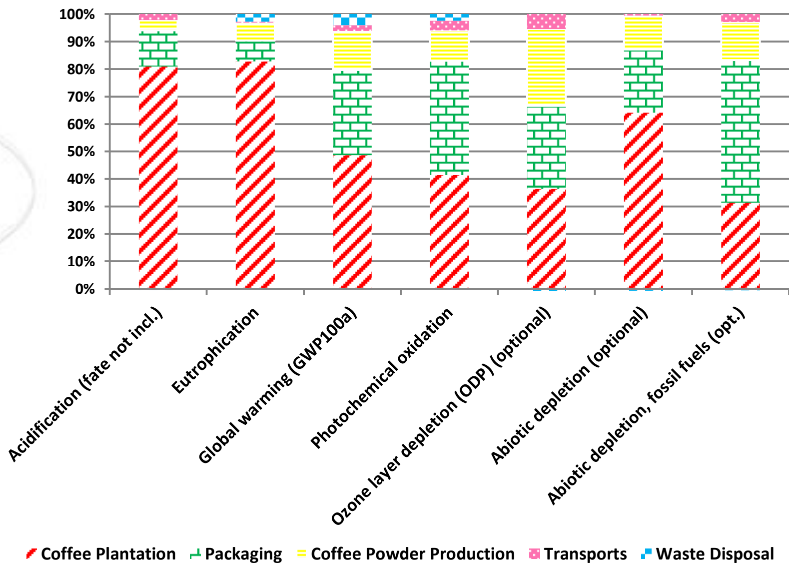
Relative environmental impacts of the aluminium capsule life cycle.

Impact assessment

- ✓ Environmental impact produced by the polypropylene capsule in multi-layer bag.
- ✓ Table and figure show the total impacts for all the considered categories and the relative impacts of each of the considered phases.

Impact category	Unit	Total	Coffee Plantation	Packaging	Coffee Powder Production	Transports	Waste disposal
Acidification (fate not incl.)	kg SO_2 eq	7,1E-04	5,8E-04	9,5E-05	2,6E-05	1,5E-05	-3,0E-06
Eutrophication	kg PO4--- eq	4,9E-04	4,1E-04	3,7E-05	3,2E-05	1,9E-06	1,3E-05
Global warming (GWP100a)	kg CO_2 eq	6,1E-02	3,0E-02	1,9E-02	8,7E-03	1,2E-03	2,5E-03
Photochemical oxidation	kg C_2H_4 eq	1,6E-05	6,4E-06	6,5E-06	1,7E-06	5,4E-07	3,8E-07
Ozone layer depletion (ODP) (optional)	kg CFC-11 eq	4,1E-09	1,5E-09	1,2E-09	1,2E-09	2,3E-10	-7,0E-11
Abiotic depletion (optional)	kg Sb eq	3,1E-07	2,0E-07	7,1E-08	3,8E-08	1,5E-09	-2,2E-09
Abiotic depletion, fossil fuels (opt.)	MJ	6,6E-01	2,1E-01	3,4E-01	9,1E-02	1,9E-02	-3,4E-03

Environmental impacts produced by the polypropylene capsule packaged in multi-layer bag



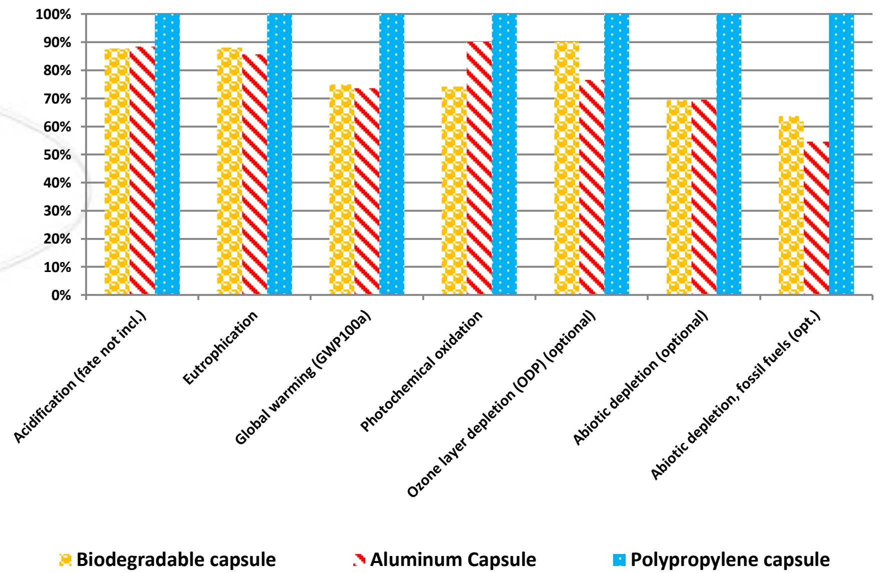
Relative environmental impacts of the polypropylene capsule life cycle.

Impact assessment

- Comparison of environmental impact produced by the three coffee capsules.
- Table and figure show the total impacts for all the considered categories and the relative impacts of each of the considered phases.

Impact category	Unit	Biodegradable capsule	Aluminum Capsule	Polypropylene capsule
Acidification (fate not incl.)	kg SO2 eq	0,000622388	0,000627555	0,00070927
Eutrophication	kg PO4--- eq	0,000434485	0,000422585	0,000493211
Global warming (GWP100a)	kg CO2 eq	0,046070457	0,045201014	0,061431819
Photochemical oxidation	kg C2H4 eq	1,15105E-05	1,3988E-05	1,55265E-05
Ozone layer depletion (ODP) (optional)	kg CFC-11 eq	3,66194E-09	3,1111E-09	4,06362E-09
Abiotic depletion (optional)	kg Sb eq	2,13174E-07	2,13517E-07	3,07082E-07
Abiotic depletion, fossil fuels (opt.)	MJ	0,417440645	0,357732909	0,655038844

Comparison of environmental impacts produced by the three coffee capsules



Relative environmental impact produced by the three coffee capsules analysed.

Sensitivity analysis

➢ A sensitivity assessment was performed to evaluate how to reduce the environmental impact of the biodegradable capsule life cycle.

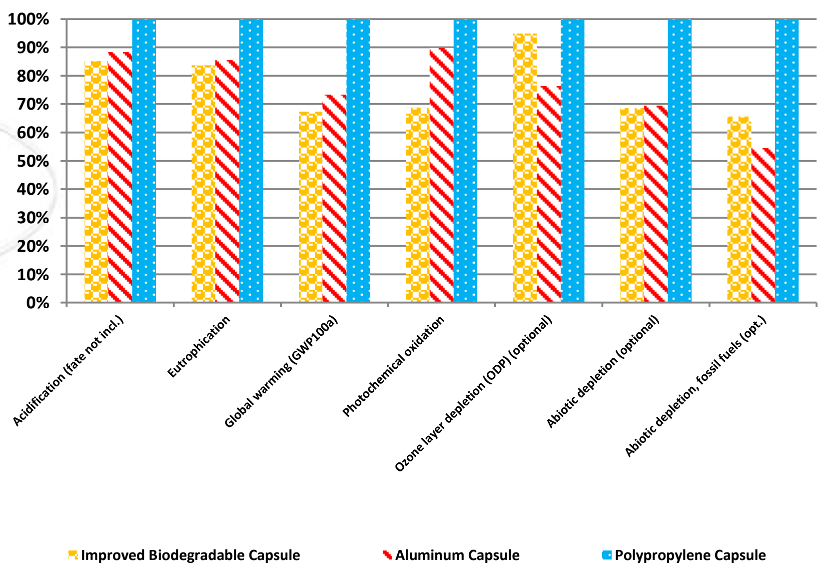
- A sensitivity assessment was performed to evaluate how to reduce the environmental impact of the biodegradable capsule life cycle. After some attempts, a less polluting bio-based polymer with which realize the capsule was found: a starch based polymer, suitable for injection moulding process
- A study about the environmental impact of organic waste disposal revealed that biogas production releases in the atmosphere a lower amount of Global Warming gases than compost production.

Sensitivity analysis

- ✓ Environmental impacts of the optimized biodegradable capsule vs the aluminum one and the polypropylene one
- ✓ Table and figure show the total impacts for all the considered categories and the relative impacts of each of the considered phases.

Impact Category	Unit	Improved Biodegradable Capsule	Aluminum Capsule	Polypropylene Capsule
Acidification (fate not incl.)	kg SO2 eq	6,04E-04	6,27E-04	7,09E-04
Eutrophication	kg PO4--- eq	4,13E-04	4,22E-04	4,93E-04
Global warming (GWP100a)	kg CO2 eq	4,13E-02	4,51E-02	6,14E-02
Photochemical oxidation	kg C2H4 eq	1,07E-05	1,40E-05	1,55E-05
Ozone layer depletion (ODP) (optional)	kg CFC-11 eq	3,85E-09	3,10E-09	4,06E-09
Abiotic depletion (optional)	kg Sb eq	2,11E-07	2,13E-07	3,07E-07
Abiotic depletion, fossil fuels (opt.)	MJ	4,30E-01	3,57E-01	6,55E-01

Environmental impacts of the optimized biodegradable capsule vs the aluminum one and the polypropylene one



Comparison of the relative environmental impacts produced by the optimised biodegradable capsule, aluminium capsule and polypropylene capsule.

Conclusions

- LCA analyses show that the polypropylene capsule in multi-layer non-recyclable bag is the most impactful one, because of the big amount of packaging material used with landfill end of life.
- The aluminum capsule is more polluting than the biodegradable one as regards acidification, photochemical oxidation and abiotic depletion, due to the aluminum production and manufacturing.
- For the other categories the biodegradable capsule results more damaging than the aluminum one because of PLA and PET granule production and manufacturing.

Conclusions

- The sensitivity analyses shows that it is possible to reduce the environmental impacts produced by the biodegradable capsule by substituting PLA with a starch bio-polymer and by producing biogas instead of compost from the organic waste collected.

- With these improvements, the biodegradable capsule results the less impactful one in all categories except than ozone layer depletion and fossil fuels depletion, where the PET tray is the main responsible of the impact produced.

Thank you for your attention

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