LCA case study
Comparison between pilot scale and semi-industrial scale of carrot soup production

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Challenge for process engineering: including environmental considerations in addition to classical productivity and economic criteria during process design, control and optimization stages in order to develop more sustainable processes (green processes).

"Life Cycle Thinking and New Business Models" Hauts-de-France research dynamic

ACV-ProPABio project (2015-2017)

- Development of eco-designed processes in agri-food industry and biotechnology
- Working on a simplified LCA methodology adapted to the stage of process development (laboratory scale) and on scaling up issue (estimating environmental impacts at higher scale)

2 case study

- Biotechnology field: Ultrasound-assisted extraction of antioxidant biomolecules from chicory industry by-product studying LCA as a tool for multicriteria optimization of an innovative process at laboratory scale
- Agri-food industry field: Carrot soup production at 2 scales studying the impact of process scaling up on LCA results; identifying key points for scaling up issue
Context and objectives

Carrot soup production at two scales

- Identifying hotspots in carrot soup production
- Identifying differences between 2 scales of production
- Identifying key points regarding scaling up issue, potential simplifications

Impact on LCA results?

Possibility of estimating LCA results at higher scale?

What are key points to consider?
Case study: carrot soup production

Pilot scale

Ingredients → Cooking mixing → Dosing bottling → Capping → Sterilization → Carrot soup bottles

18 bottles

Semi-industrial scale

Ingredients → Cooking mixing → Dosing bottling → Capping → Sterilization → Carrot soup bottles

95 bottles
LCA study

Aim and scope

Studying environmental impacts of a carrot soup production process at two different scales: pilot and semi-industrial scales
Studying environmental impacts of a carrot soup production process at two different scales: pilot and semi-industrial scales

**Aim and scope**

**Objectives**

- Identifying hotspots and most contributing phases
- Comparing results at two scales of production
- Identifying key points regarding scaling up issue
Studying environmental impacts of a carrot soup production process at two different scales: pilot and semi-industrial scales.

Aim and scope

Objectives

- Identifying hotspots and most contributing phases
- Comparing results at two scales of production
- Identifying key points regarding scaling up issue

Functional unit

Producing 1 kg of carrot soup, bottled and sterilized, at the production site gate.
Life Cycle Inventory (LCI)

- Experimental data collected during carrot soup productions (Adrianor)
  - mass of ingredients and their packaging, matter losses during processing, mass of equipments
  - energy (electricity, natural gas) and water consumptions for each processing step

- Data from suppliers (equipments, ingredients...)

- Generic data from databases (Ecoinvent, Agribalyse)
  - inputs (equipments, water, electricity, natural gas...)
  - processes (transport, waste water treatment, end of life treatment of equipments...)

- Secondary data from literature
  - Frozen vegetables, equipments
LCA study

Life Cycle Impact Assessment (LCIA)

- Simapro 8.3 software
- Environmental impacts expressed at midpoint level, ILCD method

16 impact categories:

- Climate change (CC)
- Ozone depletion (OD)
- Human toxicity, cancer effects (HTc)
- Human toxicity, non cancer effects (HTnc)
- Particulate matter (PM)
- Ionizing radiation, human health effects (IRhh)
- Ionizing radiation, ecosystems effects (IRre)
- Photochemical ozone formation (POC)
- Acidification (Ac)
- Terrestrial eutrophication (Teu)
- Freshwater eutrophication (Feu)
- Marine eutrophication (Meu)
- Freshwater ecotoxicity (Fec)
- Land use (LU)
- Water resource depletion (WD)
- Mineral, fossil & renewable resource depletion (RD)
Comparison of pilot and semi-industrial scales

LCA results

- All impacts decreased when scaling up

(water excluded)
**LCA results**

**Comparison of pilot and semi-industrial scales**

- All impacts decreased when scaling up
- Most impacting stages:
  - **Ingredients**
  - **Food processing**
  - **Packaging**
  - **Equipment** (at pilot scale)

- **Graphical representation** showing the comparison of pilot and semi-industrial scales with various impact categories and stages.
LCA results

Comparison of pilot and semi-industrial scales

➢ All impacts decreased when scaling up

➢ Most impacting stages:
  - **Ingredients**
  - **Food processing**
  - **Equipment** (at pilot scale)

→ Same impacts at both scales: glass bottle and cap

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- Packaging
- Ingredients
- Food processing
- Equipment
- Transport
- Water discharges
Comparison of pilot and semi-industrial scales

- All impacts decreased when scaling up
- Most impacting stages:
  - **Ingredients**
  - **Food processing**
  - **Packaging**
  - **Equipment** (at pilot scale)

→ little difference between the 2 scales due to higher matter losses at pilot scale
Focus on ingredients: contribution analysis

- **EoL of packagings**
- **Chicken broth**
- **Packaged olive oil**
- **Packaged cream**
- **Salt**
- **Starch**
- **Freezing**
- **Packaged onions**
- **Packaged potatoes**
- **Packaged carrots**

- **Vegetables**
  - Up to 85% contribution for RD
- **Olive oil**
  - High impacts, up to 50% for WD (only 1% of ingredients total mass)
- **Cream** is a hotspot
  - only 4% of ingredients total mass, more than 50% of impacts for 7 categories

**Study on carrot soup formulation to reduce cream quantity**
Comparison of pilot and semi-industrial scales

- All impacts decreased when scaling up
- Most impacting stages:
  - **Ingredients**
  - **Food processing**
  - **Packaging**
  - **Equipment** (at pilot scale)

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- Packaging
- Ingredients
- Food processing
- Equipment
- Transport
- Water discharges
**LCA results**

**Comparison of pilot and semi-industrial scales**

- All impacts decreased when scaling up.
- Most impacting stages:
  - **Ingredients**
  - **Food processing**
  - **Packaging**
  - **Equipment** (at pilot scale)

- Impacts reduced by factor 3-4 at semi-industrial scale due to lower energy and water consumptions.
- Most impacting steps: cooking-mixing and sterilization.

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- **Packaging**
- **Ingredients**
- **Food processing**
- **Transport**
- **Water discharges**
**LCA results**

**Comparison of pilot and semi-industrial scales**

- All impacts decreased when scaling up
- Most impacting stages:
  - **Ingredients**
  - **Food processing**
  - **Packaging**
  - **Equipment** (at pilot scale)

- Difference of impacts linked to allocated mass at each scale
- Exception for OD: higher impact at semi-industrial scale due to higher mass of PTFE
Focus on equipment

Equipments mainly composed of stainless steel:
- 88% at pilot scale
- 80% at semi-industrial scale

Environmental impacts of equipment:
variation between the base scenario and the simplified scenarios

- Scenario A: all stainless steel
- Scenario B: stainless steel + PTFE

Potential simplification of equipments modeling
# LCA results

## Focus on equipment

Equipments mainly composed of stainless steel:
- 88% at pilot scale
- 80% at semi-industrial scale

**Scenario A:** all stainless steel
**Scenario B:** stainless steel + PTFE

### Environmental impacts of equipment: variation between the base scenario and the simplified scenarios

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<td>Scenario A: all stainless steel</td>
<td>Scenario B: stainless steel and PTFE</td>
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Potential simplification of equipments modeling
Conclusions and perspectives

Scaling up issue:

- Production of 1 bottle of carrot soup was less impactant at semi-industrial scale than at pilot scale

- Key points regarding differences between the two scales:
  - energy and water consumptions (processing stage)
  - allocated mass of equipment (equipment stage)
  - matter losses (ingredient stage)

- Studying other scales of production, other case study, expanding system boundaries

Potential simplification of equipment modeling (agri-food sector)

More generally, this LCA study led to think about the eco-design of the process: energy and water consumptions of the equipment, use of cream in the formulation, impact of packaging...

- Expanding system boundaries (usage, end of life) in the view of a global eco-design approach
Thanks