Éco-conception des aliments, bio-produits et bio-procédés

Caroline Pénicaud

Éco-conception des aliments, bio-produits et bio-procédés

Séminaire EcoSD 24 janvier 2019

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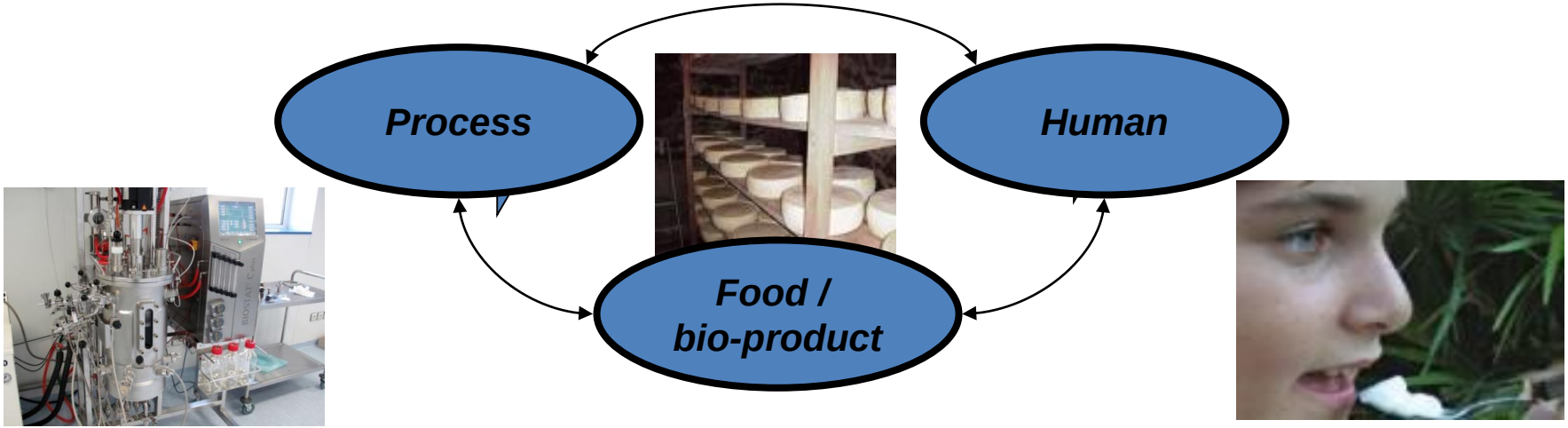
INRA SCIENCE & IMPACT

INTRODUCTION – GMPA UNIT

Control of physical and biological processes that govern transformations: from BIOPROCESSES … to humans



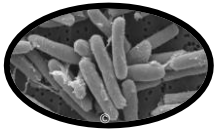
Improving knowledge and proposing useful tools for the development of products or bio-products with high sensory, nutritional, health and environmental qualities.

INTRODUCTION – BIOMIP TEAM

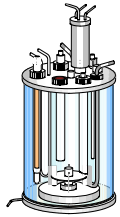
Functionalities of micro-organisms

Scales of study

- Molecular
- Cellular
- Population
- Medium - Matrix
- Process
- System



Bacteria



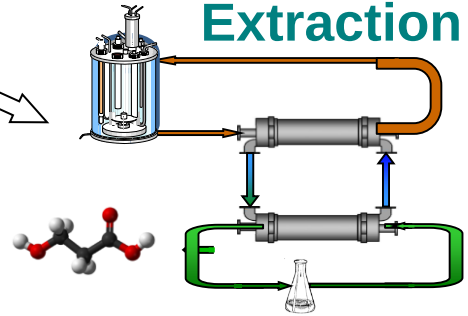
Growth

Stabilisation

Lyophilisation
Freezing
Drying
Storage

Starters
Probiotics

Bioconversion
Extraction



Extraction: membrane assisted liquid/liquid extraction, pervaporation, permeation

Aroma molecules
Synthons

Off-line studies

***In-situ*, in dynamic studies**

Mechanistic modelling

MALICES

INTRODUCTION – BIOMIP TEAM

Molecule

Cell

Population

Medium - Matrix

Process

Multi-scales

Product quality

Bio-functionality production and preservation

Process efficiency

Technological constraints

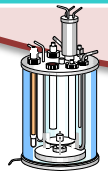
Products, Co-products

Energy

Effluents

System

Fermentation | Cooling | Concentration | Formulation | Freezing Drying | Storage (6-18 months) | Thawing Rehydration



Multi-stages

Raw materials

Energy

Water

Environment

Resources depletion

Climate change

STABILIZED LACTIC ACID BACTERIA

Fermentation
↓
Cooling
↓
Concentration
↓
Formulation
↓
Stabilization
Freeze-drying
Freezing
↓
Storage

***Lactobacillus delbrueckii ssp. bulgaricus* strain CFL1**

- Freeze-drying
  - Soft for the bacteria
  - Energy intensive: freezing + drying of the frozen product

Functionality: acidification activity (CinAc®)

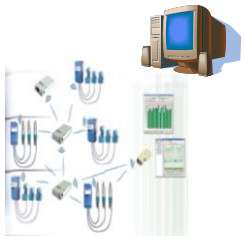
LCA OF FREEZE-DRIED BACTERIA

DATA ACQUISITION

	Growth medium preparation	Fermentation	Centrifu-gation	Protection	Freeze-drying	Storage (T = - 20°C)	Transport
Input	Water , Electricity, growth medium	Electricity, Steam, Water, chemicals products	Electricity	Composition of protective medium	Electricity	Electricity*, Packaging	Km traveled,
Output	-	Liquid wastes	Liquid wastes	-	Leakage of refrigerant gas	Leakage of refrigerant gas	Leakage of refrigerant gas

Sensors used for data collection

- Wi-LEM® energy sensors (DISTRAME, France) for electricity
- Receiver Coronis ® for water, steam and liquid wastes



Pénicaud et al. 2018

Other sources

- Data collected during handling (chemical products, water and liquid wastes)
- Database (Simapro, Ademe)
- Developed tool to estimate the electric consumption of cold storage supported by Intelligent Energy Europe. The electric consumption of storage is reported to the stored volume.

LCA OF FREEZE-DRIED BACTERIA

METHODOLOGY

➢ **Functional Unit**: stabilization of 3 kg of protected bacteria

Weighting with Physiologic state of the bacteria

SimaPro

ILCD 2011 method

• **Specific activity**

$$t_{spe} = \frac{\text{Acidifyingactivity}}{\log(\text{viability})}$$

• **Weighting**

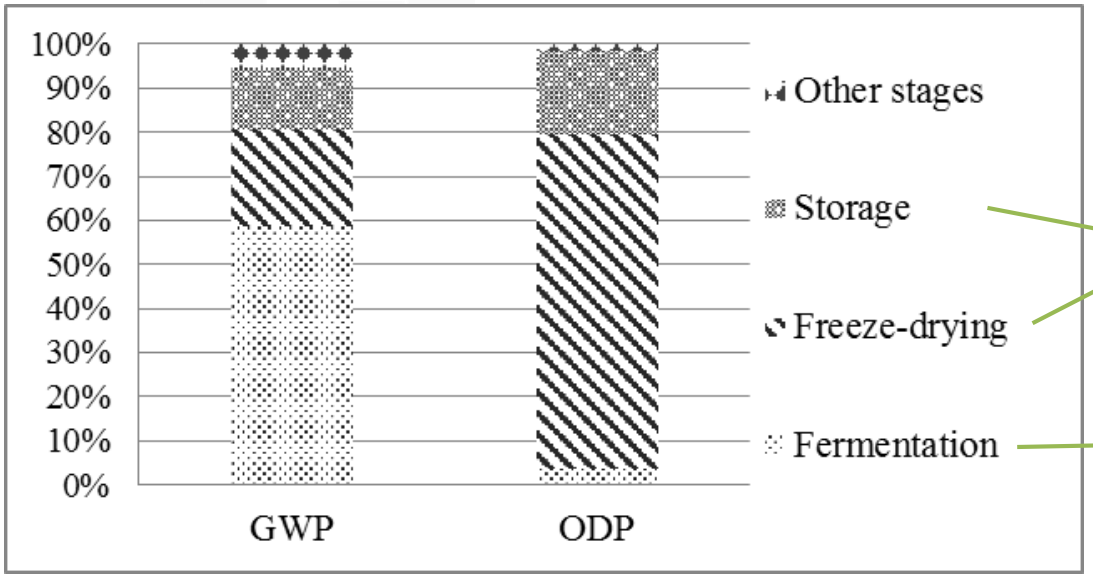
Weighted Impact = characterized impact value x Specific activity

Pénicaud et al. 2018

LCA OF FREEZE-DRIED BACTERIA

RESULTS

-20 °C storage during 1 year



electricity consumption, leakage of refrigerant gas

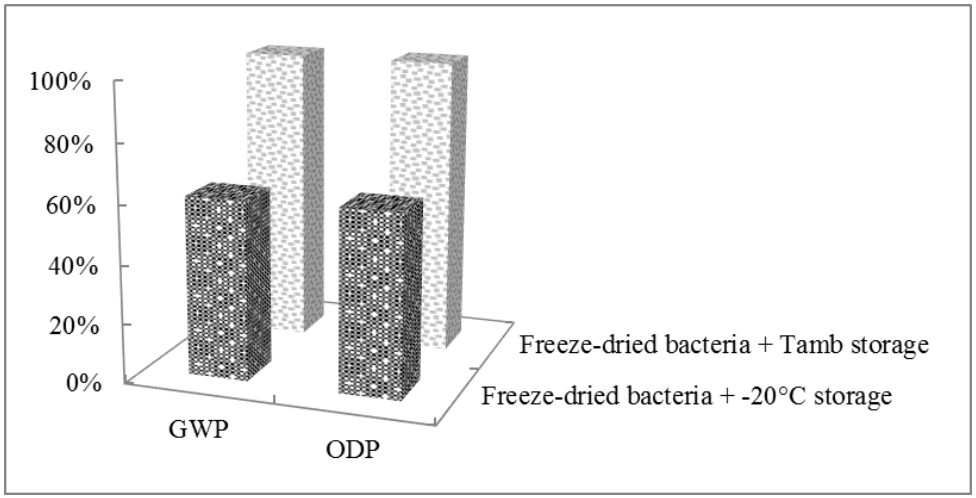
natural gas, tap water

Pénicaud et al. 2018

Reduce Energy Consumption: Increase of Storage Temperature

LCA Results

storage during 3 months



If bacteria quality remained constant, raising the storage temperature would reduce environmental impacts of about 10 %

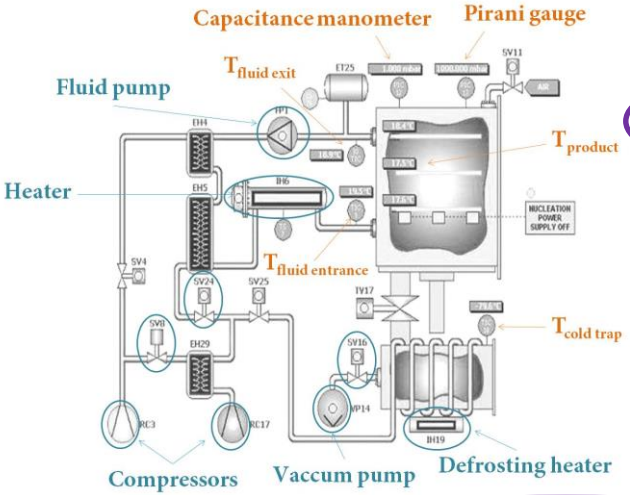
Effect of Product Quality

Weighted Impact = characterized impact value x Specific activity

Pénicaud et al. 2018

Reduce Energy Consumption: Optimization of Freeze-Drying

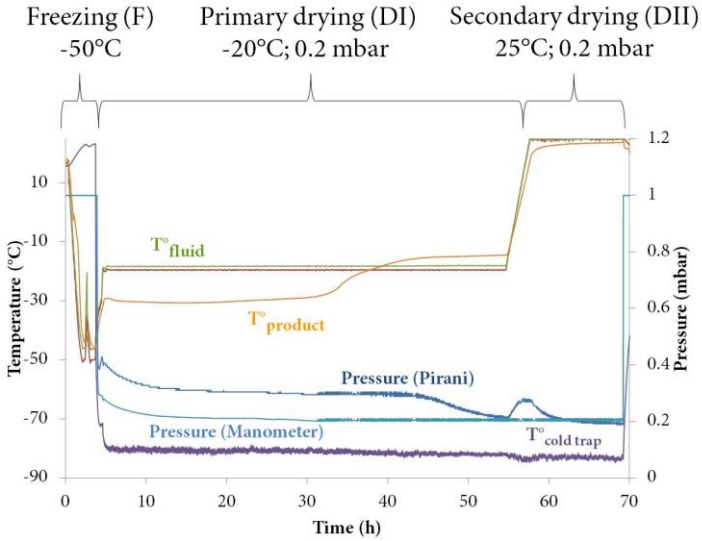
LyoBeta special
(Telstar, Terrassa, Spain)



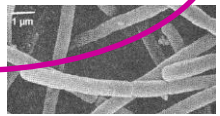
Process operating conditions

T_{fluid}, $T_{product}$ and $T_{cold\ trap}$
Pressure
Time

Mathematical model
Linear relationship



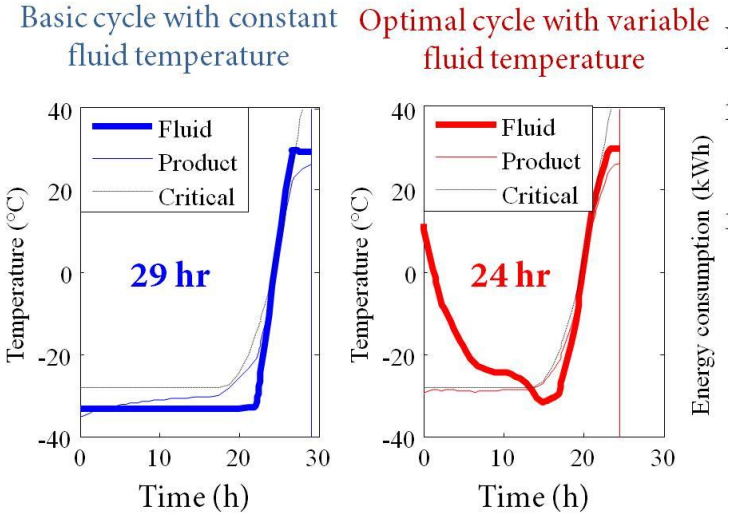
Product parameters
Viability
Acidifying activity
Structure

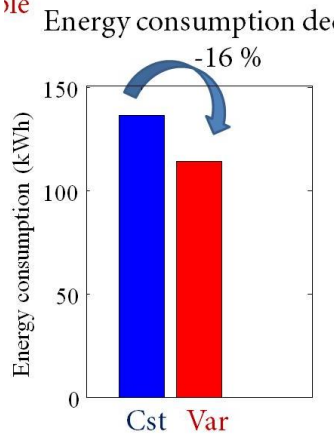


Process apparent energy consumptions

- Main components + Fans dedicated to compressors
- General supply

Reduce Energy Consumption: Optimization of Freeze-Drying





⇒ **Fluid temperature fluctuation in primary drying saves energy by shortening cycle duration, while maintaining the product quality**

Pénicaud et al. 2014, 2016

STABILIZATION ALTERNATIVE

Fermentation
↓
Cooling
↓
Concentration
↓
Formulation
↓
Stabilization
Freeze-drying
Freezing
↓
Storage

***Lactobacillus delbrueckii ssp. bulgaricus* strain CFL1**

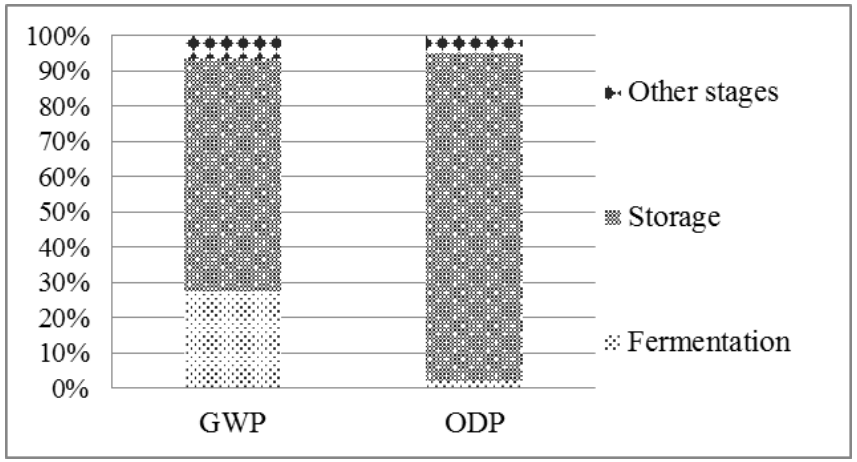
- Freeze-drying
  - Soft for the bacteria
  - Energy intensive: freezing + drying of the frozen product
- Alternative: Freezing
  - Need of frozen storage
  - **Is it really more eco-friendly than freeze-drying if we consider the whole life cycle?**

Functionality: acidification activity (CinAc®)

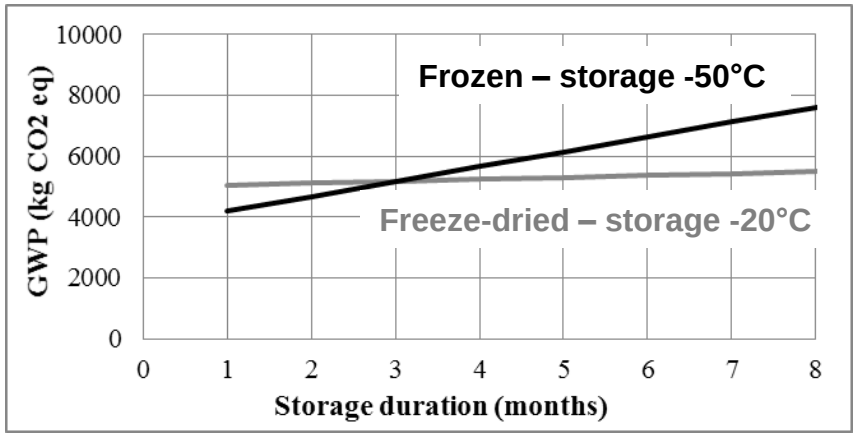
LCA OF FROZEN VS FREEZE-DRIED BACTERIA

RESULTS

Frozen, -50 °C storage during 1 year



Pénicaud et al. 2018



Trend remains the same for all indicators
BUT
Depending on the indicator, the duration for which $Impact_{frozen}$ = $Impact_{freeze\text{-}dried}$ is different (from 2 to 8 months).

CONCLUSION

Eco-design options

- Improve / re-design processes
  - Freeze-dryer
  - Fermentor
- Process alternative
  - Freezing instead of freeze-drying for short-term storage
- Preserve cell quality to allow new options
  - Increase $T_{storage}$

- **Necessary to take simultaneously into account product quality / process conditions / environmental impact**
  - Knowledge integration

KNOWLEDGE INTEGRATION – NUTRISENSAL (2016-2019)

Nutritional impact

UMR STLO

Lack of research

Lack of joint study

Sensorial impact

UMR CSGA
URTAL

DATABASE
BAGATEL

UMR MIA
Plateforme
PLASTIC

Environmental impact *UMR GMPA*

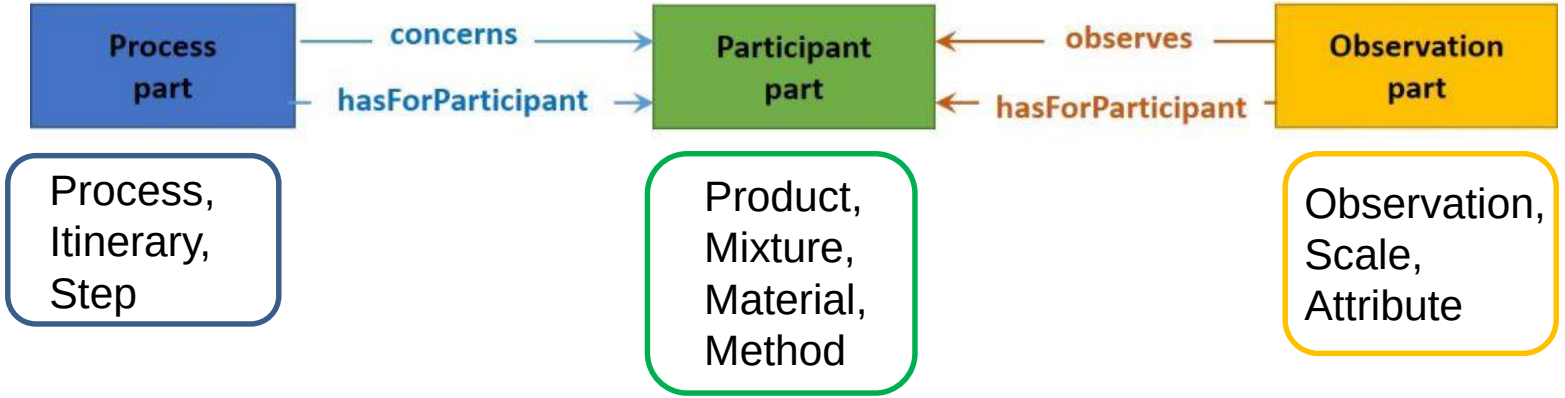
INSTITUT CARNOT QUALIMENT

Qualiment

KNOWLEDGE INTEGRATION – NUTRISENSAL

STRUCTURATION OF A DATABASE BAGATEL GUIDED BY AN ONTOLOGY

- PO^2 Ontology ⟹ Consensual model



Ibanescu et al. 2016

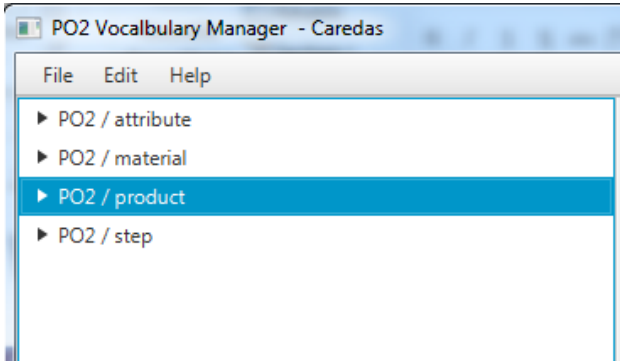
KNOWLEDGE INTEGRATION – NUTRISENSAL

STRUCTURATION OF A DATABASE BAGATEL GUIDED BY AN ONTOLOGY

- PO^2 Ontology ⟹ Shared structured vocabulary

Product

- Plant products
- Processed products
  - Dried products
  - Processed animal products
    - Milk products
      - Cheese
        - Hard cheese
        - Model cheese

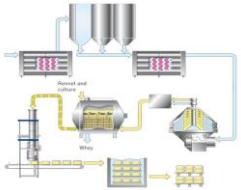


Sources:
Lexicon AgroVoc (aims.fao.org)
Lexicon Dbpedia (fr.dbpedia.org)
Lexicon Gacs (id.agrisemantics.org)

KNOWLEDGE INTEGRATION – NUTRISENSAL

CAPITALISATION OF DATA REGARDING RESEARCH ON CHEESE IN BAGATEL

Production process (different steps)



11 Projects

Cheese composition (at different steps, from milk to final product)

11 Projects

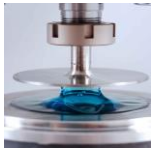
Sensory properties

8 Projects

Chewing activity

4 Projects

Rheological properties



9 Projects

Sodium release (in vivo and in vitro)

3 Projects

Aroma release (in vivo and in vitro)

4 Projects

KNOWLEDGE INTEGRATION – NUTRISENSAL

ESTIMATION OF ENVIRONMENTAL IMPACT – SYSTEM BOUNDARIES

- Which are the steps involved in the production process of hard cheese TF24 ?

Table | Raw Response | Pivot Table | Google Chart | Download as

Filter query results | Showing results from 1 to 9 of 9. Query took 0.3s, today at 17:46.

	stepType
1	Cheese ripening
2	Demoulding
3	Skimming
4	Moulding
5	Cooling
6	Milk reception
7	Brining
8	Milk standardization
9	Step in the vat

- 9 different steps were found for the production of TF24

Pénicaud et al. 2019

KNOWLEDGE INTEGRATION – NUTRISENSAL

ESTIMATION OF ENVIRONMENTAL IMPACT – DATA INVENTORY

- Available data to estimate environmental impact of TF24 production (electricity consumption)

Step	Characteristic	Object	Value	Unit
Skimming	Electricity consumption	Cream separator	0.065	kWh
Cooling	Electricity consumption	Refrigerated tank	29.04	kWh
Step in the vat	Electricity consumption	Heating unit for the vat (1st heating)	6.75	kWh
Step in the vat	Electricity consumption	Heating unit for the vat (2nd heating)	11.97	kWh
Cheese ripening	Electricity consumption	Maturing cellar 1	900	kWh
Cheese ripening	Electricity consumption	Maturing cellar 2	1350	kWh
Cheese ripening	Electricity consumption	Maturing cellar 3	2250	kWh

Pénicaud et al. 2019

KNOWLEDGE INTEGRATION – NUTRISENSAL

ESTIMATION OF ENVIRONMENTAL IMPACT – DATA INVENTORY

- Available data to estimate environmental impact of TF24 production (Ingredients used)

Step	Characteristic	Object	Value	Unit
Step in the vat	Quantity	Milk	100	L
Step in the vat	Quantity	Sodium metasilicate	200	g
Step in the vat	Quantity	Sodium carbonate	200	g
Step in the vat	Quantity	Phosphoric acid	250	g
Step in the vat	Quantity	Ethaneperoxoic acid	250	g
Step in the vat	Quantity	Hydrogen peroxide	250	g
Step in the vat	Quantity	Ethanoic acid	250	g
Brining	Quantity	Brine	200	L

Pénicaud et al. 2019

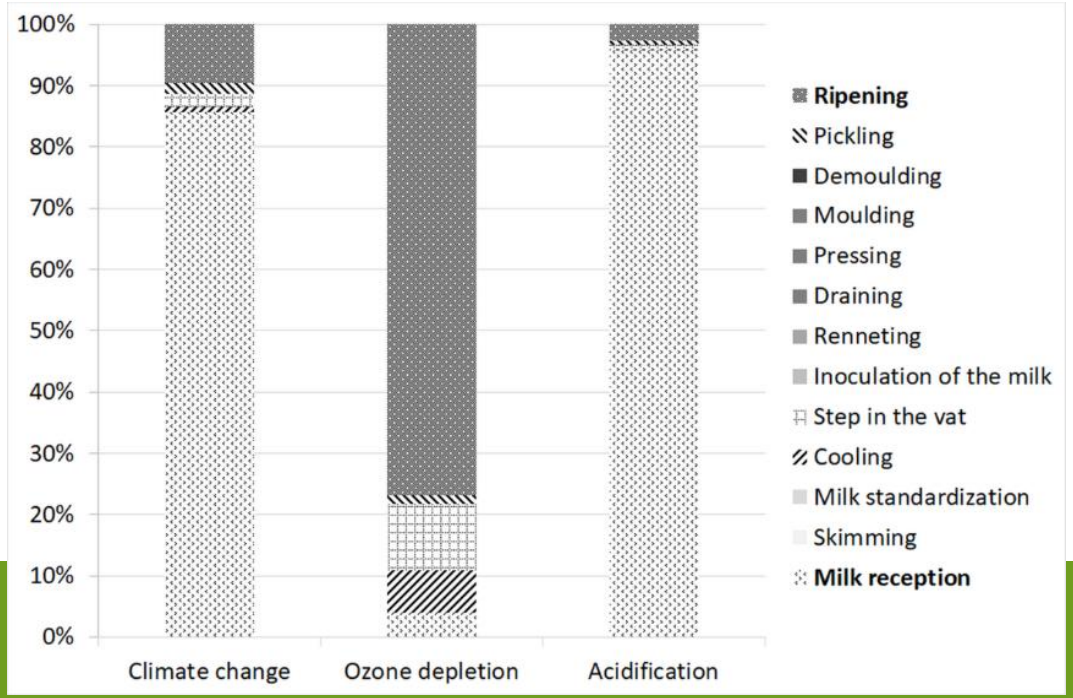
KNOWLEDGE INTEGRATION – NUTRISENSAL

ESTIMATION OF ENVIRONMENTAL IMPACT – RESULTS

100 Litres of milk  Weight of the sample: 10,5 kg

SimaPro

ILCD 2011 method



Pénicaud et al. 2019

KNOWLEDGE INTEGRATION – NUTRISENSAL

CONCLUSION AND FUTURE OUTLOOKS

BaGaTel database can be used to

- identify lack of data
- estimate missing data on a specific sample
- answer to scientific questions using data from different projects
- reformulate dairy products considering nutritional impact, sensory properties and environmental impact

More data from other projects and from the scientific litterature

Artificial intelligence tool to discover new knowledge from data

Multi-criteria analysis tool(s) → Decision support tool

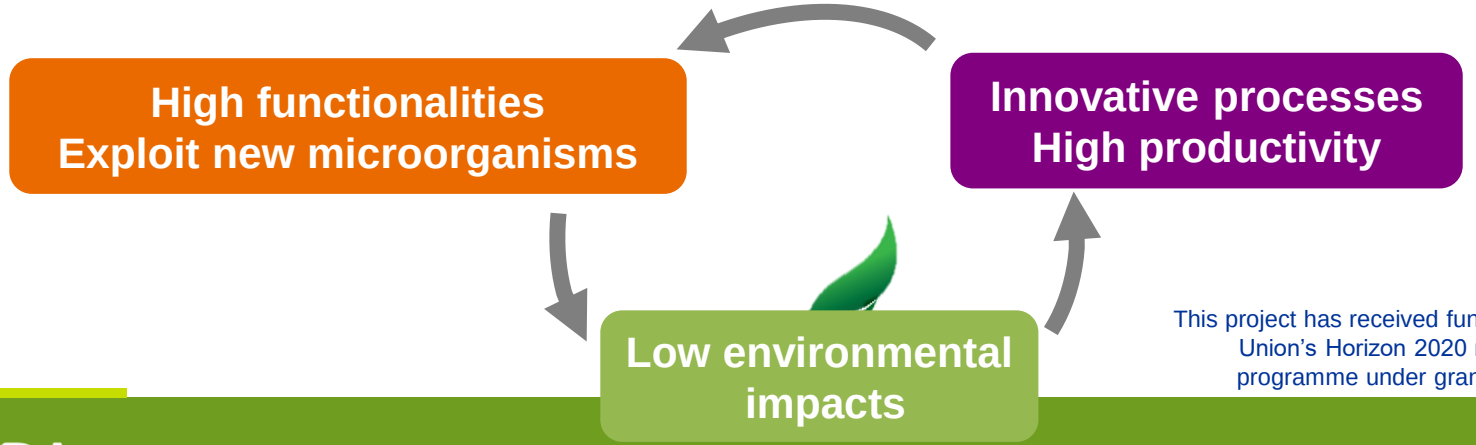
STABILIZED LACTIC ACID BACTERIA –

PREMIUM
Preserving bacteria with oligosaccharides and eco-friendly processes

(2018-2021)

A large variety of functionalities offered by microorganisms remains under-exploited due to their sensitivity to the manufacturing processes

The **objective of PREMIUM project is to develop new strategies to preserve lactic acid bacteria from laboratory to industrial scale**



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 777657

STABILIZED LACTIC ACID BACTERIA –

PREMIUM
Preserving bacteria with oligosaccharides and eco-friendly processes

Bacteria

Fermentation

Cooling

Concentration

Protection

Freezing

Freeze-Drying

Spray-Drying

Storage

Thawing / Rehydration

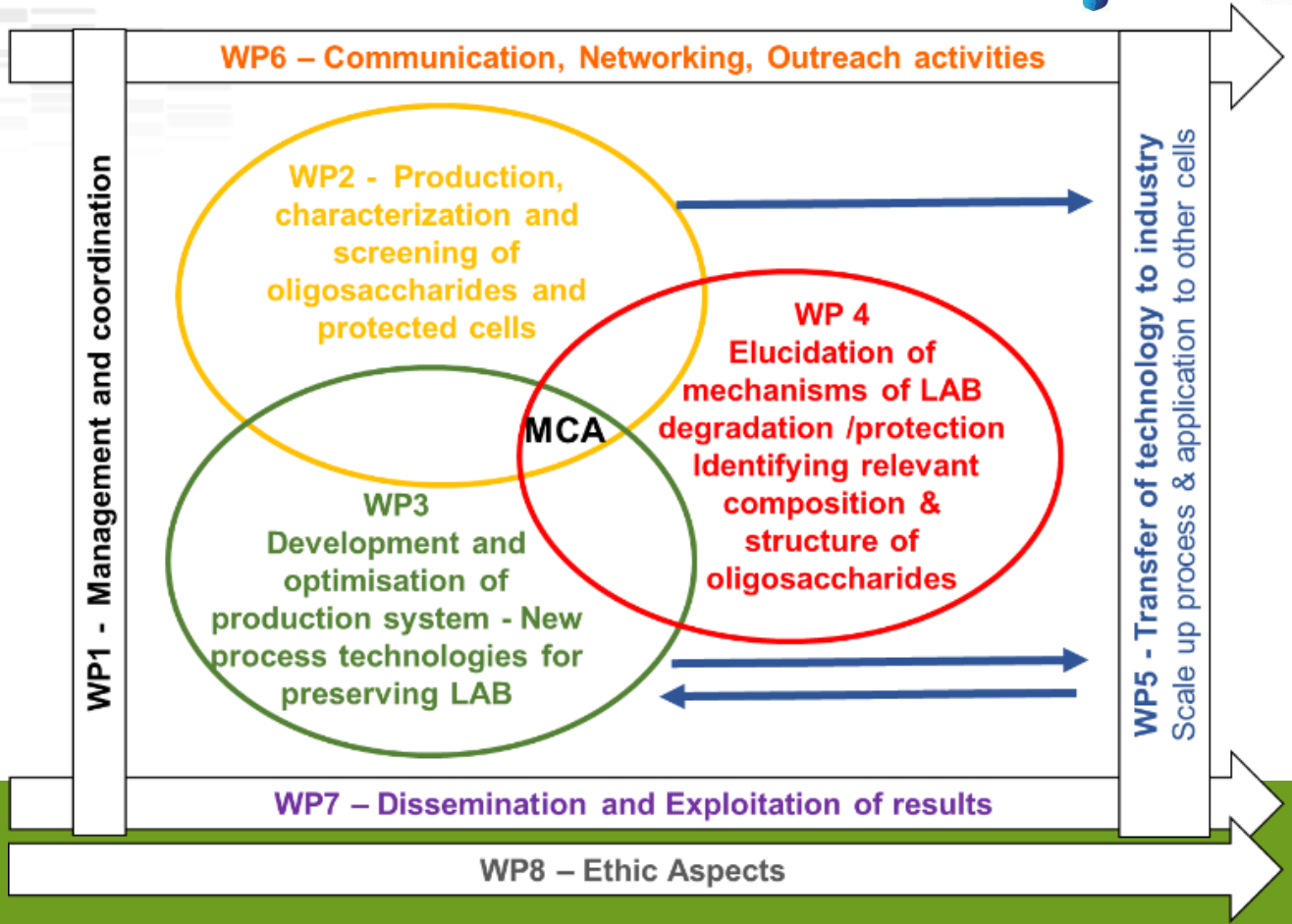
Lb bulgaricus
Lb plantarum
Carnobacterium maltaromaticum

Encapsulation

Oligosaccharides
FOS / GOS

STABILIZED LACTIC ACID BACTERIA –

PREMIUM
Preserving bacteria with oligosaccharides and eco-friendly processes



STABILIZED LACTIC ACID BACTERIA –

PREMIUM
Preserving bacteria with oligosaccharides and eco-friendly processes

- Different strains
- Encapsulated or not with FOS/GOS
- Different stabilisation processes

Environmental impact

Bacteria functionalities

Many case studies

Generalization of some results

BAGATEL DATABASE

Industrial and Pilot data

Answers to scaling issues

BIOSEARCH LIFE

Éco-conception des aliments, bio-produits et bio-procédés

Séminaire EcoSD 24 janvier 2019

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INRA SCIENCE & IMPACT