Valorization of byproducts of the food industry in a biorefinery concept using High Pressure Fluid Technologies

Case study: rice bran & onion

Ciudad Real (Spain), 9 April 2019

17th European Meeting on SUPERCRITICAL FLUIDS

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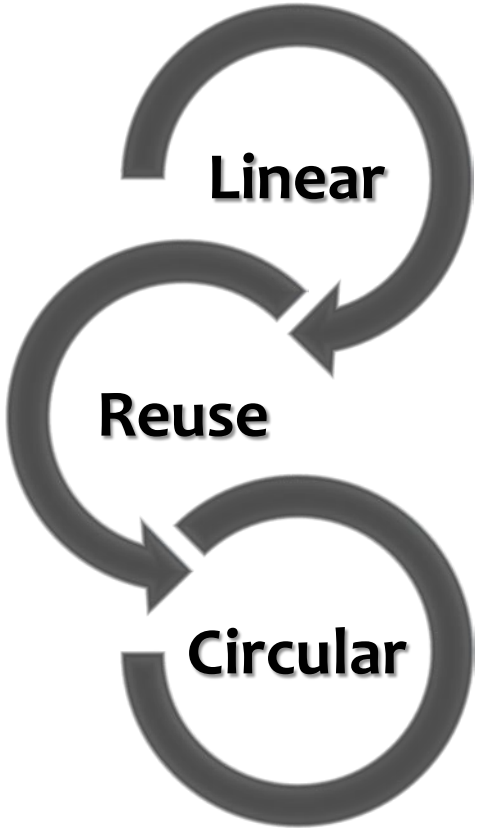
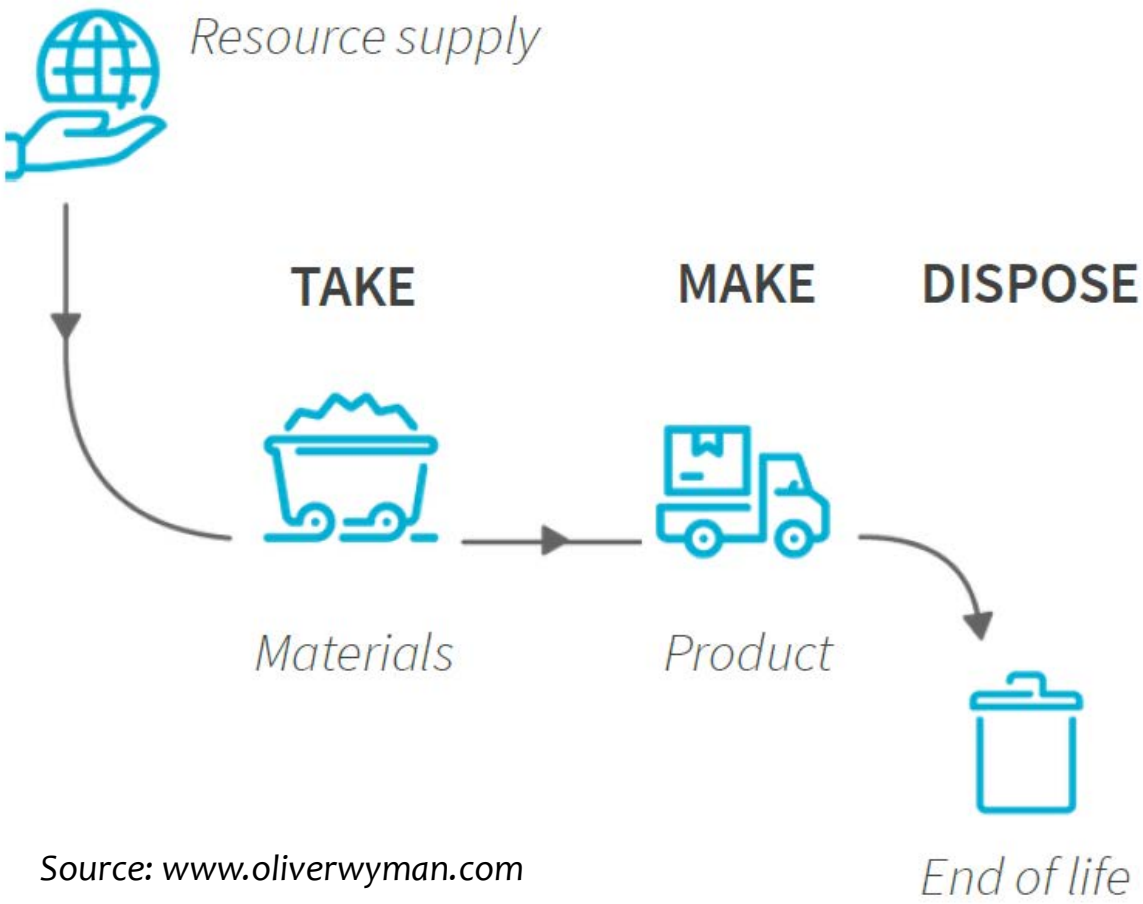
Our journey: economy is changing



From Linear to Circular Economy

What is the Linear Economy?



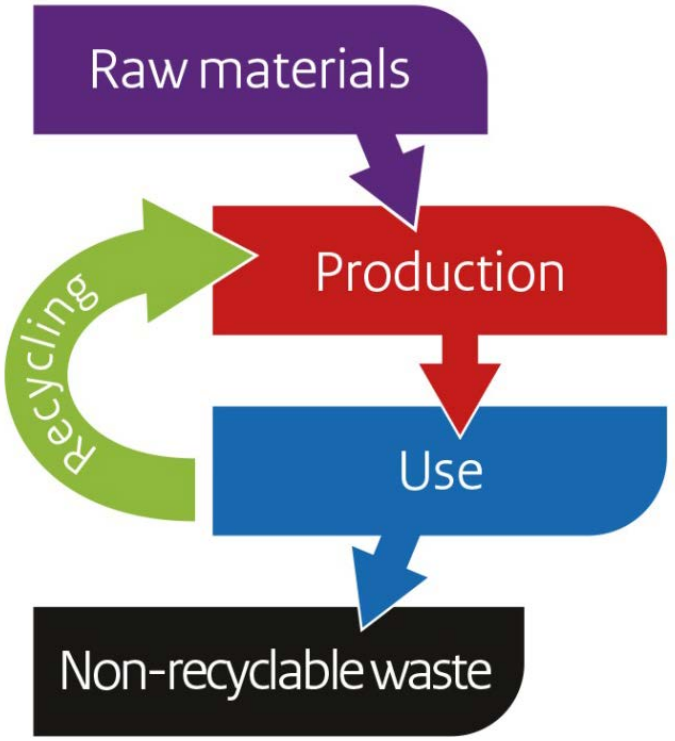
Source: www.oliverwyman.com

From Linear to Circular Economy

What is the Reuse Economy?

Intermediate step

- Some materials are reused
- Paper or glass



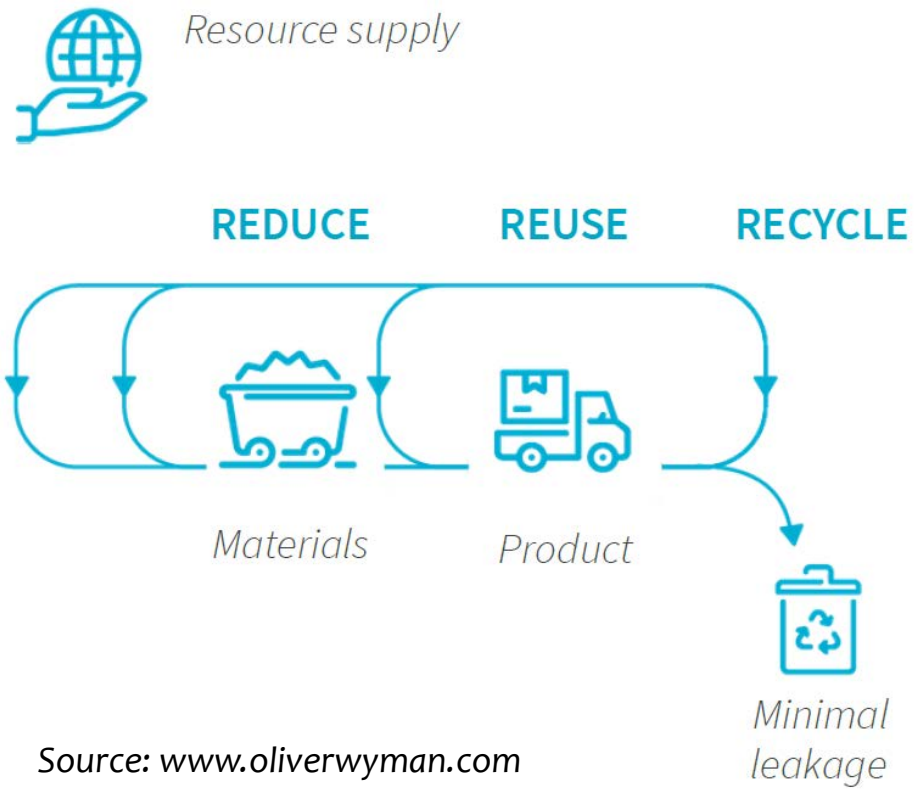
Source: www.government.nl

From Linear to Circular Economy

What is the Circular Economy?

A new paradigm

- "closing the loop"



Source: www.oliverwyman.com

Circular Economy: Background

December 2015

✓**Circular Economy Action Plan COM(2015) 614 final**

➢ **Purposes**

- new boost to jobs, growth and investment
- to develop a carbon neutral, resource-efficient and competitive economy

➢ **54 actions**

Circular Economy: Background

December 2015

✓**Circular Economy Action Plan COM(2015) 614 final**

➢ **Long term plan**

- Involves States, Regions and Cities
- Companies
- Citizens

Circular Economy: Background

✓**Stakeholders involved**

SOCIETY

Consumers
Organizations
Media
Governments

Scientists
Researchers

SCIENCE

Companies
Investors

ECONOMY

Circular Economy: Background

✓**Circular Economy Action Plan COM(2015) 614 final**

➢ **Bases**

1. Circular design and production processes **(Eco-design)**
2. Empowering consumers **(Change consume patterns)**
3. Turning waste into resources **(Recycling)**
4. Closing loops of recovered materials **(Secondary raw material)**
5. EU strategy for plastics

Circular Economy: Background

✓ **Circular Economy Action Plan COM(2015) 614 final**

➢ **Two key aspects:**

3. Turning waste into resources **(Recycling)**
4. Closing loops of recovered materials **(Secondary raw material)**

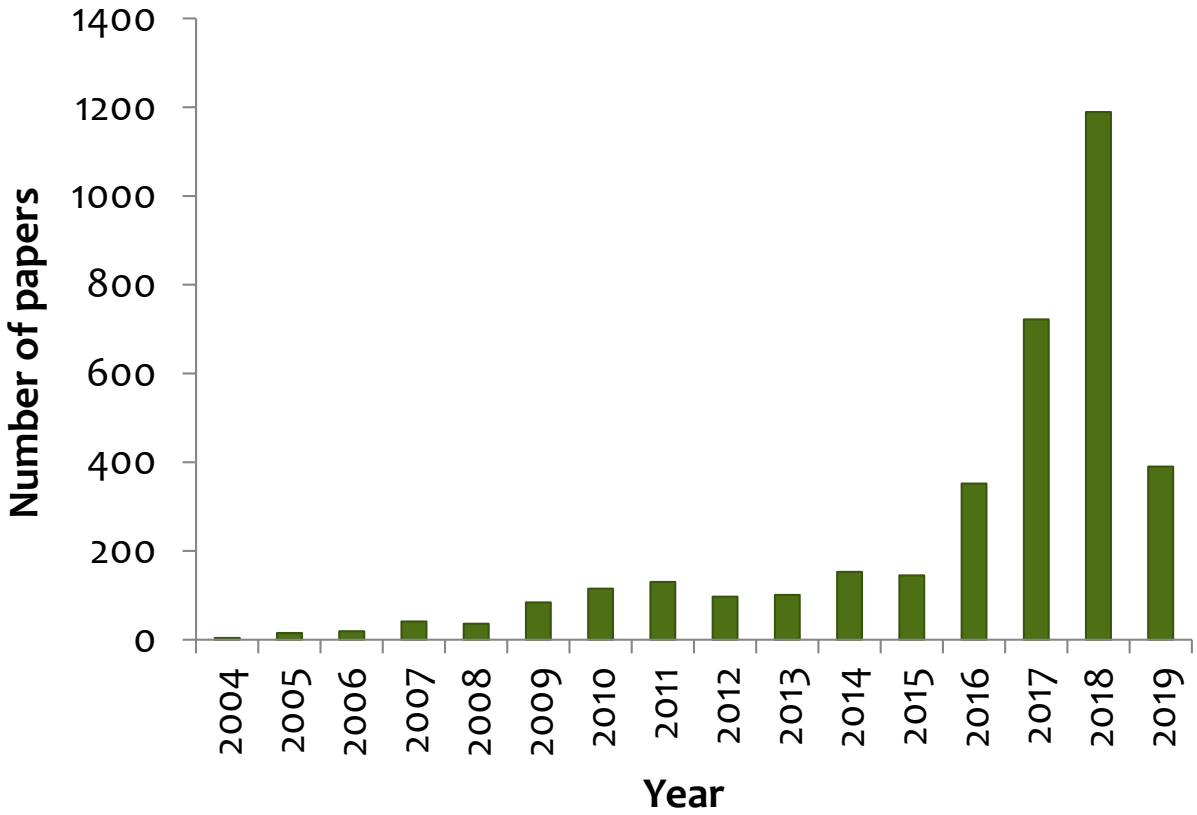
➢ **Growing concern in the EU**

- Food industry: huge amount of food wastes
- Change of paradigm:
  - ✓ Not residues anymore
  - ✓ By-products

New opportunities

Circular Economy: Background

✓Circular Economy: Growing Interest



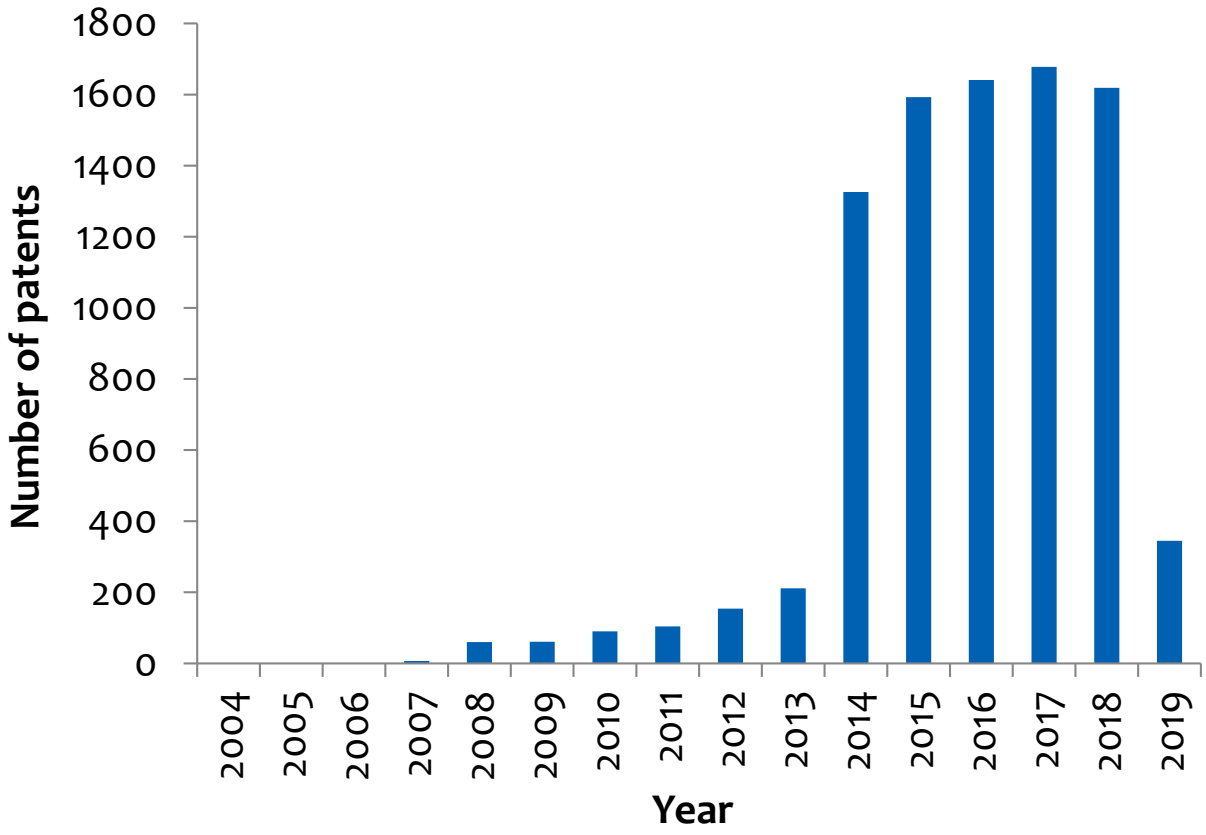
Source
Scopus

Search criteria
"circular economy"

Date
29/March/2019

Circular Economy: Background

✓Circular Economy: Growing Interest



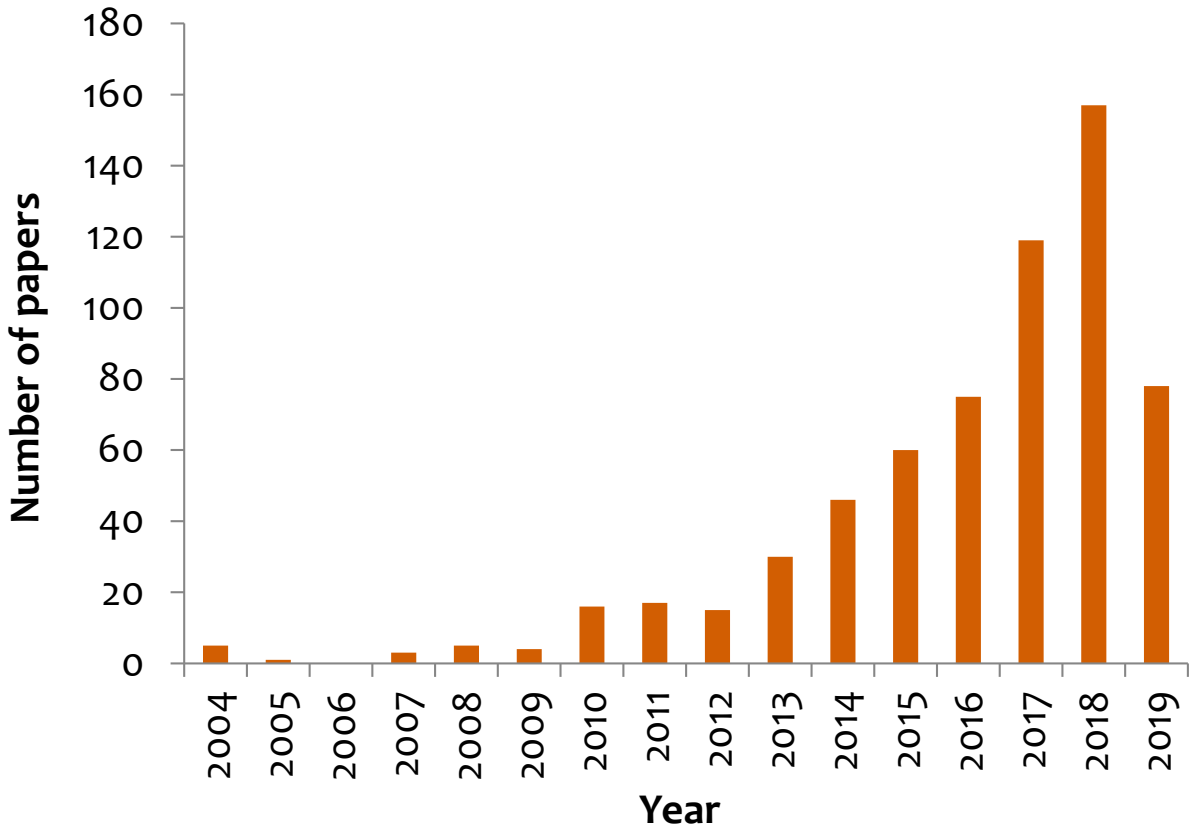
Source
European Patent Office

Search criteria
"circular economy"

Date
29/March/2019

Circular Economy: Background

✓Circular Economy: Growing Interest. "Waste Valorization"



Source
Scopus

Search criteria
"waste valorization"

Date
29/March/2019

Circular Economy: Examples

✓ **A new ecosystem is thriving all around Europe**

✓ **EIT Food** *(European Institute of Innovation & Technology)*

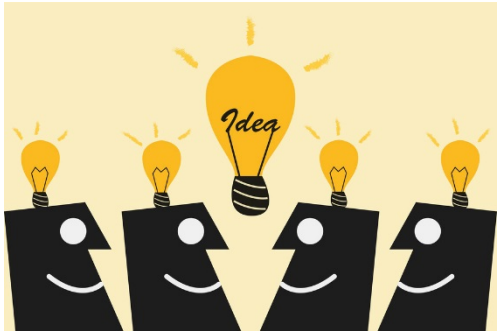
- Pan-European **partnership** empower innovators, entrepreneurs and students
- **Aim**: to develop a highly skilled food sector
- **Ambitions**: to redesign the way we produce, deliver, consume and recycle our food (circular bio-economy)

Circular Economy: Examples

✓ **EIT Food**

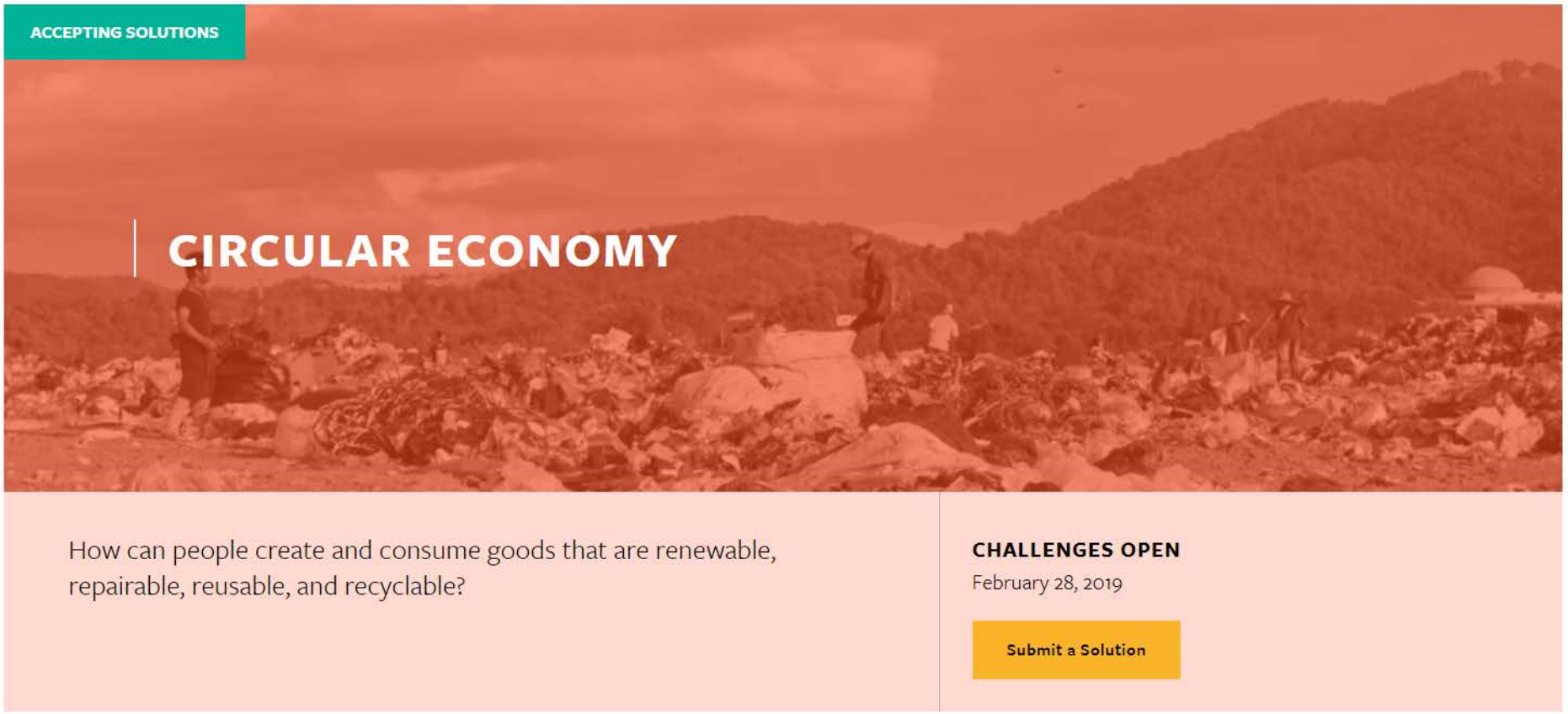
- 6 strategic objectives. The 4th:
  - Develop solutions to transform the traditional **'produce-use-dispose'** model into a circular bio-economy

- Competition: *"From food waste to food gain"*
  - EIT with one partner (*Colruyt Group*) launched this competition
  - Three largest waste streams: bananas, bread and potatoes



Circular Economy: Examples

✓ **MIT**



Spanish Strategy H2030

✓**Develop a bioeconomy based on two strategic sectors:**

Food and Agriculture

Forest and marine

BIOMASS PRODUCED

159 Mt/yr

Spanish Strategy H2030

✓Aims H2030

- **Create** scientific know-how and **apply** it to the market and to innovation
  - Development of **new technologies**
  - Creating and consolidating **technology-based companies**: *from the lab to the market*
  - Creation of **new markets:**
    - new products and services that meet people's needs,
    - development of rural areas
    - processes that are respectful with the environment

Circular Economy: Example - 2

✓ **Compañía Cervecera de Canarias**

(Brewery Industry)

- Launched a challenge:
  - New uses for the brewer's spent grain (Program DEMOLA Canarias)
  - BSG: 8000 t/yr
  - Current use: Cattle feeding (30 farmers in Tenerife)
  - https://bit.ly/2uyxAmk

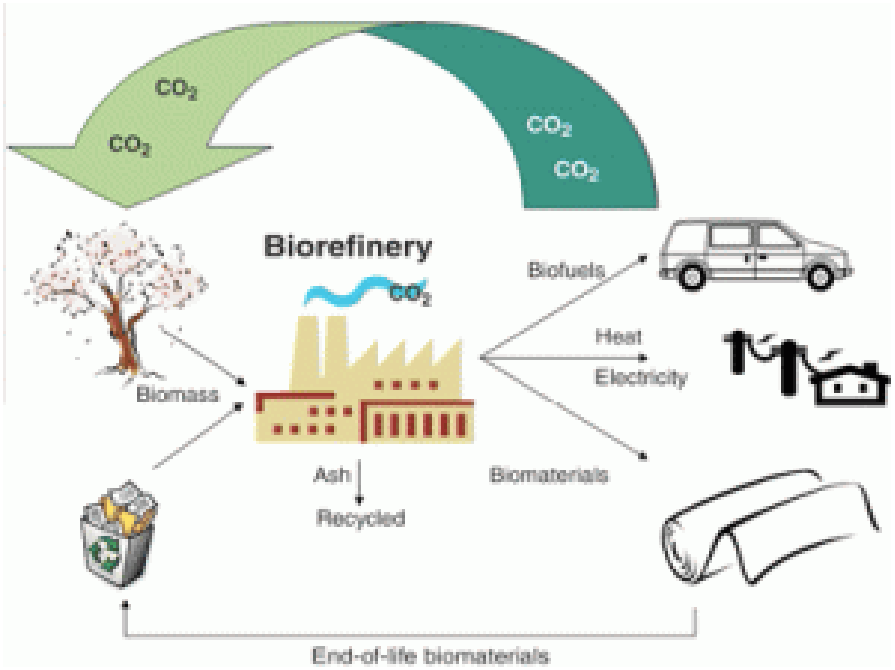
Spanish Strategy H2030

✓**What can we offer, as researchers, to the circular economy and valorization of biomass *(i.e. byproducts of food industry)*?**

- Knowledge on pressurized fluid technology to process biomass and generate scientific know-how:
  - SC-CO_2
  - Water (sub/supercritical)

Biorefinery. Concept

Facility where, using diverse and complementary technologies, biomass is processed obtain one or more of the bioproducts in the most sustainable way



https://www.ecomena.org/biorefinery/

Biorefinery. Types

TECHNOLOGY

- Liquefaction
- Solvent Extraction
- Enzyme
- Supercritical Conversion of Biomass
- Pyrolysis
- Gasification
- Incineration
- Fermentation
- Hydrolysis
- Refuse Derived Fuel

WASTE

- Municipal
- Agricultural
- Industrial
- Forestry
- Animal

Waste Biorefineries: Enabling Circular Economies in Developing Countries. Bioresource Technology 241 (2017). 1101-1117.

Biorefinery. Types

TECHNOLOGY

Liquefaction

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Municipal

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Forestry

Animal

WASTE

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Biorefinery. Types

TECHNOLOGY

Pressurized fluids

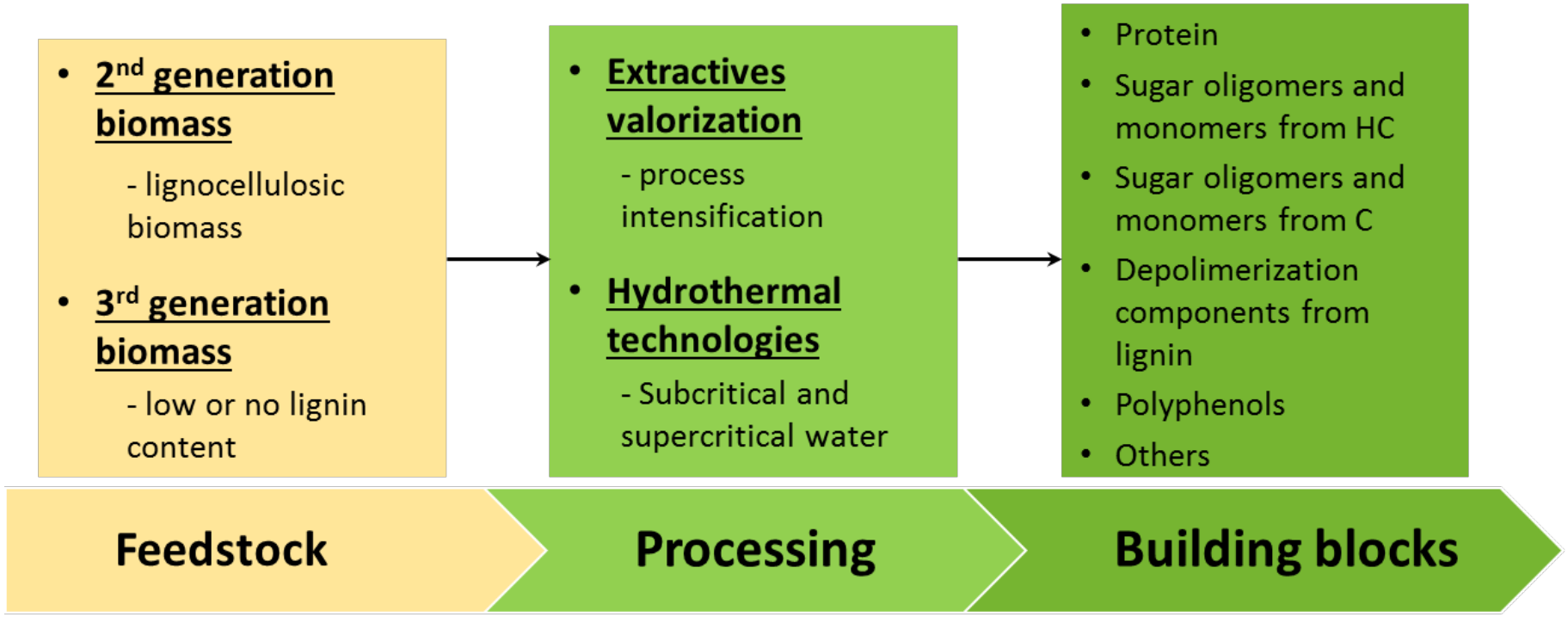
- SC-CO_2
- PHW
- SC-Water

Agricultural Industrial

- 2nd & 3rd generation

WASTE

The Biorefinery Approach



The Biorefinery Approach

- **2nd generation biomass**
  - lignocellulosic biomass
- **3rd generation biomass**
  - low or no lignin content

Feedstock

- ✓ **Analysis of the structural components**
  - Cellulose
  - Hemicellulose
  - Lignin
- ✓ **Analysis of the extractives**
  - Oils
  - Bioactive molecules
  - Antioxidants

The Biorefinery Approach

- **Extractives valorization**
  - process intensification
- **Hydrothermal technologies**
  - Subcritical and supercritical water

Processing

- ✓ **Sustainable green extraction**
  - Low energy
  - Low time
  - Process Intensification
- ✓ **Pressurized solvents**
  - SC-CO_2
  - PHW
  - SC-H_2O

The Biorefinery Approach

- Protein
- Sugar oligomers and monomers from HC
- Sugar oligomers and monomers from C
- Depolimerization components from lignin
- Polyphenols
- Others

Building blocks

✓ **Building blocks**

- raw material for new processes

BIOMASS VALORIZATION

2nd Generation Biorefinery: BIOLIGNO

High Pressure Processes Group

Hiperbaric
HIGH PRESSURE PROCESSING

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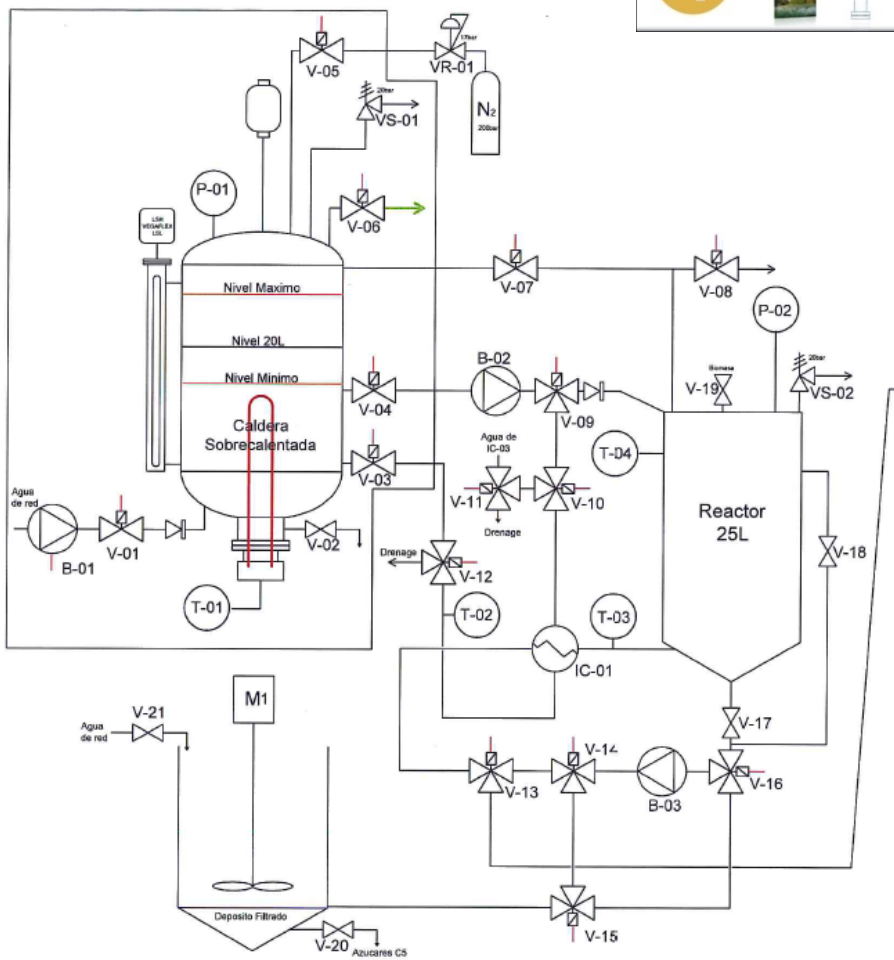
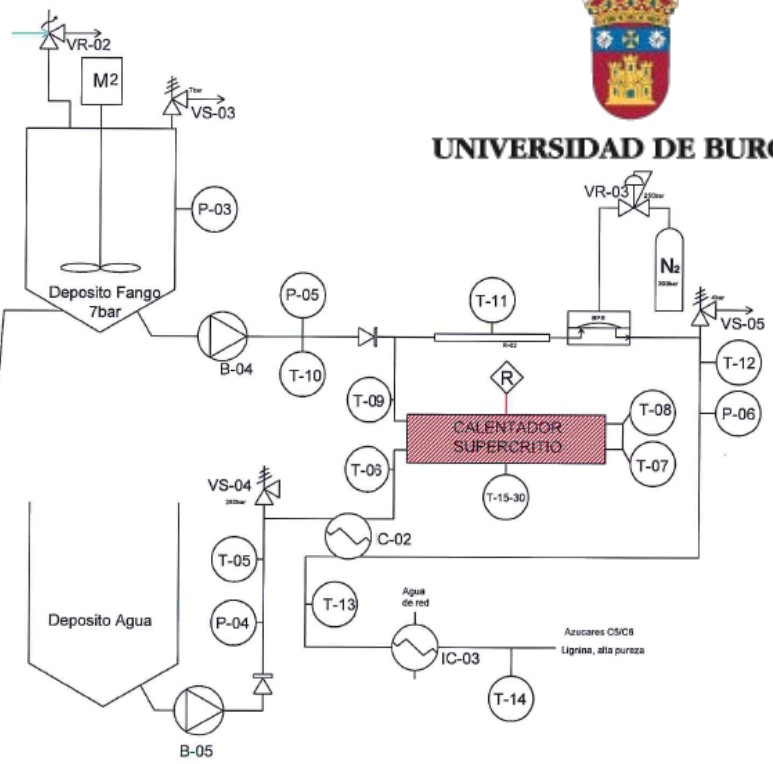




Etapa Sub-Critica

Etapa Supercritica

Case Study: Rice Bran (*Oryza sativa*)

Excellent candidate to be valorized

Industry byproduct

740 Mt rice worldwide

8% rice bran (60 Mt)

90% animal feeding

10% oil recovery

Bioactive Molecules

Phenolics

Flavonoids

Tocopherols

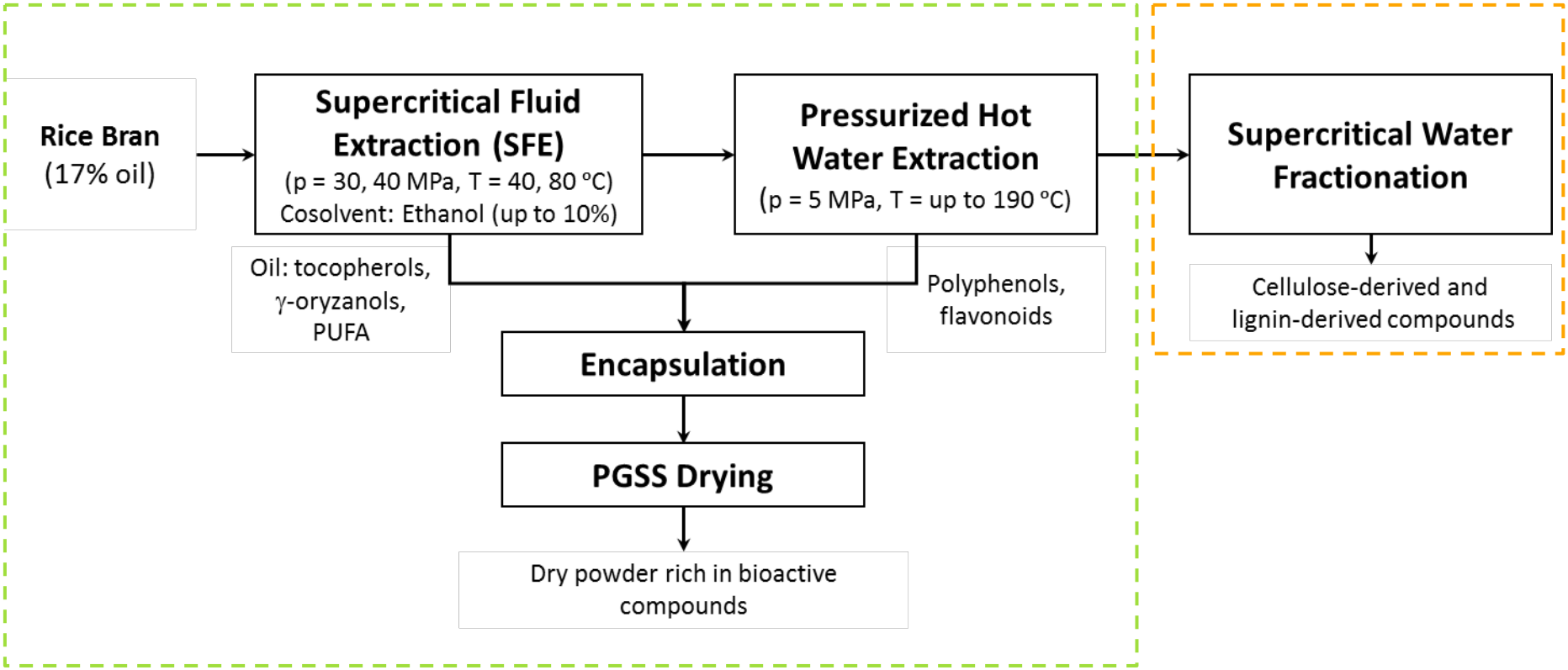
γ-oryzanol

Unsaturated FA

22% oil content

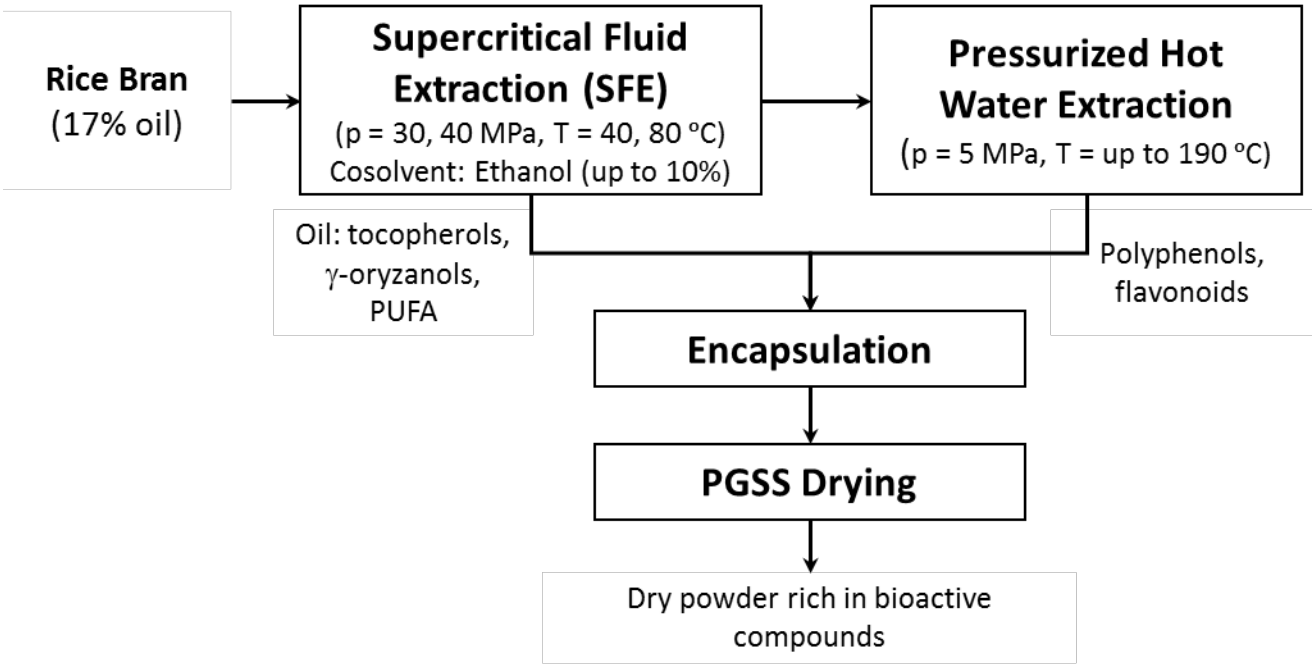
Case Study: Rice Bran (*Oryza sativa*)

✓Biorefinery approach proposed



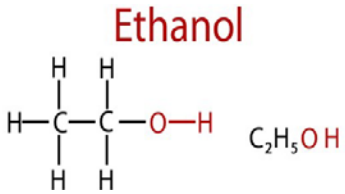
Case Study: Rice Bran (*Oryza sativa*)

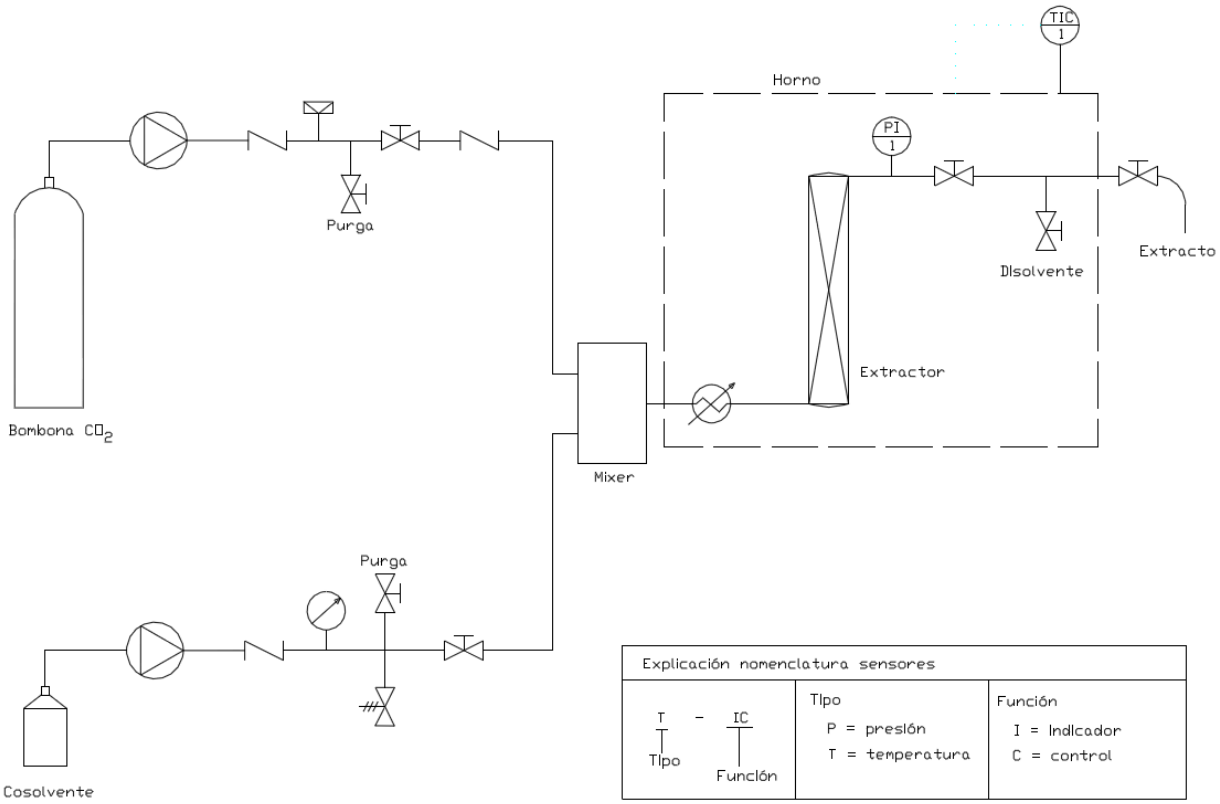
✓**Biorefinery approach proposed**



Case Study: Rice Bran (*Oryza sativa*)

STEP 1. Oil recovery





Case Study: Rice Bran (*Oryza sativa*)

STEP 1. Oil recovery

Supercritical
7 MPa
31 °C

Excellent solvent for oil extraction

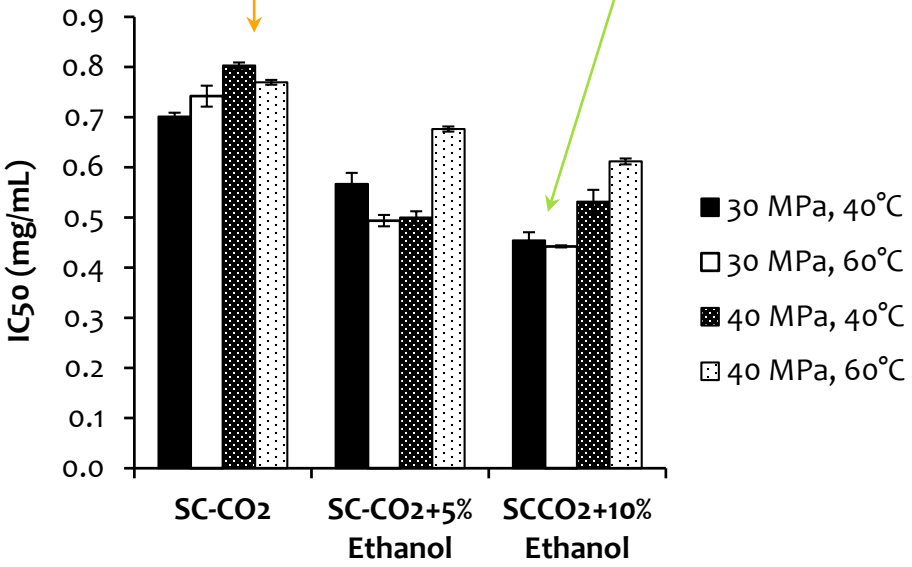
Polar molecules not extracted

Addition of co-solvent

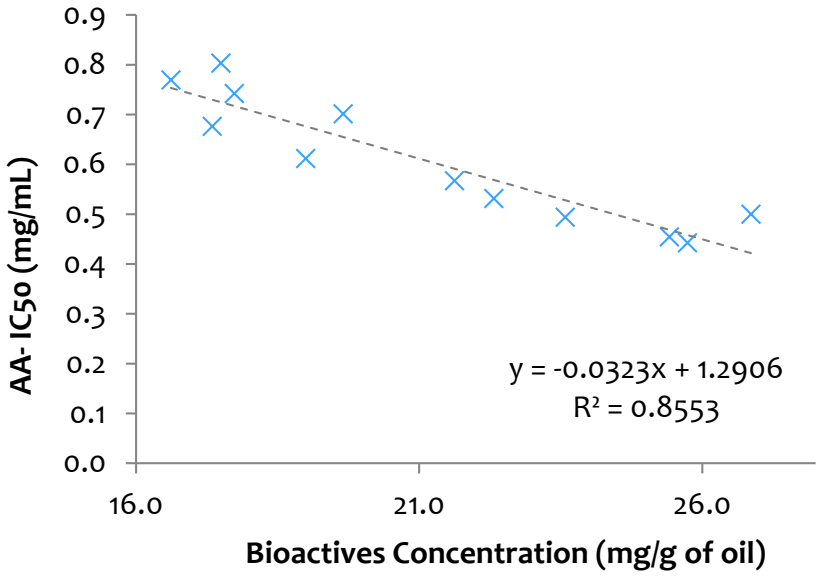
Pressure (MPa)	30-40
Temperature (°C)	40-60
Ethanol (%)	0-10

Case Study: Rice Bran (*Oryza sativa*)

STEP 1. Oil recovery (SC-CO_2)



- Increased amount of bioactive molecules
- High antioxidant activity (AA)
- Correlation bioactive molecules and AA



Case Study: Rice Bran (*Oryza sativa*)

STEP 1. Oil recovery (SC-CO_2)

Best conditions

40MPa, 40°C, 5% EtOH

TPC *(mg GAE/g oil)*	3.0±0.2
TFC *(mg QE/g oil)*	3.7±0.1
γ-oryzanol *(mg/g oil)* 24-Methylene cycloartanyl ferulate	20.6±0.6
Fatty acids *(mg/g oil)* 43% MUFA 40% PUFA	759±25

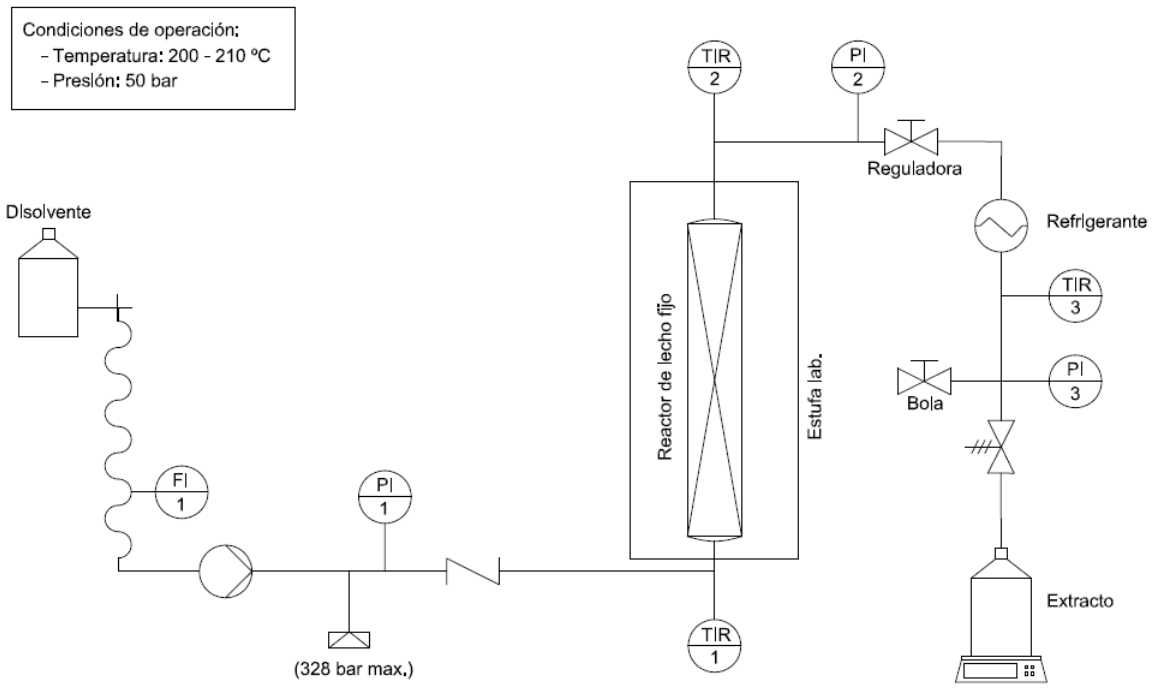
Case Study: Rice Bran (*Oryza sativa*)

STEP 2. Pressurized Hot Water Extraction

Raffinate from SC-CO_2 extraction

FIXED BED EXTRACTION

Temperature: 130-190°C
Flow rate: 2-4 mL/min
Pressure: 5 MPa



Case Study: Rice Bran (*Oryza sativa*)

STEP 2. Pressurized Hot Water Extraction

Raffinate from SC-CO_2 extraction → **FIXED BED EXTRACTION** → Aqueous extract

TPC *(mg GAE/g dry extract)*	34.1±0.1
TFC *(mg QE/g dry extract)*	8.6±0.4
Proteins *(mg/g dry extract)*	228±3
FRAP *(mg FeSO4/g dry extract)*	123±4

Case Study: Rice Bran (*Oryza sativa*)

STEP 3. Oil encapsulation

Microfluidization

reproducibility/scalability

Oil Phase

SC-CO_2 extracted

Carrier

vegetable protein and MD

Aqueous Phase

PHW extraction liquor

Case Study: Rice Bran (*Oryza sativa*)

STEP 3. Oil encapsulation

Microfluidization

Process parameters

Y SHAPE

- **PRESSURE**: 60-150 MPa
- **CARRIER**: protein/MD 50/50-90/10
- **RATIO CARRIER/OIL**: 2-4
- Up to 8 cycles
- 15% solids

Droplet diameter ($D_{4,3}$)

Stability with time

Case Study: Rice Bran (*Oryza sativa*)

STEP 3. Oil encapsulation

Microfluidization

Optimal Conditions

Pressure (MPa)	Carrier (Pea/MD)	Ratio carrier:oil (-)
118	60/40	3.8

7 cycles

$D_{4,3}$=180±5 nm

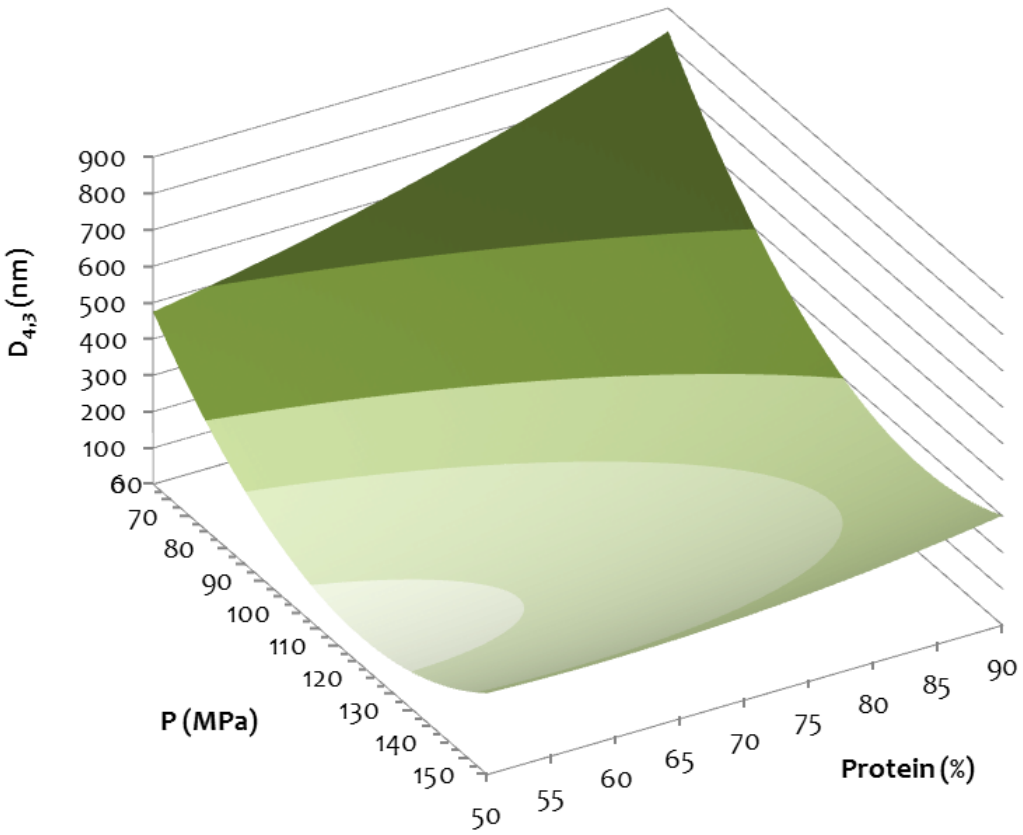
Case Study: Rice Bran (*Oryza sativa*)

STEP 3. Oil encapsulation

SURFACE PLOT

Effect of pressure and protein content of the carrier on the emulsion droplet diameter

RSM – Central Composite Design Approach

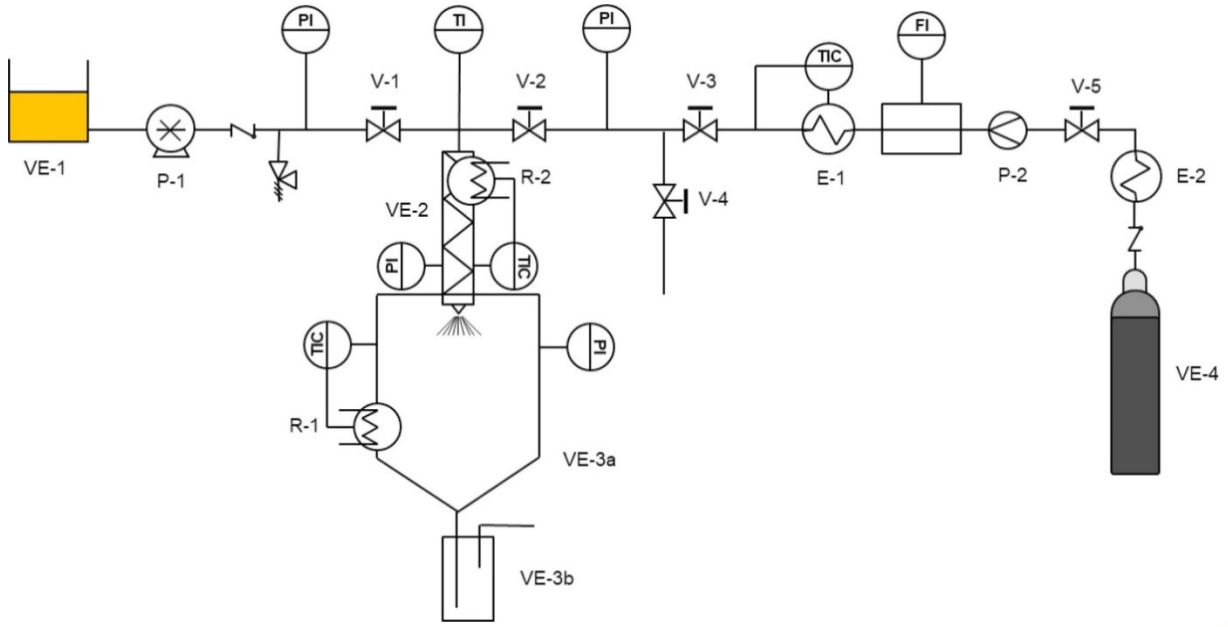


Case Study: Rice Bran (*Oryza sativa*)

STEP 4. Emulsion Drying

PGSS Drying

Encapsulation efficiency
Bioactive properties



Case Study: Rice Bran (*Oryza sativa*)

STEP 4. Emulsion Drying

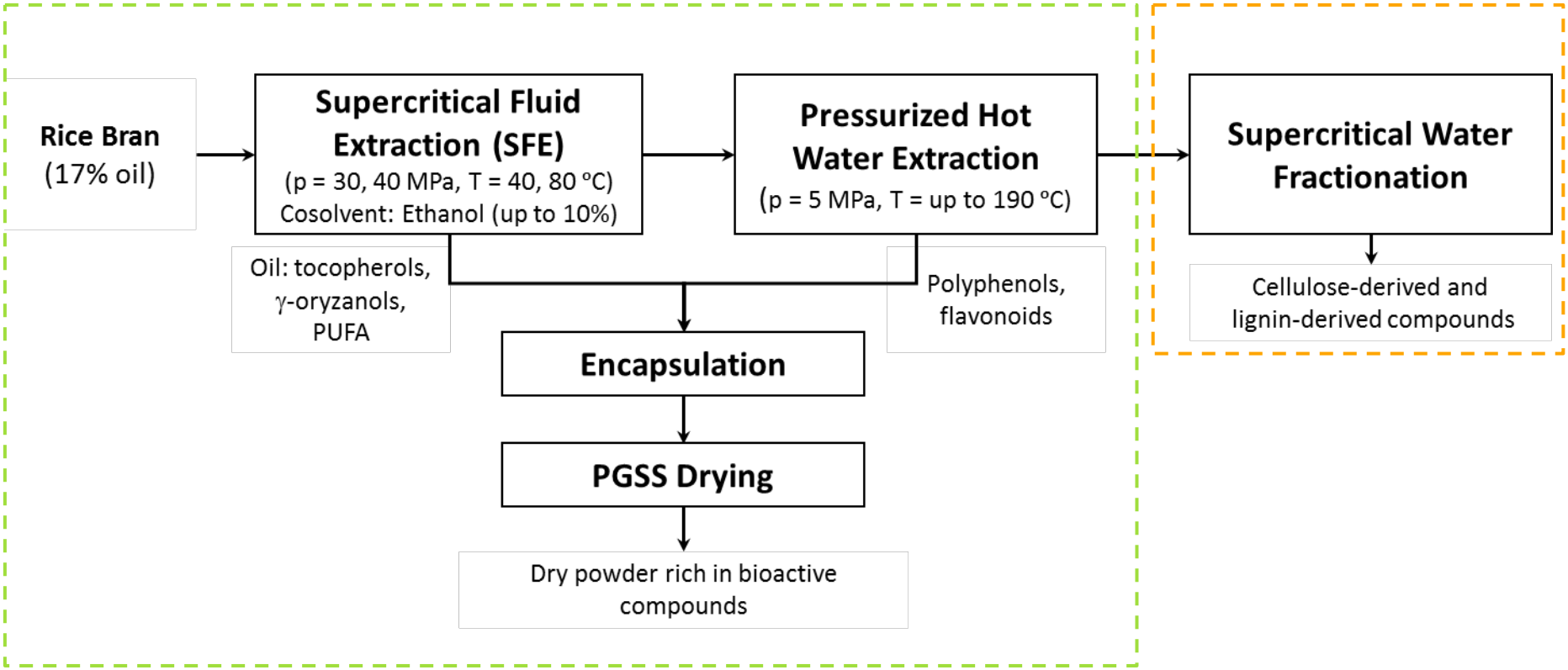
PGSS Drying

FINAL USE
Use in meat preparations (food company)

PROJECT Undergoing: Improvement of the nutritional profile of meat products

Case Study: Rice Bran (*Oryza sativa*)

✓Biorefinery approach proposed



Other cases: onion external layers

Valorization of onion. Background

- Key Ingredient for blood sausage production
- Local Company (http://www.morcilladeburgos.com/)
- Uses 350 t/year of onion, producing 11 t/year of external skin
- Project: *"Application of emerging technologies for the formulation of bioactive compounds of interest for the food industry"* (JCYL-FEDER 2016-18-BU055016)

Other cases: onion external layers

Valorization of onion. Problems and opportunities

PROBLEM

✘ Not to be used for animal feeding or fertilizing

OPPORTUNITIES

✓ Rich quercetin and other flavonoids

✓ Extraction and formulation

Other cases: onion external layers

Development of an extraction process to recover **quercetin**

- Incorporation in meat preparations
- Substitute artificial antioxidants

USE

Powerful antioxidant activity

Mild taste and smell

Conclusions

✓**The transition towards circular economy**

- New opportunities
- Application of fundamental research to solve problems
- Society and companies demand solutions we can provide, using pressurized fluids
- Biorefiney approach to convert "*residues*" in valuable products

Conclusions

✓**Food wastes**

- No longer residues
- Important amount of bioactive molecules underused
- Cases studies: rice bran and onion
  - Development of new products rich in bioactive molecules
  - To substitute artificial antioxidants in the food industry

Circular Economy

"For a sustainable world, the transition from linear to circular economy is a necessary boundary condition. A circular economy requires innovation in the areas of material, component and product reuse, as well as related business models"

Frans Van Houten (CEO at Philips)

Acknowledgements

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Case study: rice bran

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