Laboratório Nacional de Energia e Geologia, I. P.

The Pros and Cons of Upgrading Fruits & Vegetables Wastes in the Biorefinery Framework

Luís C. Duarte, Florbela Carvalheiro, Luísa B. Roseiro,

Ivone Torrado, Patrícia Moniz, Cristina Oliveira, Júnia Ferreira-Alves, Pedro Martins, …

Laboratório Nacional de Energia e Geologia

National Laboratory for Energy and Geology

www.lneg.pt

COMISSÃO EUROPEIA

HR EXCELLENCE IN RESEARCH

7º ANIVERSÁRIO
2020

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Implementação dos Princípios da Carta Europeia do Investigador e do Código de Conduta para o Recrutamento de Investigadores.

Em 2010, o Laboratório Nacional de Energia e Geologia aderiu aos princípios da Carta Europeia do Investigador e Código de Conduta para o Recrutamento de Investigadores, em 2013 recebeu o Logo de Excelência em RH de Investigação.

Carta e Código do Investigador Europeu

Investigador Europeu

Profissionais que trabalham na conceção ou criação de novos conhecimentos, produtos, processos, métodos, sistemas e na gestão dos projetos.

Definição de investigador do Manual de Frascati.

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A profissão de investigador abrange todas as pessoas envolvidas em I&D em qualquer fase da carreira e independentemente da categoria profissional.

Empregadores e Financiadores

- Condições de trabalho
- Estabilidade de emprego
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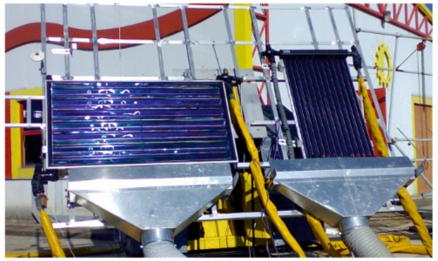
- Desenvolvimento de carreira

Princípios Gerais do Investigador

- Liberdade de investigação
- Responsabilidade profissional
- Princípios éticos
- Deveres de orientação e gestão



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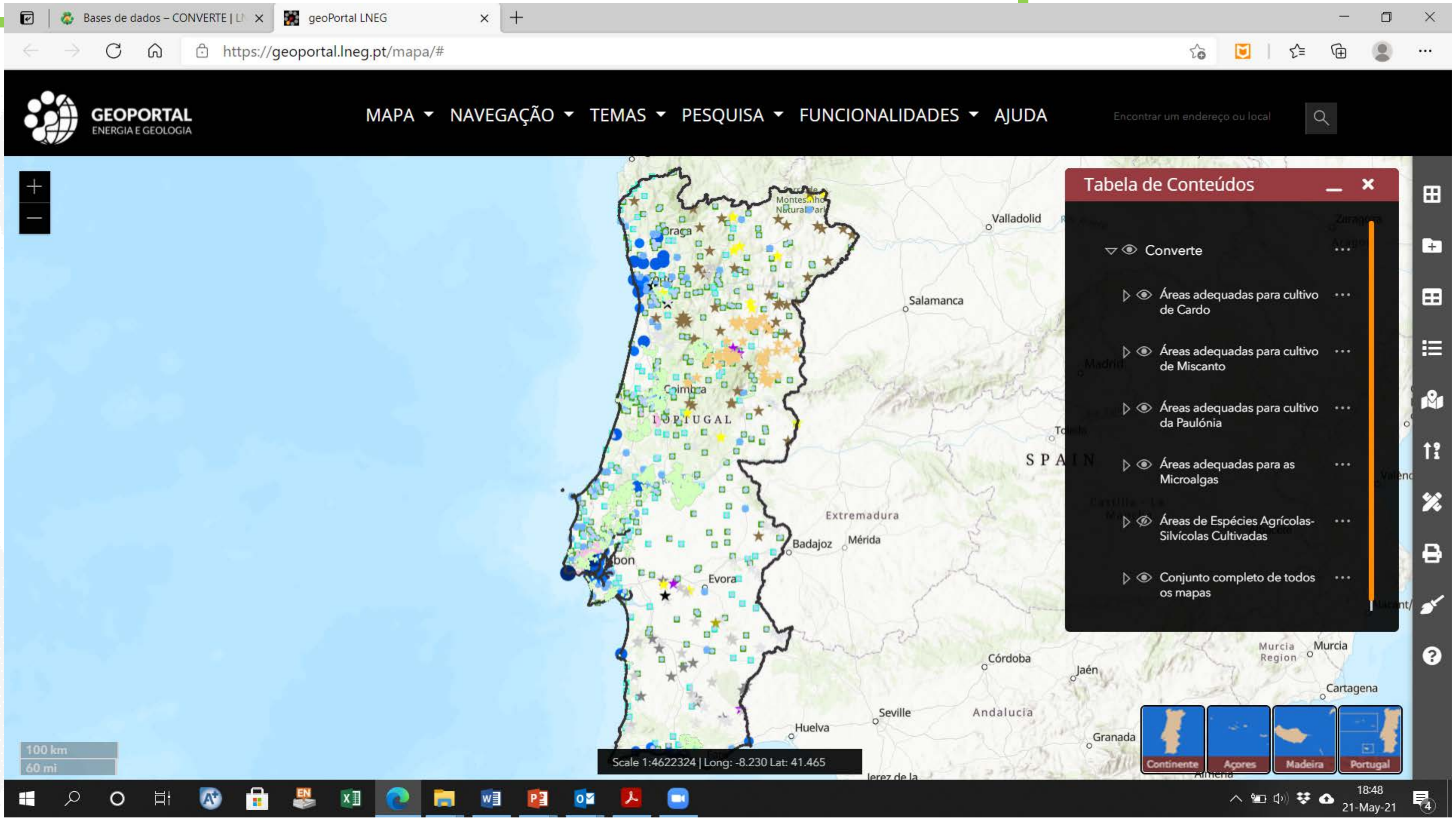
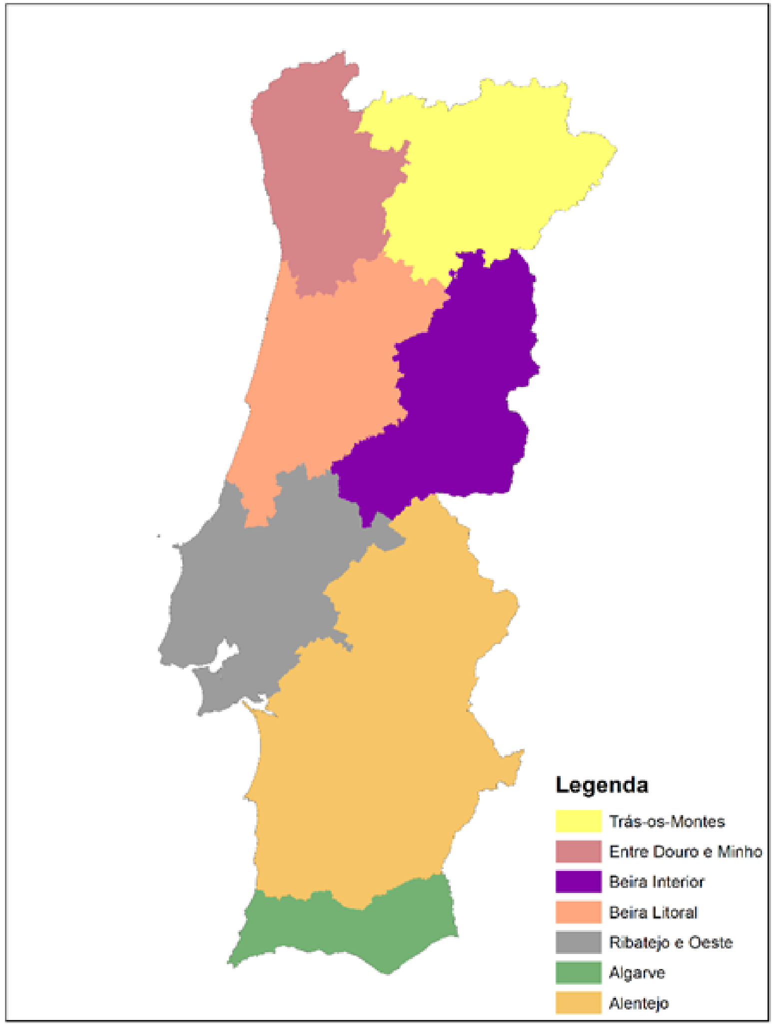
REPÚBLICA PORTUGUESA
AMBIENTE E AÇÃO CLIMÁTICA

Information resources

geoPortal LNEG: National potential for the production of energy crops



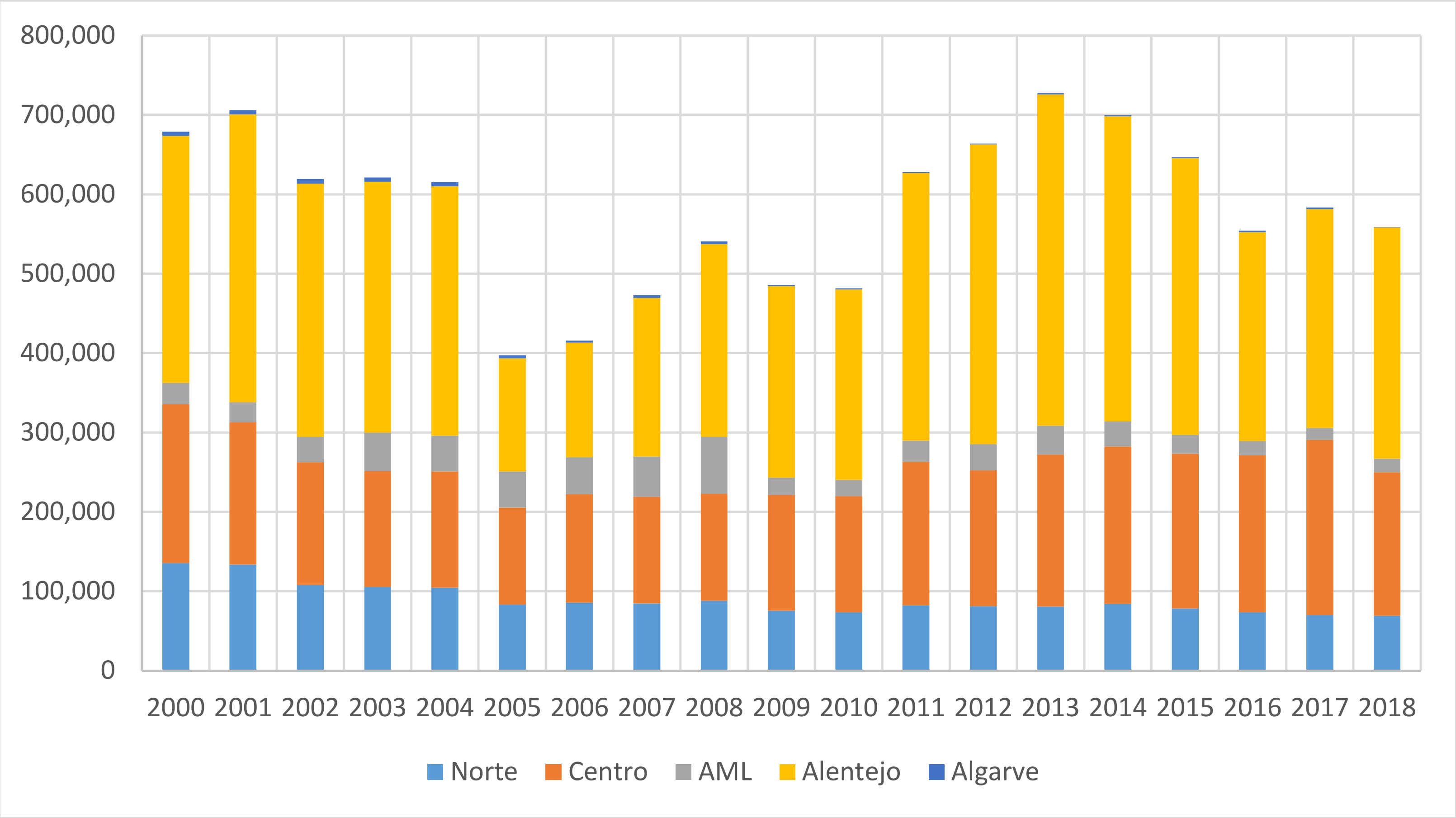
Combining Geographical and Statistical Information resources



Instituto Nacional de Estatística
Statistics Portugal

Agricultural residues

Corn stover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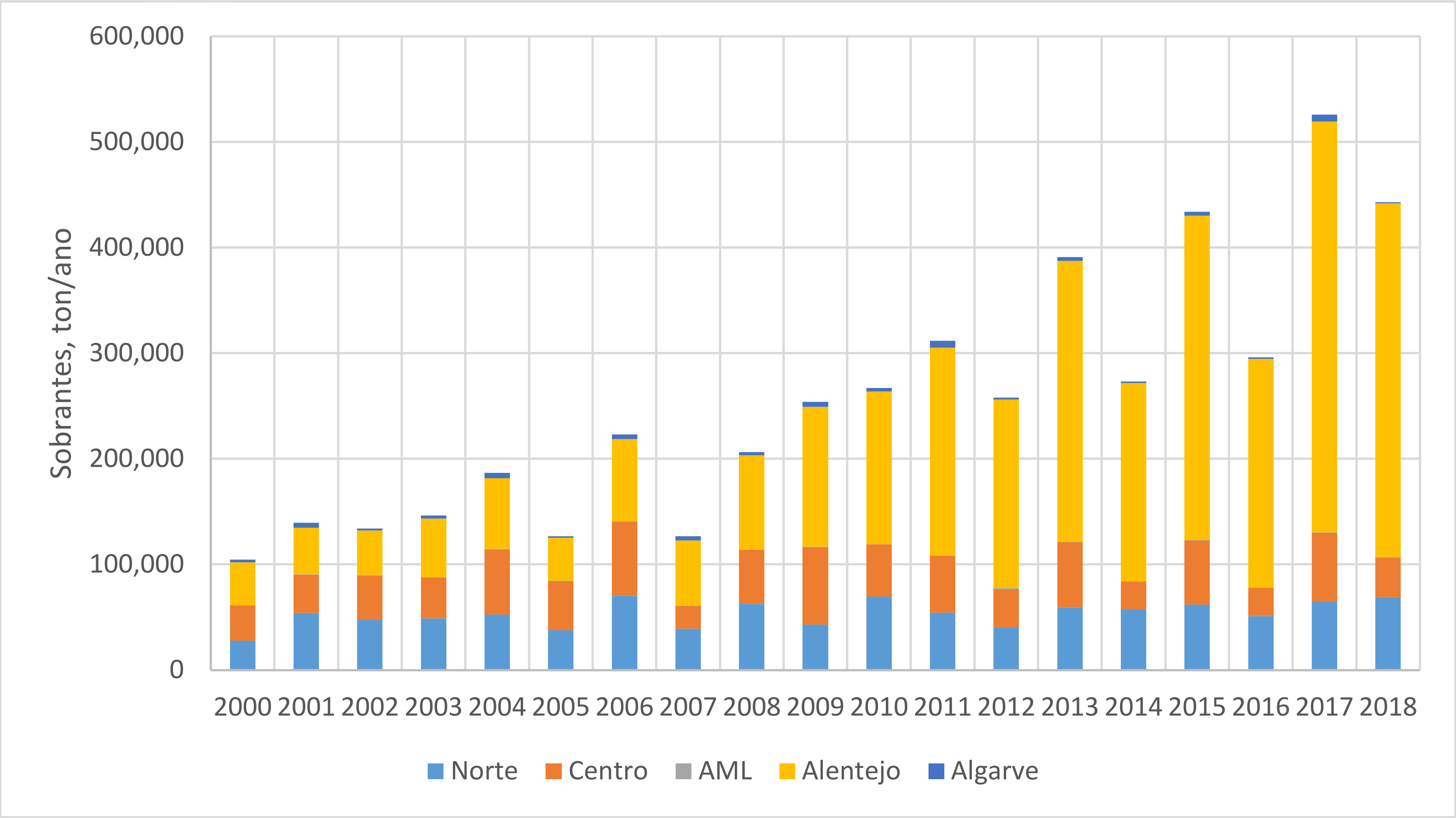
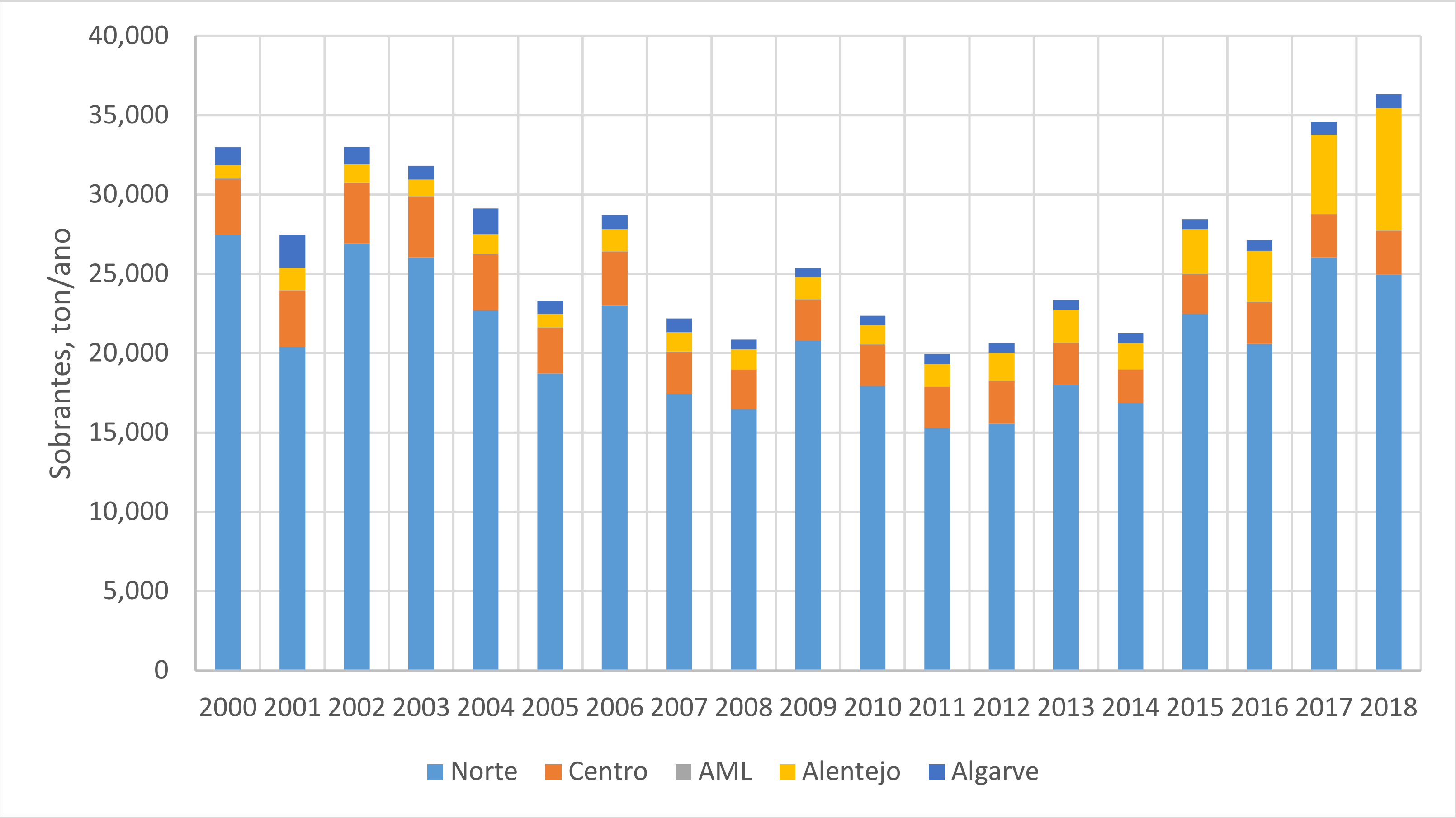
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Norte
Centro
AML
Alentejo
Algarve

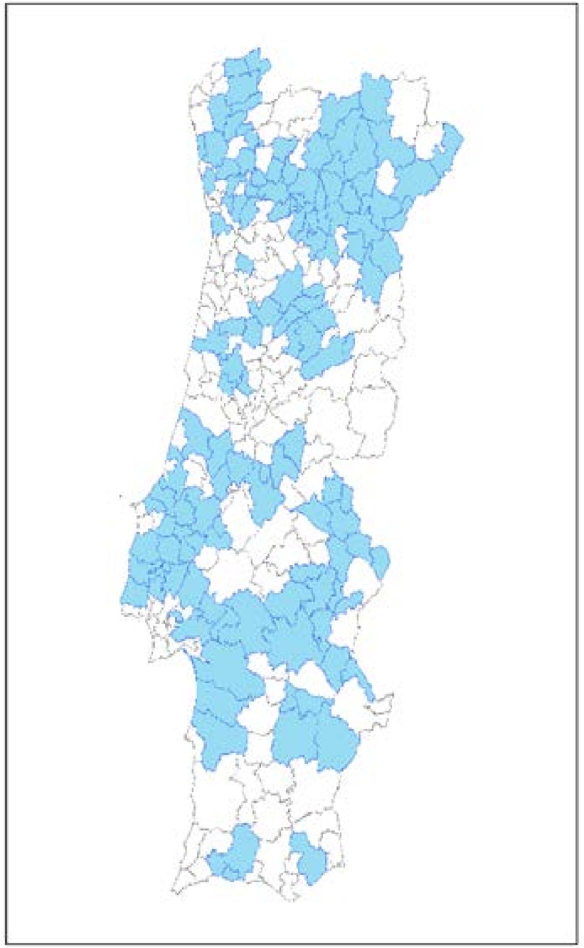
Olive tree prunnings



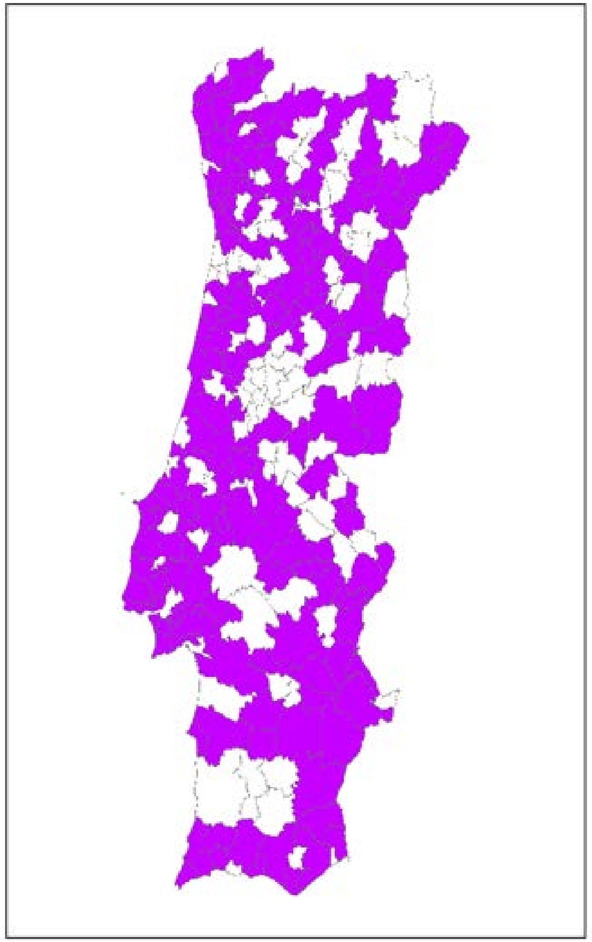
Orchards prunnings



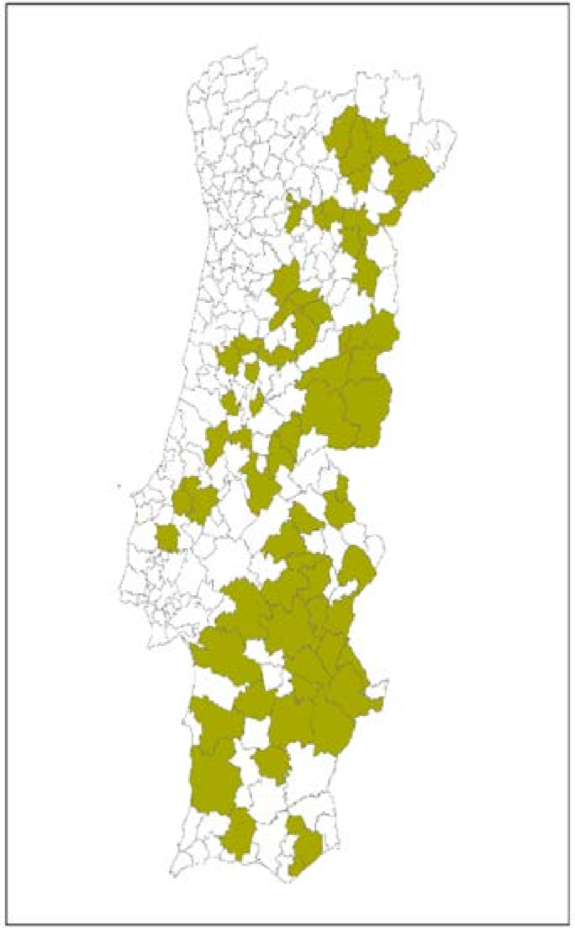
Agro-food industrial residues



Wine sector:
- Wine lees
- Grape pomace



Fruits and vegetables (F&V):
- ✓ **Carob pulp**
- ✓ **Nuts shells**
- ✓ **Peach stones**
- ✓ **Tomato pomace**



Olive oil industry
- ✓ **Extracted Olive Pomace (EOP)**

ArcGIS

These Materials are not created equal!

Biological Nature

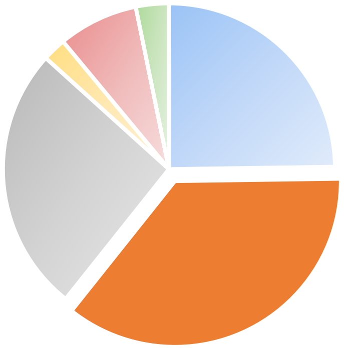
Chemical Composition

Structural differences

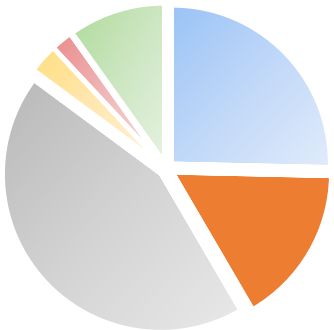
and many other factors

Extracted olive Pomace

Almond Shell



Pine nut shell



DO IMPACT SIGNIFICANTLY

on the their upgrade potential

How to estimate the upgradeability of a given material?

What are the **main restrictions to its use?**

What are their

Strengths,

Weaknesses,

Opportunities and Threats?

When can they be used**?**

There are no easy answers to these questions, and they are often dealt with in a rather subjective and non-systematical way

The BVPI concept

Biotechnology Journal
DOI 10.1002/biot.200700183
Biotechnol. J. 2007, 2, 1556–1563

Technical Report

Biotechnological valorization potential indicator for lignocellulosic materials

Luís C. Duarte, Maria P. Esteves, Florbela Carvalheiro and Francisco M. Gírio

INETI, Departamento de Biotecnologia, Lisboa, Portugal

Upgrade potential can be modeled as a function of 4 main criteria

The BVPI Concept

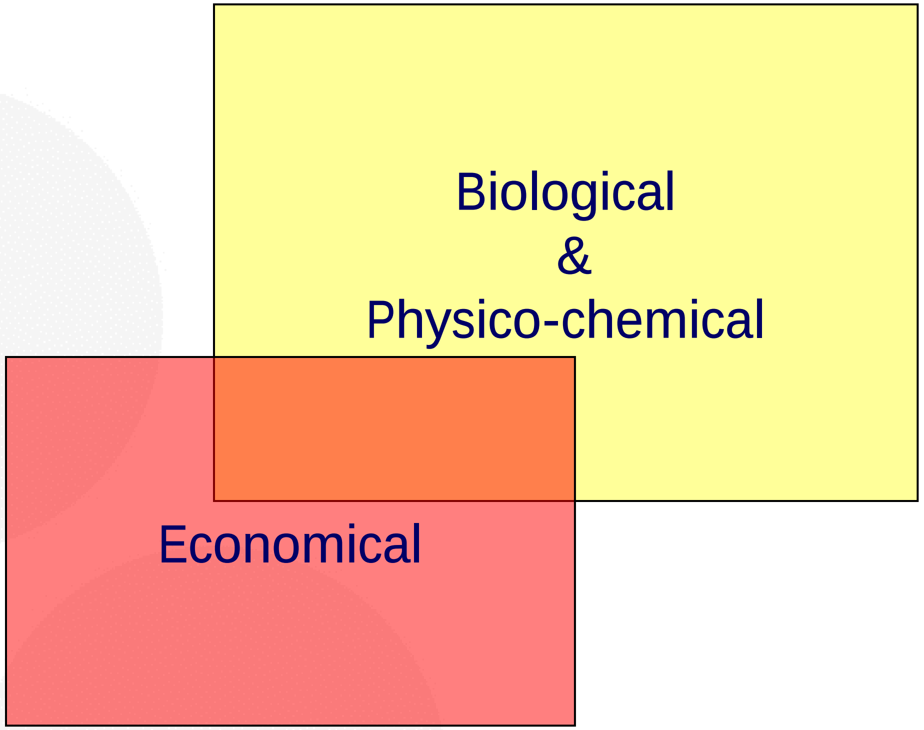
4 Main Evaluation criteria

Biological
&
Physico-chemical

Duarte et al 2007. *Biotechnol. J.* 2:1556-1563

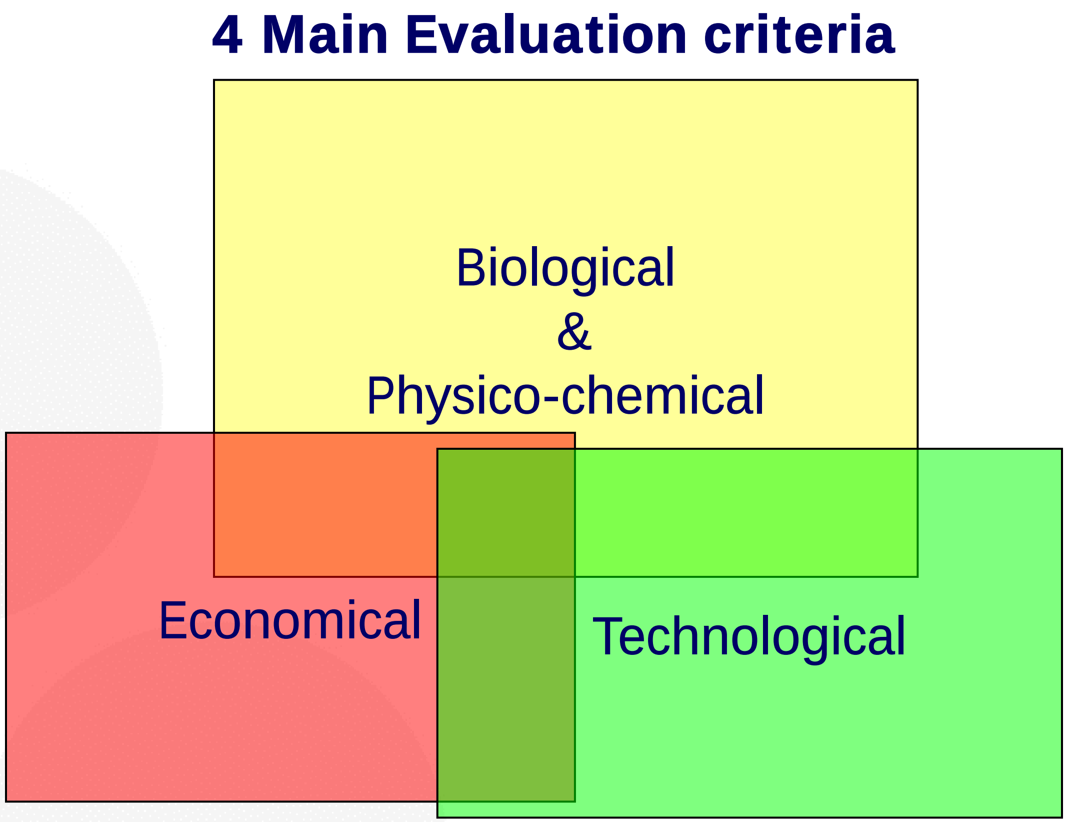
The BVPI Concept

4 Main Evaluation criteria



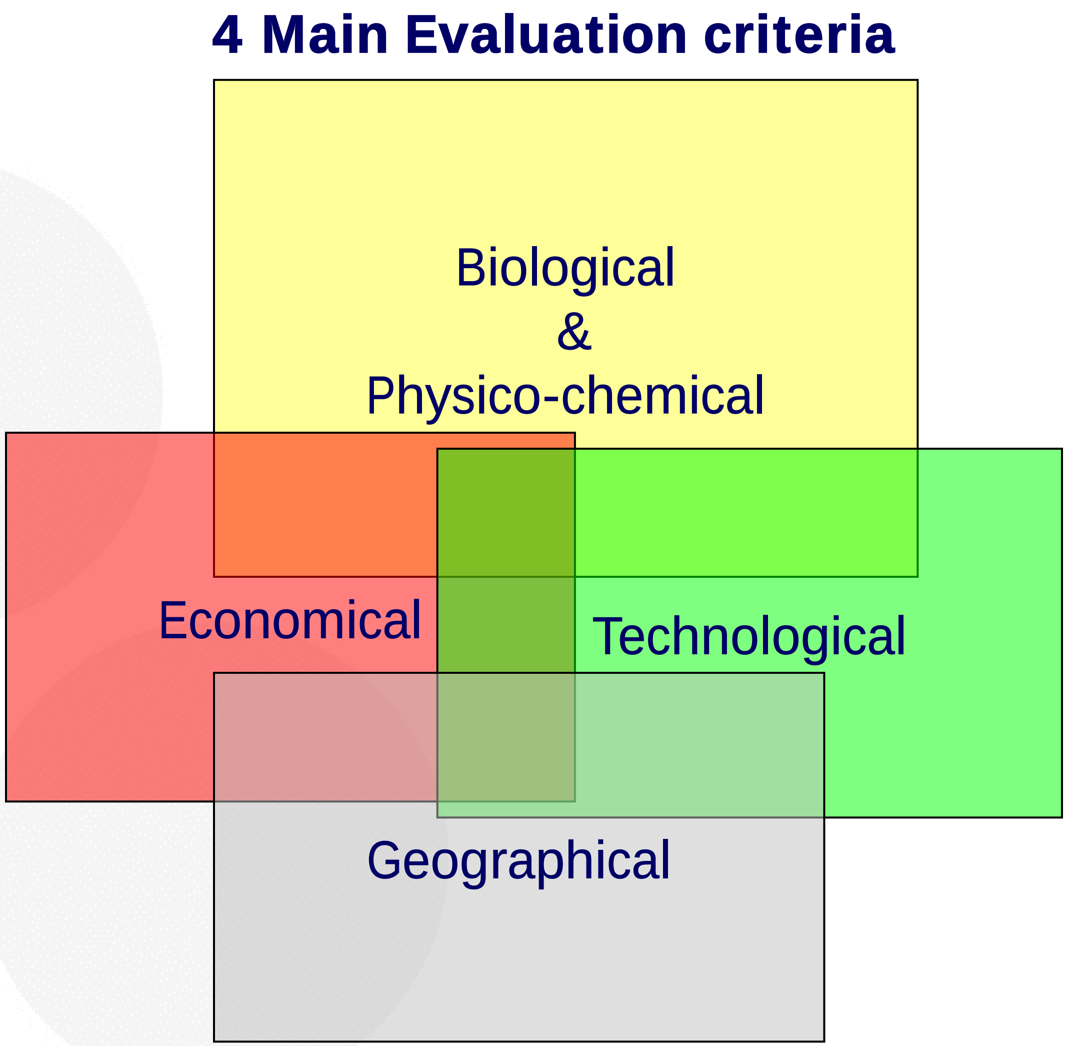
Duarte et al 2007. *Biotechnol. J.* 2:1556-1563

The BVPI Concept



Duarte et al 2007. *Biotechnol. J.* 2:1556-1563

The BVPI Concept



Duarte et al 2007. *Biotech. J.* 2:1556-1563

The BVPI Rating

Within each factor, the Lignocellulosic material under study is given a score (S_i) from

0
(Undesirable characteristic)

To

3
(Strong Positive Impact)

Biological and physico-chemical factors grid

Factors	Criterion	Score
Biological nature	Herbaceous	3
	Softwoods	2
	Hardwoods	1
	Mix	0
Macromolecular composition (main or relevant fraction)	Mono-, disaccharides or starch	3
	Hemicellulose (C6)	2
	Hemicellulose (C5)	1
	Cellulose	1
	Protein / Other	0
	Lignin	0
Water content (%)	< 15	3
	< 40	2
	40-80	1
	> 80	0
Physical characteristics	Soft and high density materials	3
	Soft and low density materials	2
	Hard and high density materials	1
	Hard and low density materials	0

Economical factors grid

Factors	Criterion	Score
Seasonality (available during...)	All year	3
	< 9 months	2
	< 6 months	1
	< 3 months	0
Economic value (€/t)	< 0	3
	0-40	2
	40-120	1
	> 120	0
Market dependency	High	3
	Medium	2
	Low	1
	Null	0

Technological factors grid

Factors	Criterion	Score
Currently applied technology/destination	None	3
	Energy	2
	Recycling/upgrade	1
	Reutilization	0
	Industrial feedstock	0
Development stage of the Biorefinery processing technology	Mature	3
	Demonstration	2
	Development	1
	Null	0

Geographical factors Grid

Geographical factors classification grid

Factors	Criterion	Score
Total available quantities (current or potential) (t/year)	> 80 000,0	3
	< 80 000,0	2
	< 24 000,0	1
	< 8 000,0	0
Geographical concentration (t / (year Region)	> 80 000,0	3
	< 80 000,0	2
	< 24 000,0	1
	< 8 000,0	0
Political or legal constrains (Situation concerning upgrading)	Compulsory/strongly supported	3
	Supported/Subsidized	2
	Neutral	1
	Prohibit	0

neiro F, Gírio FM, 2007.

The BVPI Concept

Computation

$$BVPI = \sum_{i=1}^{i=12} S_i$$

No weighting

No scaling

The BVPI Evaluation results

Order	Material	Biological nature	Macromolecular composition	Water content	Physical characteristics	Seasonality	Economic value	Market dependency	Current technology / destination	Development stage of upgrade technology	Available quantities (actual)	Geographical concentration	Political or legal constraints	BVPI
1	Rice husks	3	1	3	2	3	2	3	3	1	2	2	1	26
2	Brewery’s spent grain	3	1	1	2	3	2	3	3	1	3	2	1	25
3	Carob pulp	1	3	3	3	3	0	3	1	1	2	2	1	23
4	Tomato pomace	3	1	1	2	0	2	3	3	1	2	2	1	21
5	De-alcoholized grape bagasse	1	1	1	2	2	2	3	3	1	2	2	1	21
6	Extracted olive bagasse	1	1	3	3	3	2	0	2	1	2	2	1	21
7	Grape stalks	1	1	3	2	1	2	3	3	1	1	0	1	19
8	De-alcoholized wine lees	1	1	1	3	2	2	3	3	1	1	0	1	19
9	Pine nut shells	2	1	3	1	3	2	0	2	1	1	1	1	18
10	Rice bran	3	3	3	3	3	1	1	0	0	0	0	1	18
11	Rice middlings	3	3	3	3	3	1	1	0	0	0	0	1	18
12	Rice greens	3	3	3	3	3	1	1	0	0	0	0	1	18
13	Olive bagasse	1	0	1	2	1	2	3	0	1	3	2	1	17
14	Citrus peels	1	1	1	3	1	2	2	1	2	1	1	1	17
15	Grape seeds	1	0	3	2	2	2	3	0	1	0	1	1	16
16	Malt dust	3	0	3	3	3	1	1	0	1	0	0	1	16
17	Almond shells	1	1	3	1	3	2	0	2	1	0	0	1	15
18	Nuts shells	1	1	3	1	3	2	0	2	1	0	0	1	15
19	Fruit pulp	1	1	1	3	1	2	2	1	2	0	0	1	15
20	Malt culms	3	0	3	3	3	0	1	0	1	0	0	1	15
21	Grape bagasse	1	0	1	2	1	0	0	0	1	3	1	0	10
22	Wine lees	1	0	1	2	1	0	0	0	1	3	1	0	10

Main advantages:

- No significat Seasonality
- Quantities: Ok

Main restrictions:

- **Macromolecular composition**,
- Underdevelop Technology,
- Lack of national political support

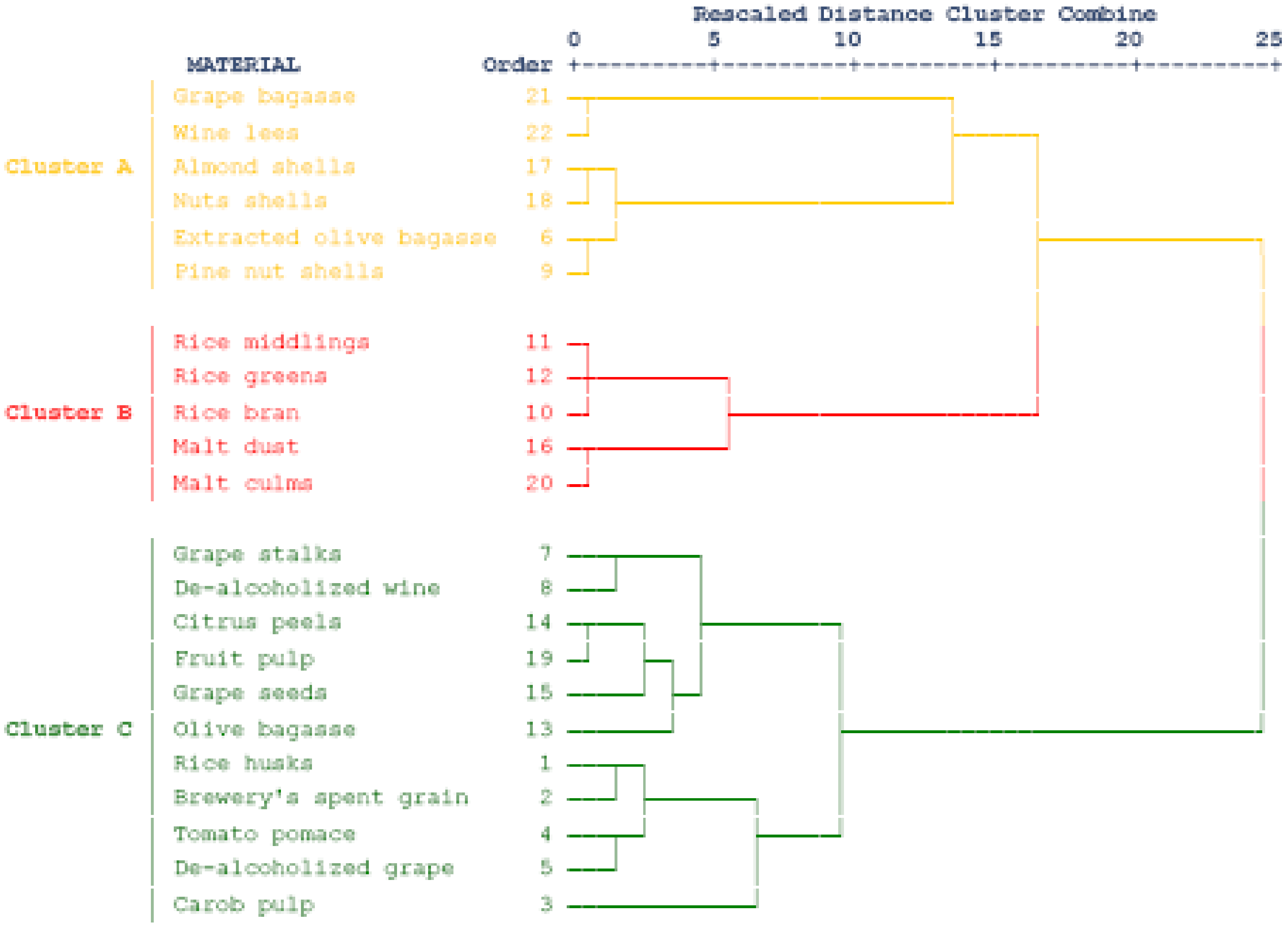
The BVPI Analysis

3 Main groups

- **Feedstock for the Biorefinery Thermochemical Platform**

- **Agro-industial CO-PRODUCTS (Uninteresting for the Biorefinery)**

- **Feedstock for the Biorefinery Biochemical Platform**



neiro F, Girio FM. 2007

The “ideal” feedstock:

Carob Pulp

- **High (40-50%) sugar (Sucrose, Fru and Glc) content**
- Significant amountSD: >> 40.000.000 kg/yr
- Highly geographically concentrated (Algarve)
- No seasonality problems (easy storage)
- Favorable policies (carob plantation is being subsidized)

Price…



ValorAlfa Valorization Strategy

Bioactive Extractives

Food Fiber

HeLa
MCF-7
Neuroblastomes

Use of Bioactive substances (PT105731)

Solvent Extraction (PT104631)

Aqueous extraction

Fermentation (PT104632)

Polyfunctional Drink

Anti-oxidant
Anti-hyperglycemic
Probiotic
Non-dairy

Fermentation (PT104633)

Mannitol

Alternative sweetener

UPCYCLED FOOD Definition

"Upcycled foods use ingredients that otherwise *would not have gone to human consumption*, are procured and produced using *verifiable supply chains*, and *have a positive impact on the environment*."

Upcycled products prevent food waste by **creating New, High Quality Products out of surplus food.**

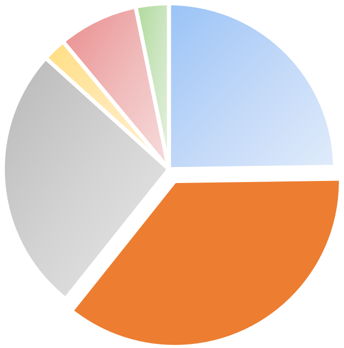
UPCYCLED FOOD Elements

1. Upcycled foods are made from ingredients that would otherwise have ended up in a food waste destination
2. Upcycled foods are value-added products
3. Upcycled foods are for human consumption
4. Upcycled foods have an auditable supply chain
5. Upcycled foods indicate which ingredients are upcycled on their labels

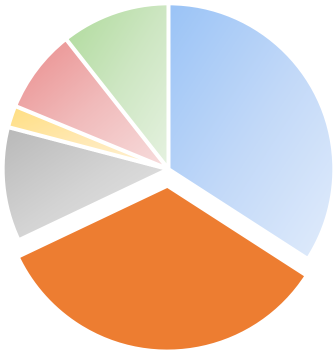
Recalcitrant (non-edible) materials

Extracted olive Pomace

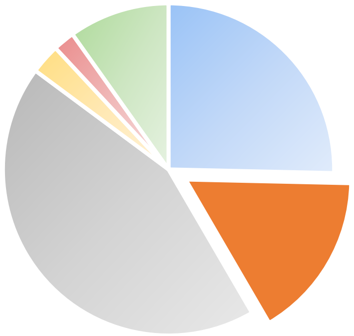
Almond Shell



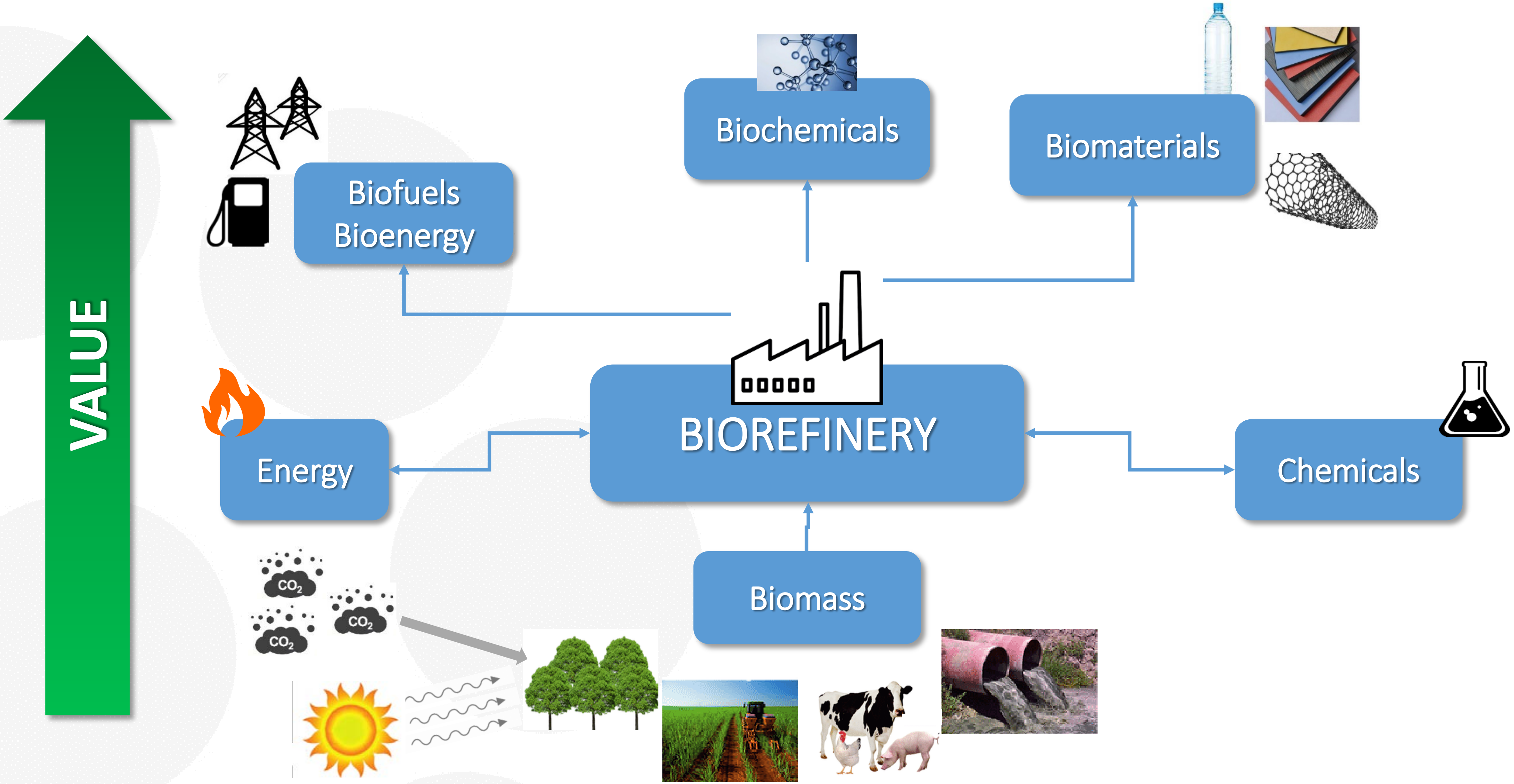
Corncobs



Pine nut shell



Biorefineries



SIADED, 2011

Fractionation process options

Biomass deconstruction/ Fractionation Processes

Mechanical

- Grinding
- Milling
  - Super fine milling
- Freezing
- Radiation
- Extrusion
- Ultrasonication

Chemical

- Acid
- Alkaline
- Inorganic salts
- Organosolv
- Ionic liquids
- Ozonolysis
- Deep eutectic solvents

Physicochemical

- Steam explosion
- Liquid hot water
- Ammonia fiber explosion
- Wet oxidation
- CO2 explosion

Biological

- Microorganisms
  - Fungi
  - bacteria
- Enzymes

Fractionation process options

Biomass deconstruction/ Fractionation Processes

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- Deep eutectic solvents

Physicochemical

- Steam explosion
- **Liquid hot water**
- Ammonia fiber explosion
- Wet oxidation
- CO_2 explosion

Biological

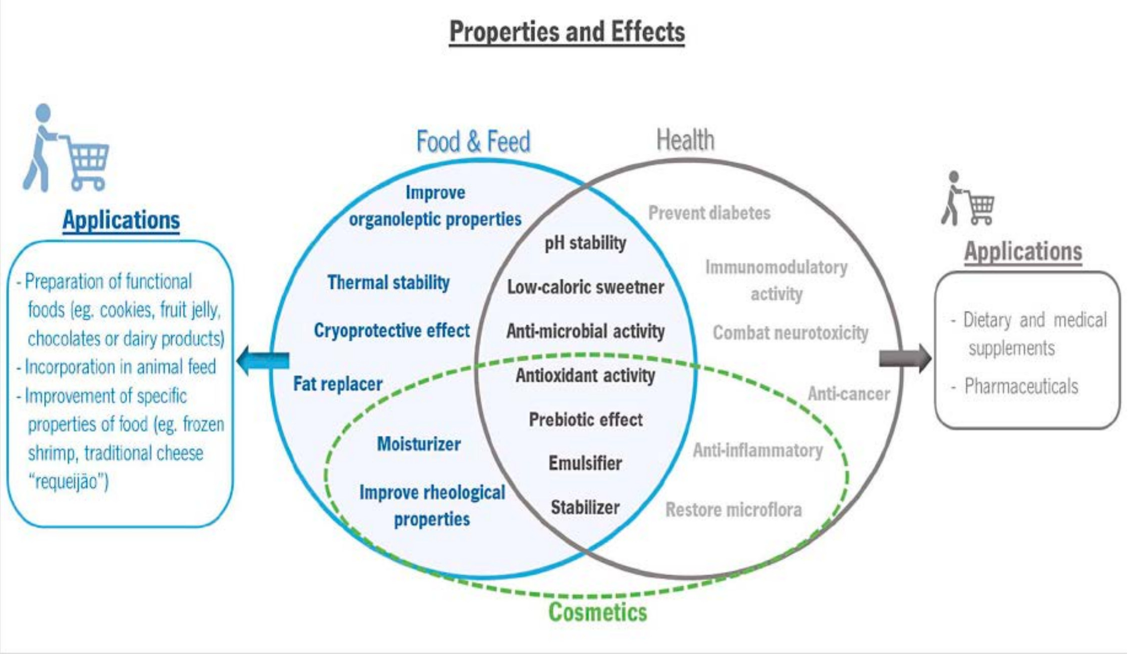
- Microorganisms
  - Fungi
  - bacteria
- Enzymes

Liquid hot water: Fractionation and upgrading step

Modeling and Analysis

Biofpr Biofuels Bioproducts & Biorefining

Techno-economic and life-cycle assessments of small-scale biorefineries for isobutene and xylo-oligosaccharides production: a comparative study in Portugal and Chile



(Xylo-) Oligosacharides

XOS

- Functional food ingredients **recognized by FDA** (2019)
- High Market Value
- But still **low market demand**

Biomass Conversion and Biorefinery
https://doi.org/10.1007/s13399-023-05244-z

ORIGINAL ARTICLE

Check for updates

Microwave-assisted hydrothermal processing of pine nut shells for oligosaccharide production

Ivone Torrado[1,2,3] · Beatriz Guapo Neves[1] · Maria da Conceição Fernandes[1,4] · Florbela Carvalheiro[3] · Helena Pereira[2] · Luís C. Duarte[3]

Waste Management 119 (2021) 306–314

Contents lists available at ScienceDirect

Waste Management

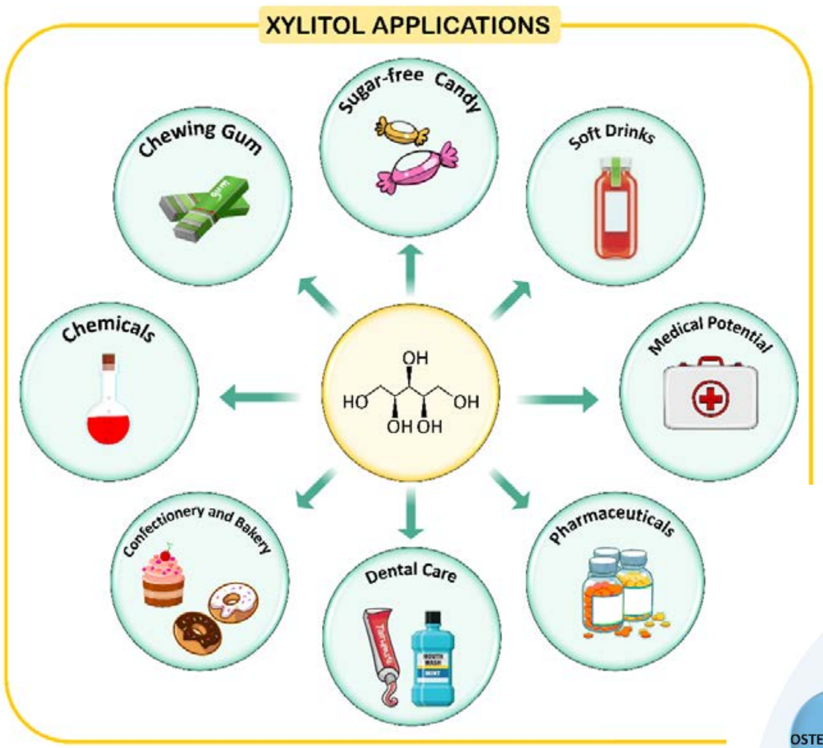
journal homepage: www.elsevier.com/locate/wasman

ELSEVIER

Assessment of the effect of autohydrolysis treatment in banana's pseudostem pulp

Sara Díaz[a], Zaida Ortega[a], Antonio N. Benítez[a], Diogo Costa[b], Florbela Carvalheiro[b], Maria C. Fernandes[c,d], Luís C. Duarte[b,*]

Monosaccharides and Polyols as pivotal biorefinery products

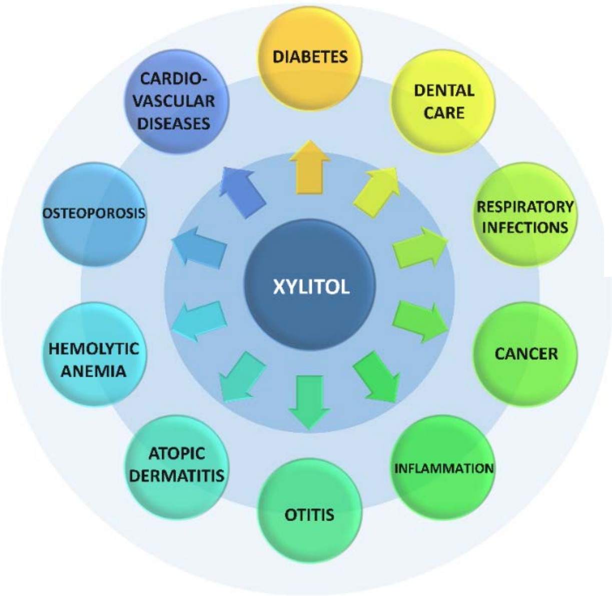


reactions MDPI

Article

Combination of Autohydrolysis and Catalytic Hydrolysis of Biomass for the Production of Hemicellulose Oligosaccharides and Sugars

Léa Vilcocq [1,*], Agnès Crepet [2], Patrick Jame [3], Florbela Carvalheiro [4] and Luis C. Duarte [4]



fermentation MDPI

Article

Xylitol Production by *Debaryomyces hansenii* in Extracted Olive Pomace Dilute-Acid Hydrolysate

Ana Rita C. Morais [1], Luís C. Duarte [1], Pedro Lourenço [2], Ivone Torrado [1], Teresa Brás [3,4], Luísa A. Neves [5] and Florbela Carvalheiro [1,*]

Take home messages

- BVPI can be a useful tool to ascertain the upgrade potential of a give material

- might be useful starting point for the development of more robust classification criteria for food waste products

- Biorefinery concepts are useful for the upgrade of food waste materials and to enable their maintenance/upscale as food products

Dr Léa Vilcocq
Dr Sara Díaz
Dr Pedro Branco
Dr Rita Morais
Dr Teresa Brás
Dr Pedro Lourenço
Dr Helena Pereira
Dr Bartha Sandor
Dr Tiago Lopes
Diogo Costa
Bruno Sampaio
Gabriel Mota Ribeiro
Mafalda Batalha
Inês César
João Fialho
Céu Penedo
Belina Ribeiro

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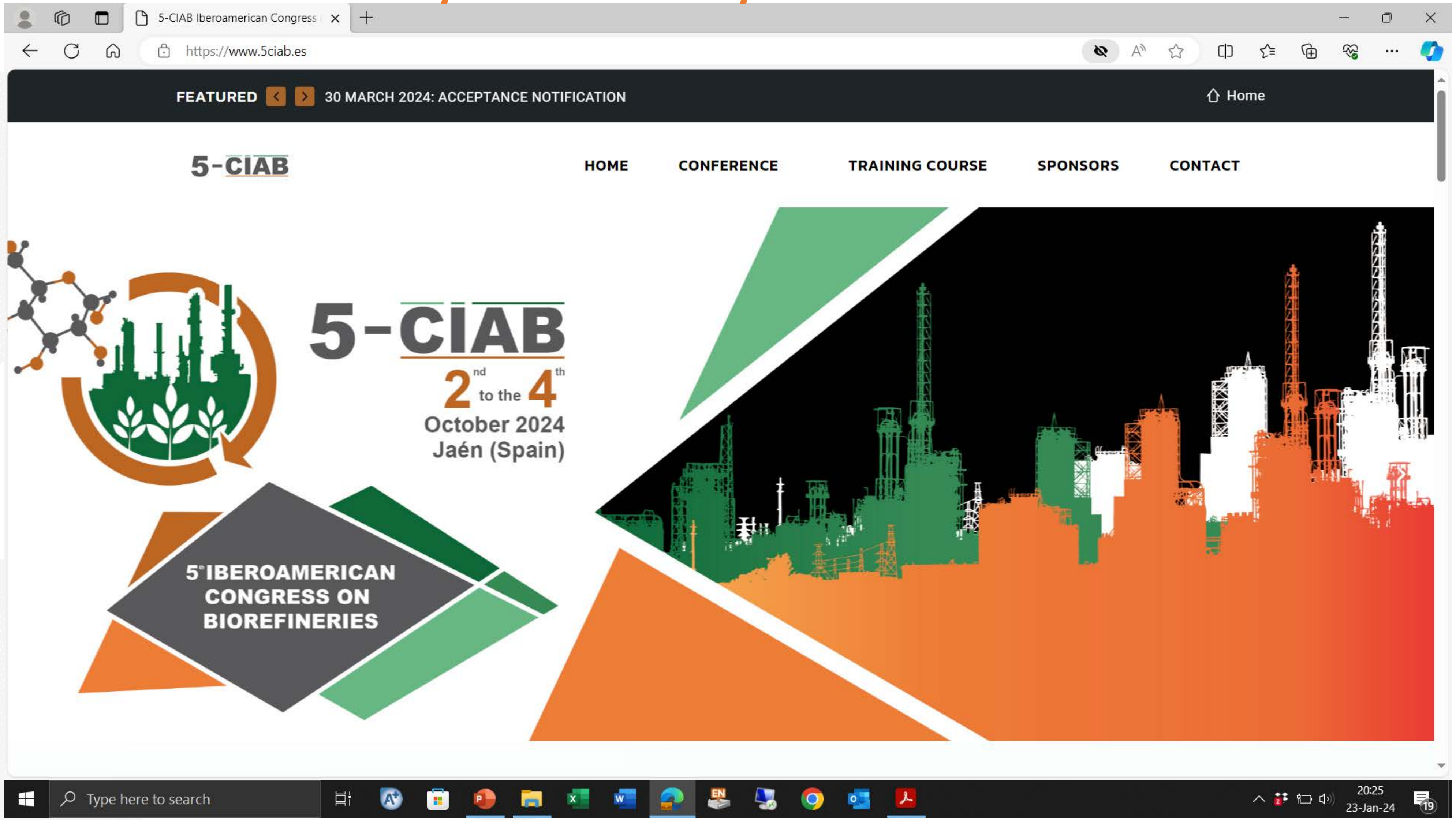
Thank you for your attention



https://www.5ciab.es