Biorg4WasteWaterVal+

Bioorganic Novel Approaches for Food Processing Waste Water Treatment and Valorisation: Lupanine Case Study

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Water JPI
WaterWorks2014 Cofunded Call
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CONSORTIUM DESCRIPTION

ACRONYM	TOPIC	Coordination	Partners
Biorg4WasteWaterVal+	**I**		
Bioorganic Novel Approaches for Food Processing Waste Water Treatment and Valorisation: Lupanine Case Study		**water saving-reuse-recycling; added value products; food industry processing; membrane separations; microbial-organic processes**	

PRINCIPAL INVESTIGATOR	INSTITUTION	COUNTRY
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Francesca Malpei	Politecnico di Milano (POLIMI)	Italy
Thomas Schäfer	Basque Centre for Macromolecular Design & Engineering (POLYMAT)	Spain
Michalis Koutinas	Cyprus University of Technology (CUT)	Cyprus
Dina Bastos	A Tremoceira Estrela da Piedade Lda (lupin beans processing company) (TEP)	Portugal
Nuno Maulide	University of Vienna (Collaborative Partner)	Austria
Giovan B. Salinetti	SADES (Collaborative Partner; lupin beans processing company)	Italy

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Project aim

Address the Topic 1 of the Call: *Research and Innovation for Developing Technological Solutions and Services for Water Treatment, Reuse, Recycling and Desalination* within the specific existing challenges for food processing industries:

- **The food sector is comprised of several factories of small/medium size, calling for the development of modular technological solutions which could be quickly implemented at the companies' site;**
- **Novel separation processes using low energy and chemicals will be developed at low cost based on novel membrane processes and adsorbers capable of purifying the water for *in-situ* recycling at zero cost for the companies;**
- **A concept is proposed in which alkaloids are isolated and converted into building blocks of value for the pharmaceutical and chemical industries, compensating for water detoxification costs;**
- **New biological and chemical tools will be developed for conversion of alkaloids into added-value compounds, while lupanine is used as a particular example to illustrate this case.**

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The case study

The food processing industry uses a large volume of fresh water to deliver safe food;

Examples: m^3 of water/ton of food: 54-77 (green beans); 11.5-22.5 (sugar beet) or 3.6-22 (peach and pears);

In UK (2010) 100 million m^3 of water, from which 20 million m^3 were specifically applied in fruit and vegetable processing;

The case of lupin beans processing:

lupin beans before processing

Requires aprox. 14 m^3 fresh water/ton of salted beans

lupin beans ready for human consumer

The global production of lupin beans is ca 930 000 tons (2009)

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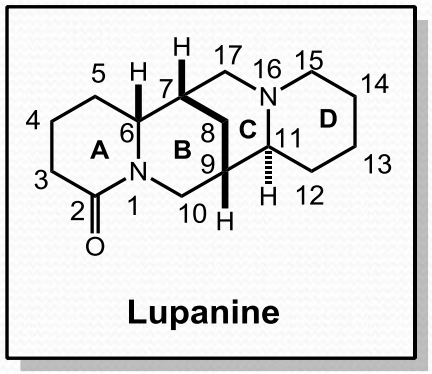
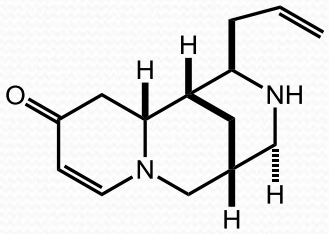
The case of lupin beans processing

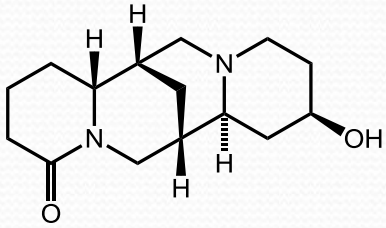
Lupin beans before processing contains up to 1.3 wt% of the following toxic quinolizidine alkaloids in which racemic lupanine represents about 90% of the plant alkaloids content;



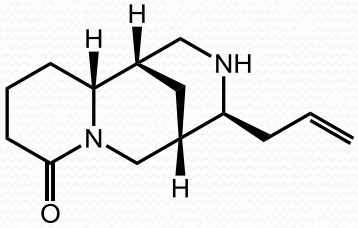
Lupanine



Albine



13*(R)*-Hydroxylupanine



Angustifoline

Great Britain, France, Australia and New Zealand fixed a maximum limit of 200 mg/kg for the total quinolizidine alkaloid content in lupine flours and foods;

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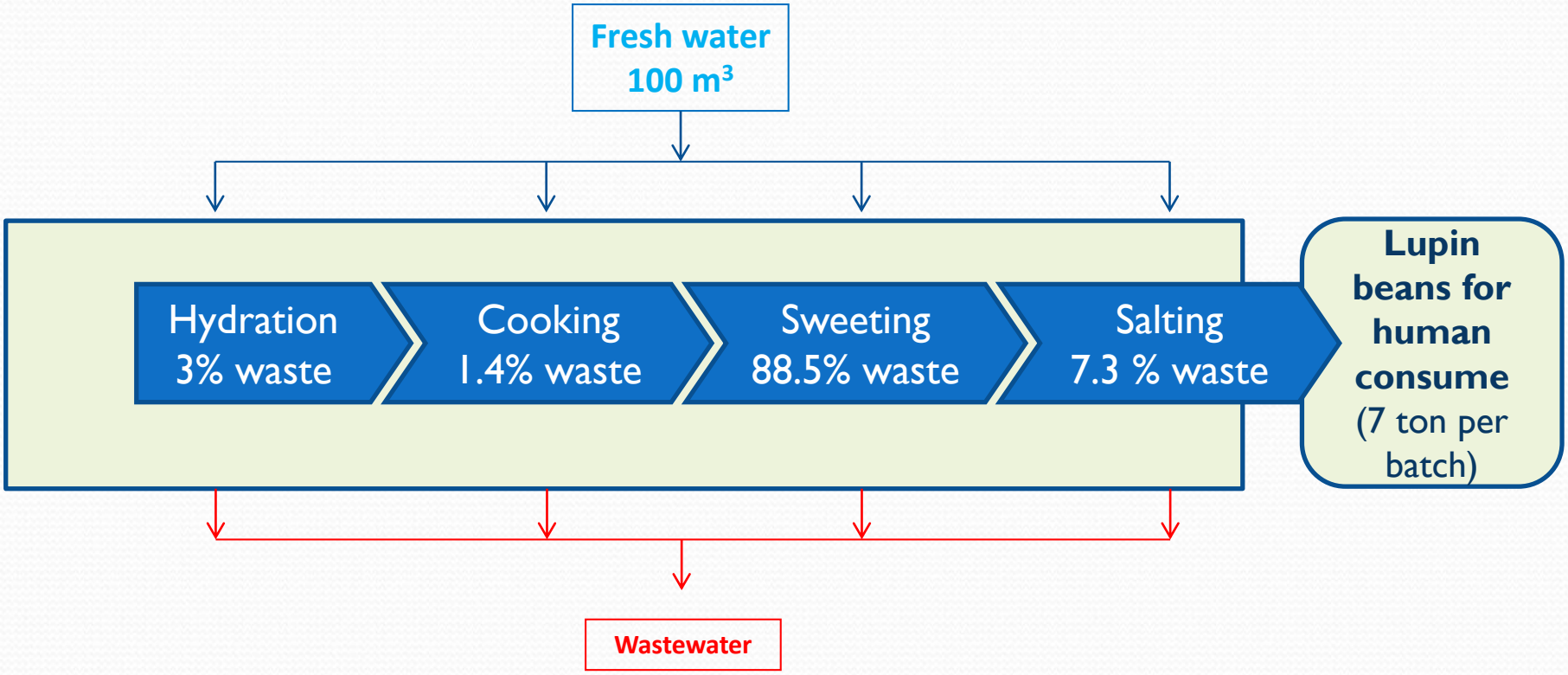
The case of lupin beans processing

Overview of current lupin beans processing



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The case of lupin beans processing

Selection of processed lupine producers for human consumers

Company name	webpage	Country
Altramuz ltda	http://www.altramuz.cl/	Chile
Sades	http://www.sadesolive.it/	Italy
Tremoceira	http://www.tremoceira.com/	Portugal
Maçarico	http://www.macarico.com/pages/home.asp	Portugal
Saladitos	http://www.saladitos.com/index.html	Spain
Cosmos	http://www.cosmosfoods.com/index.asp	USA
Castella	http://www.castella.com/	USA
Cedar	http://www.cedarsfoods.com/about-us/the-cedars-story/	USA

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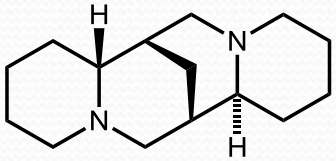
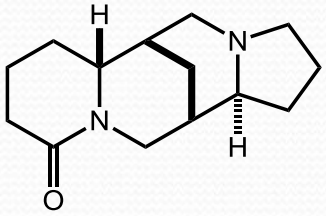
The case of lupin beans processing

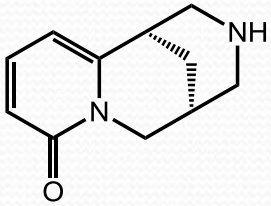
Lupanine valorization
Examples of valuable alkaloids



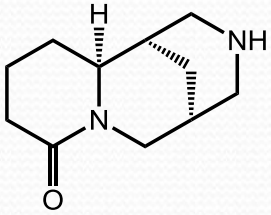
(-)-Sparteine



Camoensidine

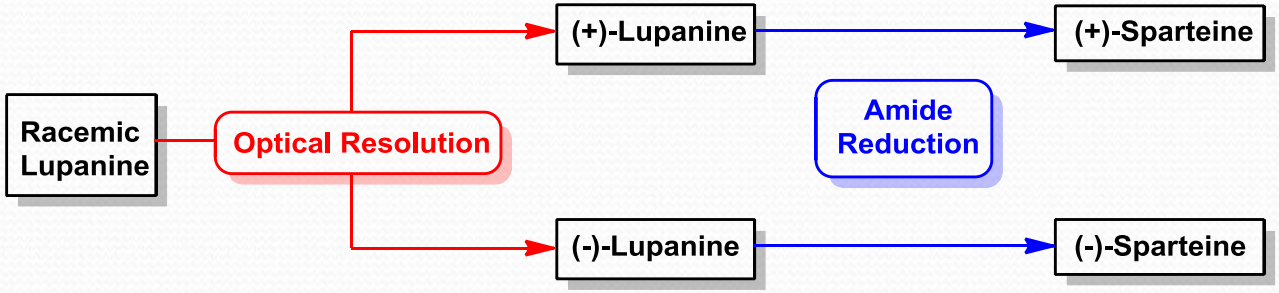


(-)-Cytisine



(+)-Sparteine surrogate

Maulide (Austria) and Afonso (Portugal) teams already developed a laboratory scale technology for the resolution of lupanine and transformation to (+)- and (-)-sparteine



N. Maulide, B. Peng, C. A. M. Afonso, R. F. M. Frade, EP2808326A1; WO2014191261A1 (2013)

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Originality and innovative aspects of the project

- **A modular water detoxification process system easy to use and maintain, comprised of two membrane stages, articulated by a dedicated design to re-use up to 80% of the water within the food processing unit and to deliver a highly concentrated solution of alkaloids;**
- **New membrane adsorbers based on DNA-aptamer or molecularly imprinted polymers (MIPs) for efficient binding of alkaloids;**
- **Bioconversion of alkaloid, without full degradation, isolating new structural motifs for organic synthetic transformations;**
- **A compact system able to provide a new diastereomeric resolution of alkaloids and new conversion of each enantiomer, with recycling of resolving agent;**
- **Application of known functional group transformations to the specific substrates derived from the bioconversion;**
- **Novel business models to bring economic, environmental and societal positive impacts targeting a 3rd party able to provide water detoxification *in-situ* techs and to produce and commercialize the added value products.**

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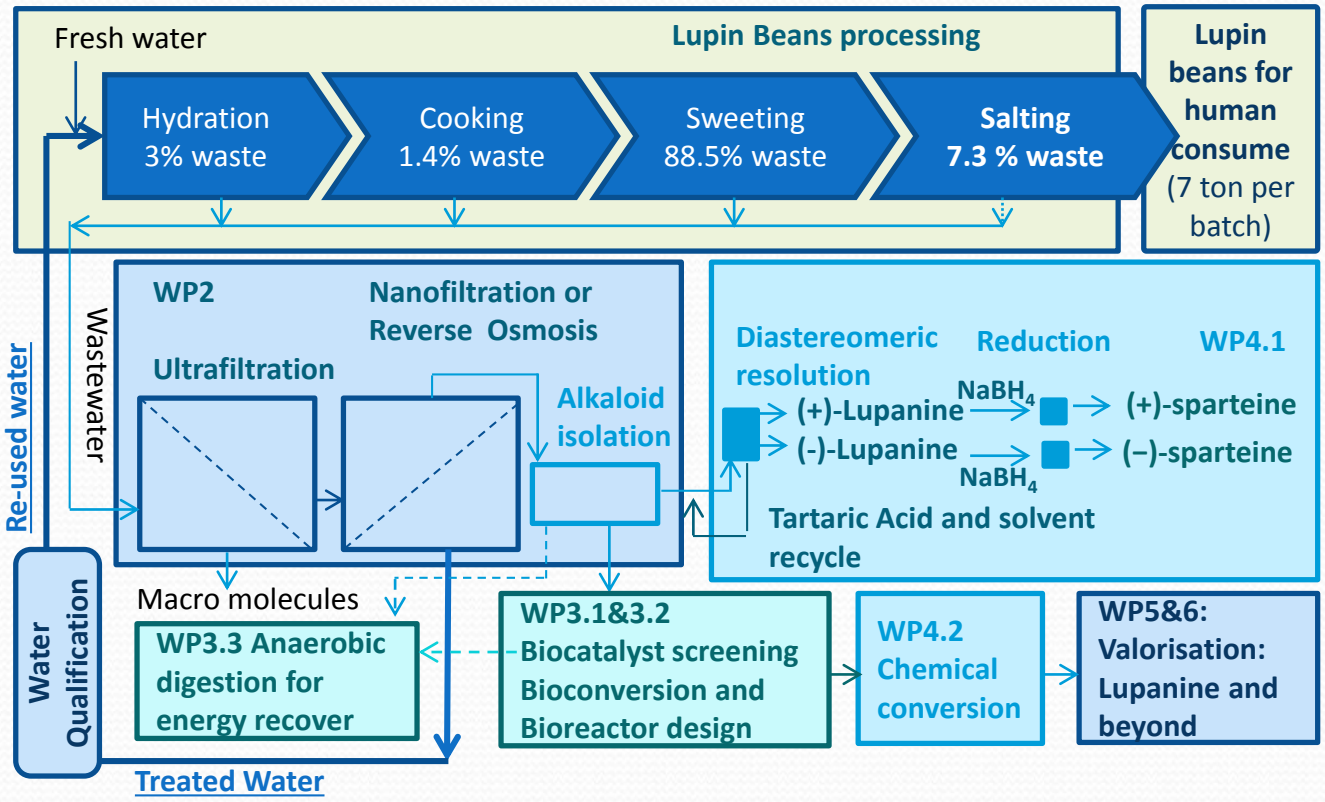
Project overview



We aim to recover 80% of wastewater

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Work package overview

- **WP1: Consortium Management,** *(CAfonso (FF-UL)*
- **WP2: Process and separation design and validation,** *(FMalpei, POLIMI)*
  Task 2.1: Ultrafiltration and nanofiltration, *(FMalpei, FFerreira, TSchäfer)*
  Task 2.2: Membrane adsorber development, *(TSchäfer, FFerreira)*
  Task 2.3: Process integration and validation, *(FFerreira, CAfonso, DBastos, F.Malpei)*
- **WP3: Biological valuation of isolated fractions,** *(MKoutinas, CUT)*
  Task 3.1: Screening for biocatalyst targeting a selected range of alkaloids, *(MKoutinas, FMalpei)*
  Task 3.2: Development of a bioreactor process for alkaloids bioconversion, *(MKoutinas, FFerreira)*
  Task 3.3: Valuation of macromolecules through anaerobic digestion for energy production, *(FMalpei, MKoutinas)*
- **WP4: Chemical valuation of isolated compound,** *(CAfonso, FF-UL)*
  Task 4.1: Chiral isolation of lupanine by diaesteromeric resolution, *(CAfonso, FFerreira)*
  Task 4.2: Chemical conversion of Lupanine in Sparteine, *(CAfonso, NMaulide)*
  Task 4.3: Chemical conversion of products from bioconversion in added value compounds, *(CAfonso)*
- **WP5: Cost effectiveness assessment and water qualification,** *(DBastos, TEP)*
  Task 5.1: Cost effectiveness analysis, *(DBastos, FFerreira, CAfonso)*
  Task 5.2: Water qualification, *(DBastos, FFerreira, CAfonso)*
  Task 5.3: Sustainable business model *(FFerreira, CAfonso, DBastos)*
- **WP6. Evaluation of the concept beyond the Lupanine case study,** *(FFerreira, IST-ID/UL)*
  Task 6.1: Impact assessment on alkaloid contamination on food industries wastewater, *(CAfonso)*
  Task 6.2: Feasibility assessment of key unit operations, *(CAfonso, FFerreira, TSchäfer)*
  Task 6.3: Processes and cost effectiveness analysis, *(CAfonso, FFerreira, DBastos)*
- **WP7- Results dissemination and exploitation,** *(C.Afonso, FF-UL)*

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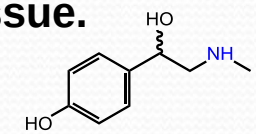
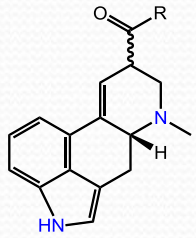
Beyond the lupanine case study

- **Alkaloids are mainly present in higher plants being known from ancient times as poisons, stimulants, narcotics, insecticides, aphrodisiacs and medicines;**
- **Alkaloids are present in the modern Western diet contained in vegetables, tea or food supplements and may cause adverse health effects due to high toxicity to mammals even when consumed in small quantities;**
- **Ergot Alkaloids (EAs) has been responsible for serious poisoning epidemics in the human history still constituting a cause for serious economic losses in grain production especially when the application of fungicides against sclerotia fails;**
- **Selected examples of potential implementation of the proposed technology:**
  - **The EAs detoxification of wastewater from beer production and isolation of the main EA molecules;**
  - **Isolation and valorization of α-solanine and α-chacoline, present in potato peel waste;**
  - **Olive mill wastewater issue.**



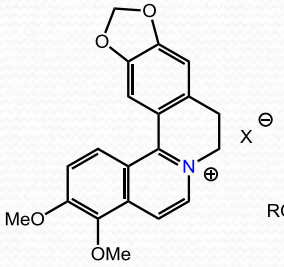
***(D,L)-p*-synephrine**

pharmaceutical active molecule present in Citrus aurantium (bitter orange)



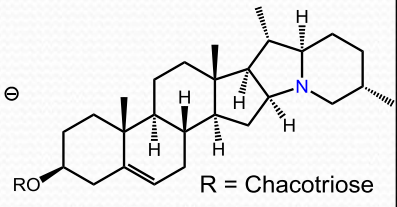
Ergot alkaloids (EAs)

core structure of toxic Eas produced by the fungus species *Claviceps*



Berberine

undesirable contaminant of *Rhizoma Coptidis*



α-Chaconine

main glycosteroidal alkaloid from potato peel waste

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Expected impacts

- **Contribution to the goals of the WaterWorks 2014 Cofunded Call:**

  Developing low-energy, low cost, low chemical and high-efficiency technologies and processes for water treatment and desalination;

  Developing water recycling technologies and concepts leading to the production of safe resources for reuse;

  Promoting innovative separation and extraction technologies in industrial areas to harvest resources from wastewater;

- **Transnational added-value of the collaboration between consortium partners;**
- **Potential impact of the proposed innovative solutions and/or services on business/industries, improvement of social wellbeing and environment; several socio-economic effects are considered;**

This Team will certainly put the maximum efforts, knowledge, expertise and dedication to achieve the success of this project

Thank You