Techno-economic evaluation of an integrated biorefinery using dairy and winery by-products for the microbial oil production

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3rd INTERNATIONAL CONFERENCE
on Sustainable Solid State Waste Management
Tinos 2nd - 4th July 2015

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AGRICULTURAL UNIVERSITY OF ATHENS

Outline

- Introduction
  - ✓ Global cheese whey and wine lees production
- Techno-economic Analysis of the new processes
  - ✓ Extraction of added-value products
    - ✓ Antioxidants, tartaric acid, ethanol and fermentation supplement rich in N sources and other nutrients
    - ✓ WPC60 and fermentation supplement rich in C source
  - ✓ Production of microbial oil via fermentation
    - ✓ From cheese whey derived lactose
    - ✓ From wine lees hydrolysates
- Conclusions and future recommendations

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MSc direction entitled "*Food Bioprocesses and Biorefineries*"

Organisation: Department of Food Science and Technology, Agricultural University of Athens

Duration: 18 months

Language: Greek

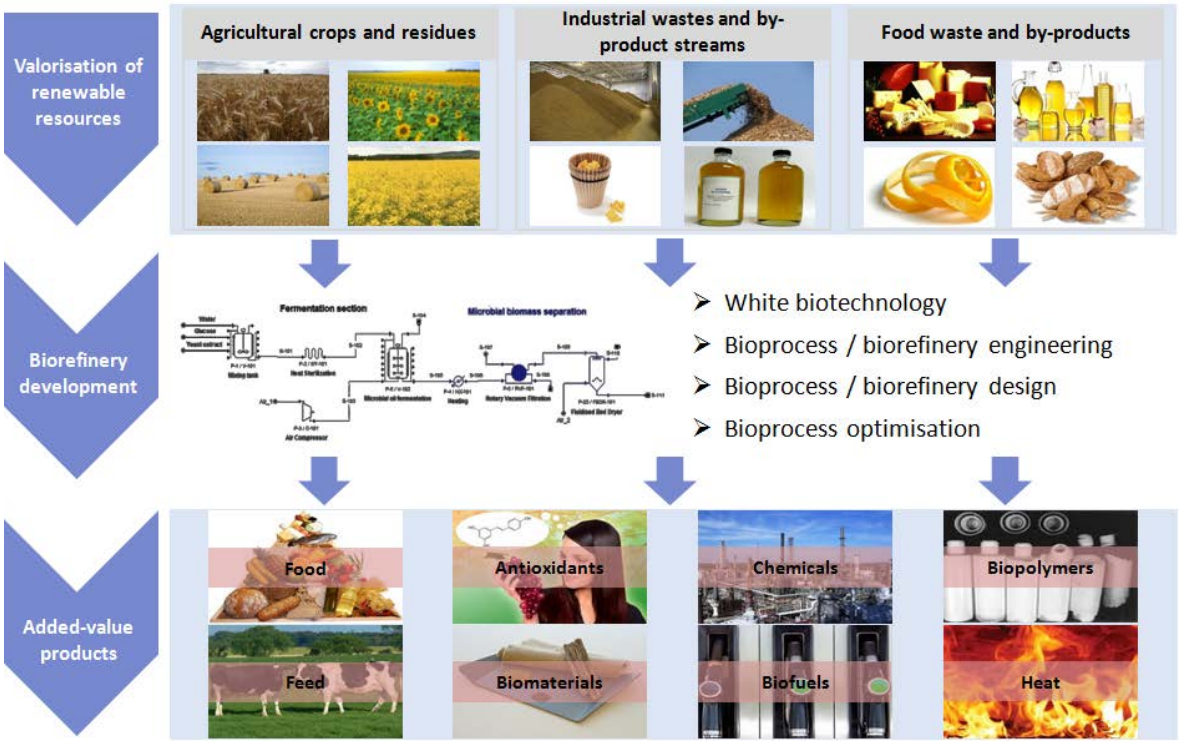
Website: www.aua.gr/bioprocesses/msc-course.html

Contact: Dr A. Koutinas (akoutinas@aua.gr)

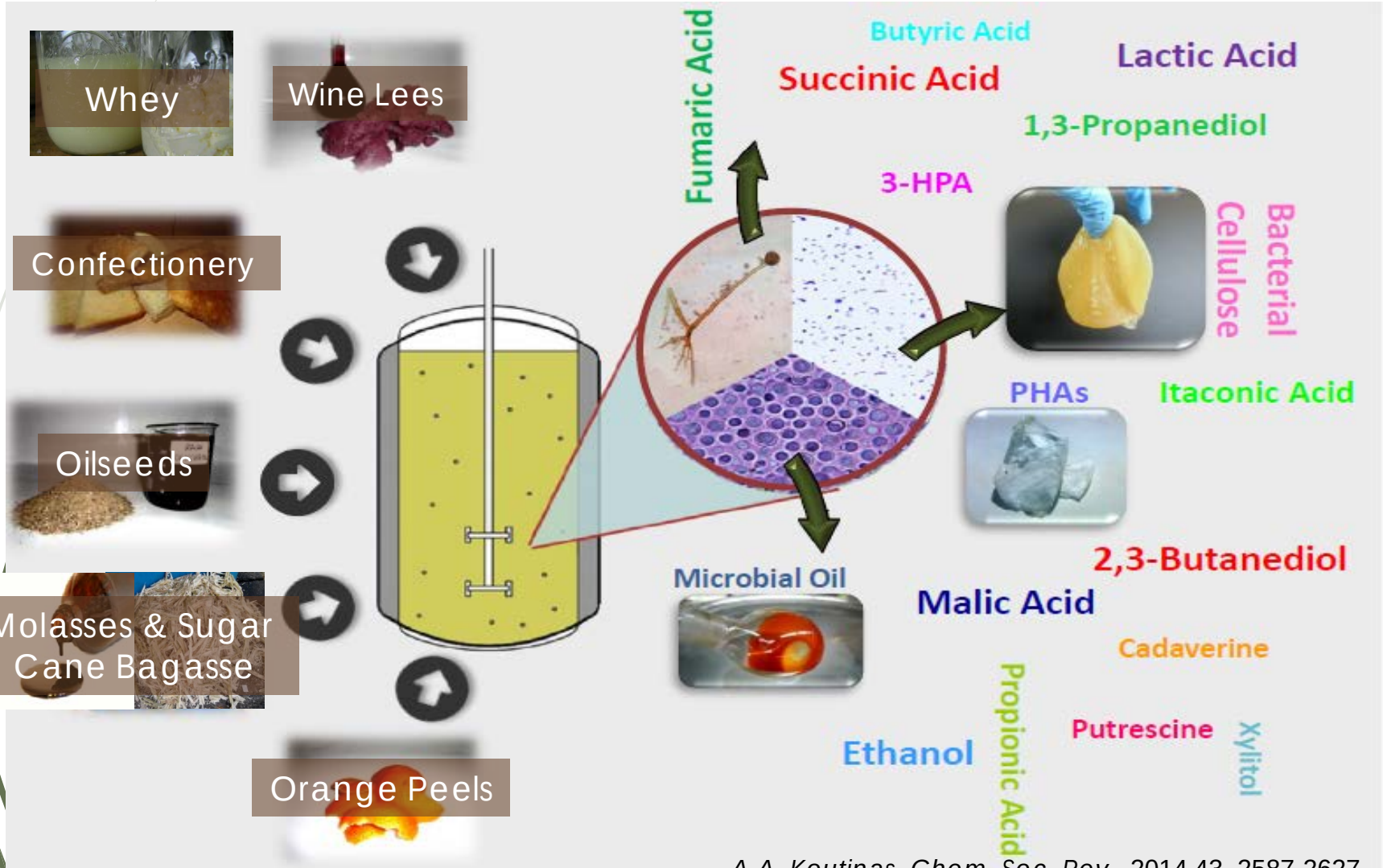
Scope: to provide novel knowledge and expertise in bioprocesses and biorefinery development with special emphasis given to integration opportunities in the food industry sector. Graduates will be trained in state of the art bioprocess- and biorefinery-based value chains following an interdisciplinary approach combining academic expertise in chemistry and analysis of renewable resources, biotechnology, food science and technology and (bio)chemical engineering.

Modules:

1. Experimental design and analysis
2. Food chemistry (optional)
3. Food engineering (optional)
4. Food waste management
5. Industrial (white) biotechnology
6. Chemistry and analysis of renewable resources
7. Bioprocess / biorefinery design
8. Bioprocess / biorefinery engineering
9. Bioprocess modelling and optimisation



Fermentation cases of FSCW integrated in biorefinery schemes



A.A. Koutinas, Chem. Soc. Rev., 2014,43, 2587-2627

Common Processes in Food Waste Biorefineries

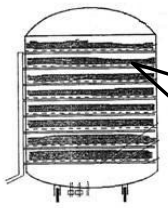
Extraction of high added value chemicals

Food Wastes

Upstream Processing

Enzymatic Hydrolysis

Solid State Fermentation

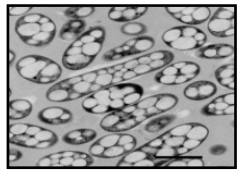


Fermentation

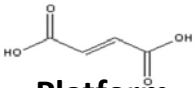
Downstream processing

Filtration
L-L Extraction
Distillation
Crystallisation
Drying

Value-Added Materials



Biopolymers



Platform chemicals

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Cheese whey production

- 160 million tons are produced annually worldwide
- **6-9 L** of cheese whey produced per **1kg of cheese**
- **High organic content** (60 - 80 COD g/L)

Composition	% w/v
Lactose	4.5 - 5.0
Soluble proteins	0.6 - 0.8
Lipids	0.4 - 0.5
Mineral salts	8.0 - 10.0

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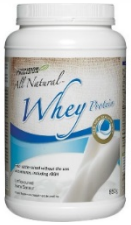
Cheese Whey Valorization

Whey proteins isolation

- pharmaceutical field
- food additive
- feed products

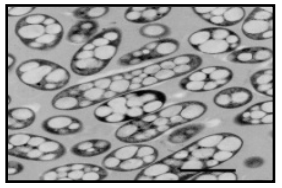


Whey cheese production

- Ricotta
- Mizithra

High-added value products via fermentation

- Fermented whey beverages
- Ethanol
- Single cell protein
- Organic acids
- **Microbial oil**



Biopolymers

Platform chemicals

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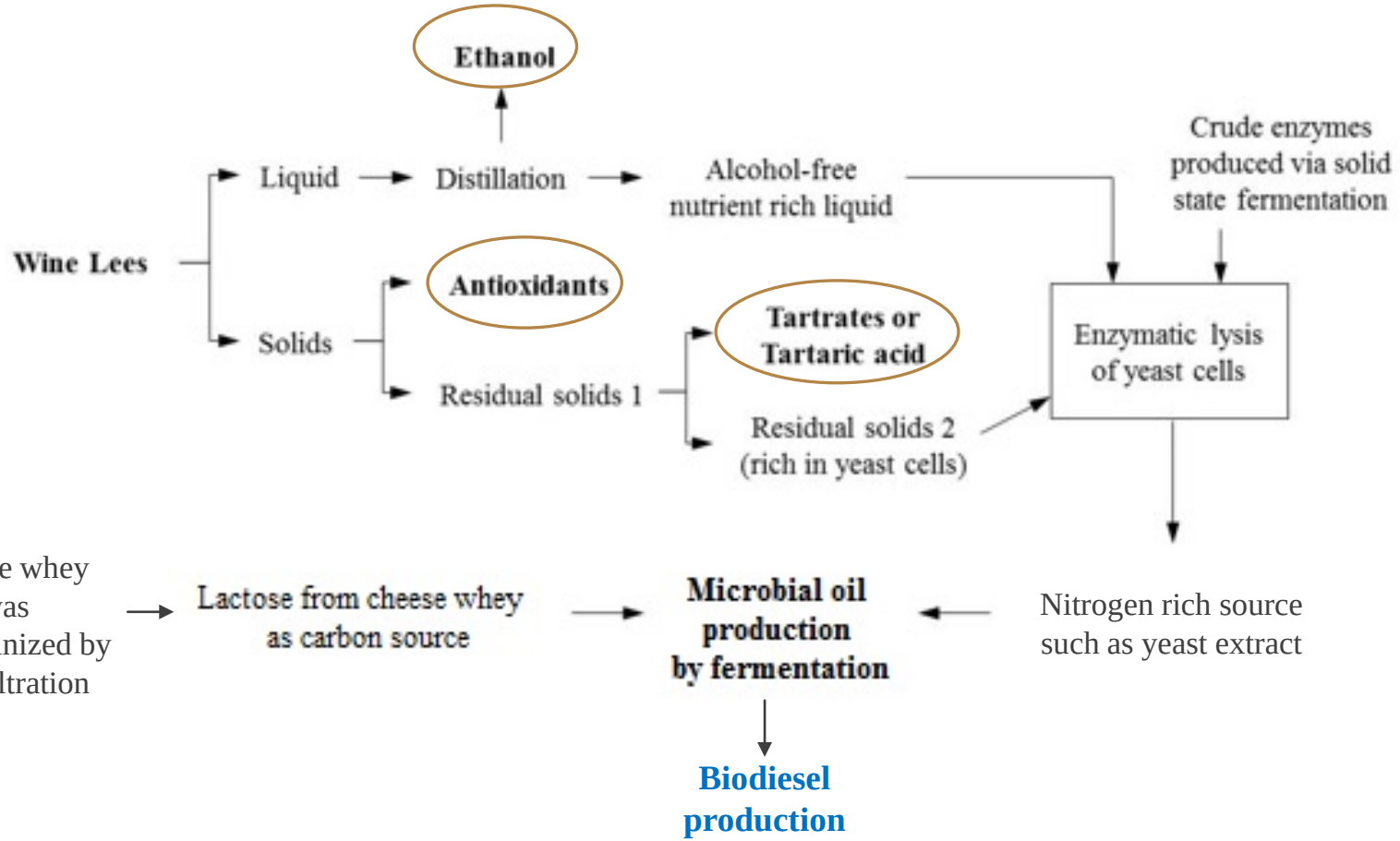
Winery Wastes

- Worldwide wine production amounts to ca. 280 million hectoliters

Grape pomace, grape stalk and **wine lees** the main wastes

- Wine lees: 2 - 6% of the total volume of wine produced
- Mainly contains ethanol, tartaric acid, phenolic compounds and yeast cells

Process flow of cheese whey-wine lees biorefinery



Ref: C. Dimou et al. / Food Research International 73 (2015) 81–87

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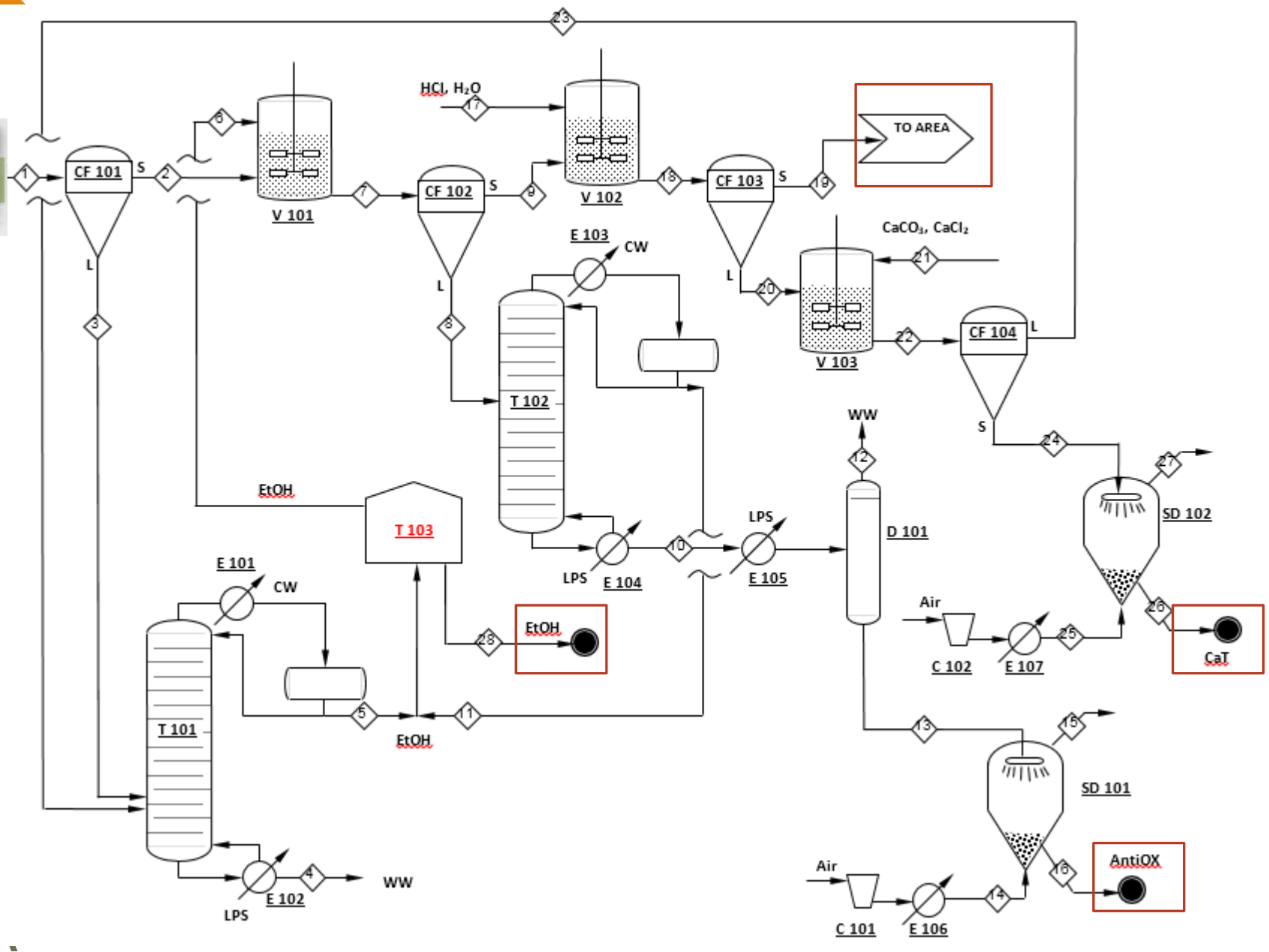
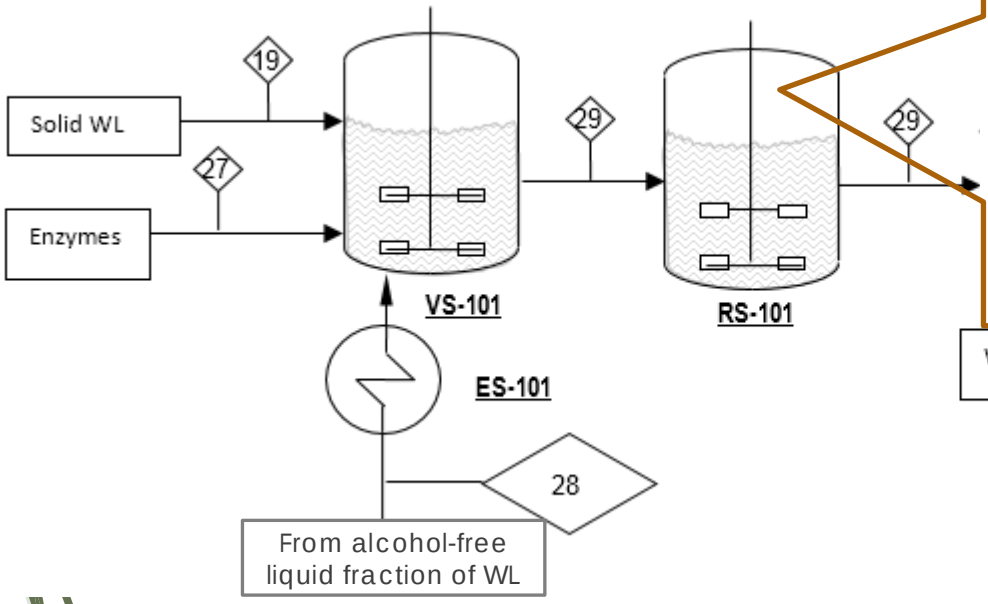
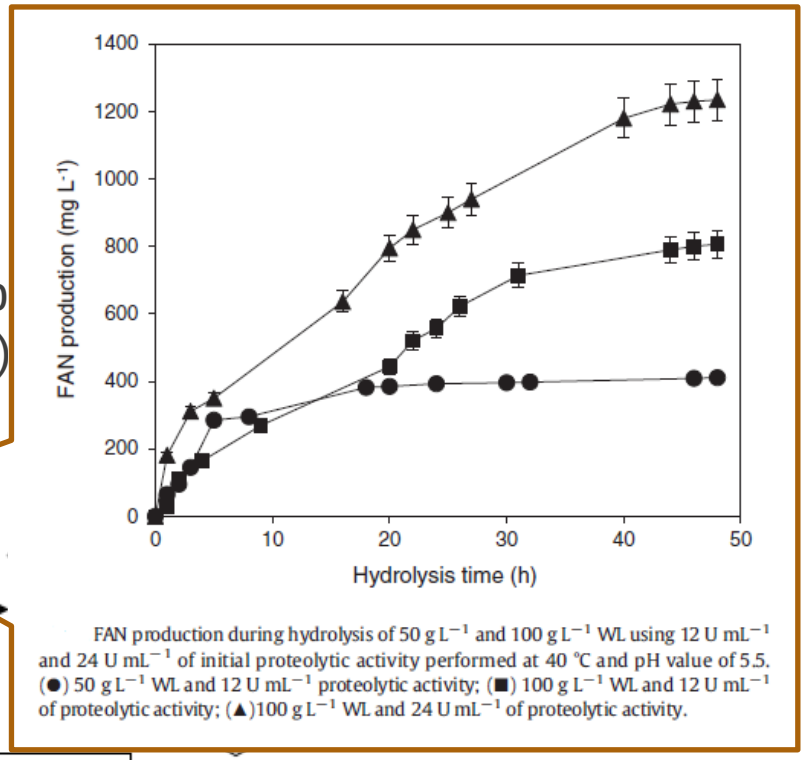
PFD for Wine Lees Valorisation



Production of a fermentation supplement rich in N source

- Hydrolysis of the solid fraction of WL
  - Using commercial enzymes
  - Or crude enzymes produced in the
- Production of a generic medium suitab fermentation medium (rich in N source)





FAN production during hydrolysis of 50 g L^{-1} and 100 g L^{-1} WL using 12 U mL^{-1} and 24 U mL^{-1} of initial proteolytic activity performed at 40 °C and pH value of 5.5. (●) 50 g L^{-1} WL and 12 U mL^{-1} proteolytic activity; (■) 100 g L^{-1} WL and 12 U mL^{-1} of proteolytic activity; (▲)100 g L^{-1} WL and 24 U mL^{-1} of proteolytic activity.

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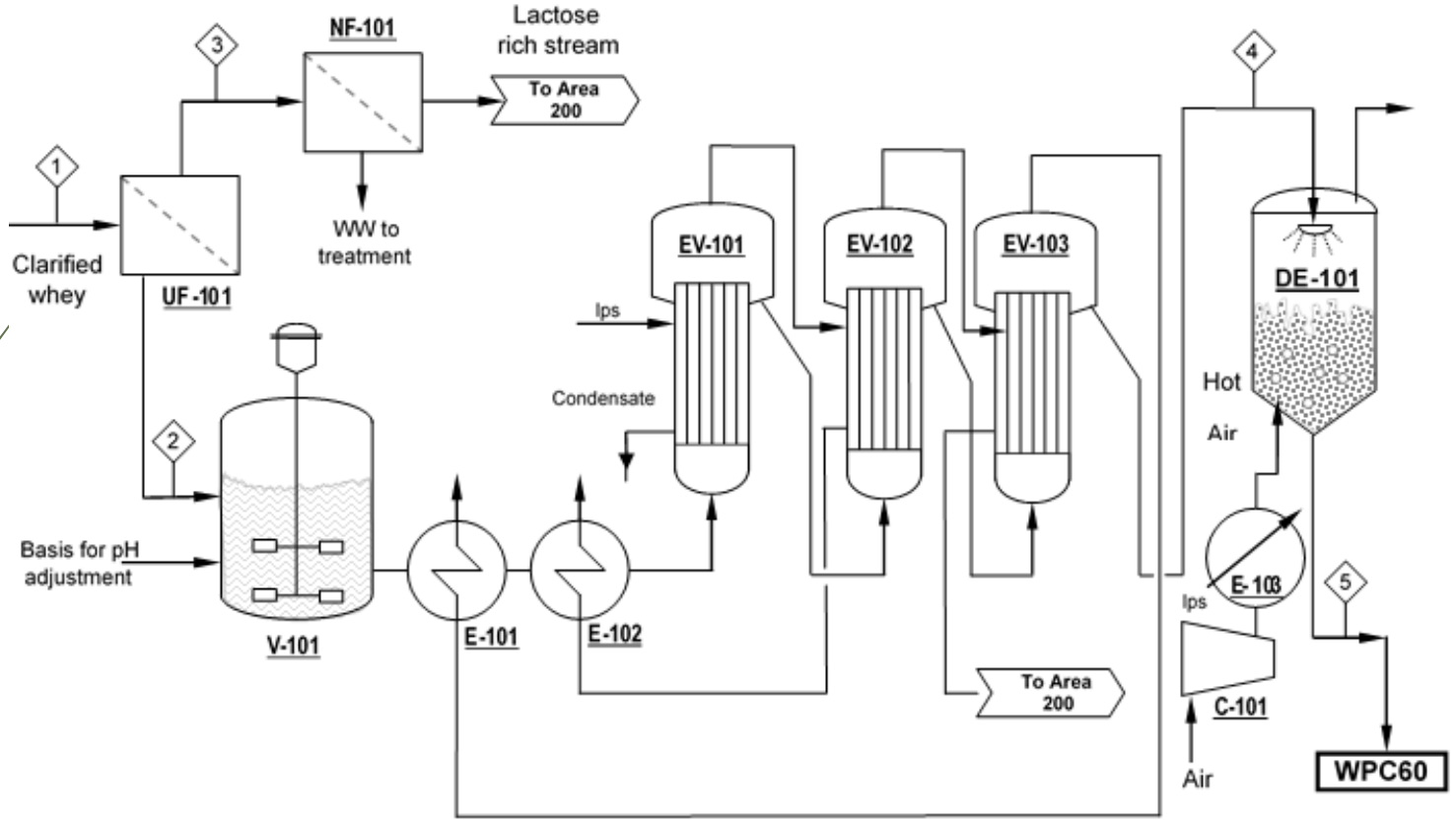
PFD for Cheese whey



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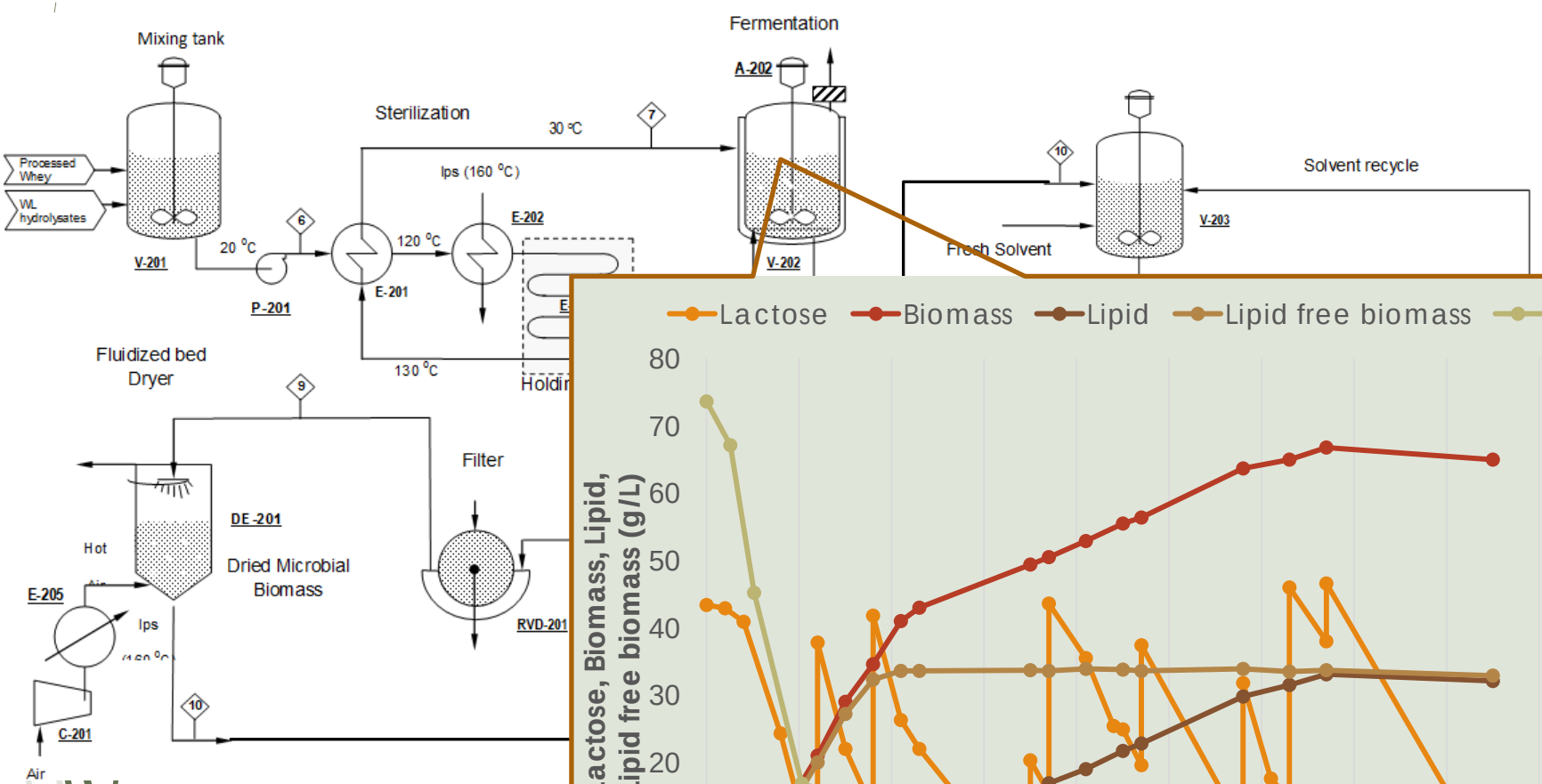
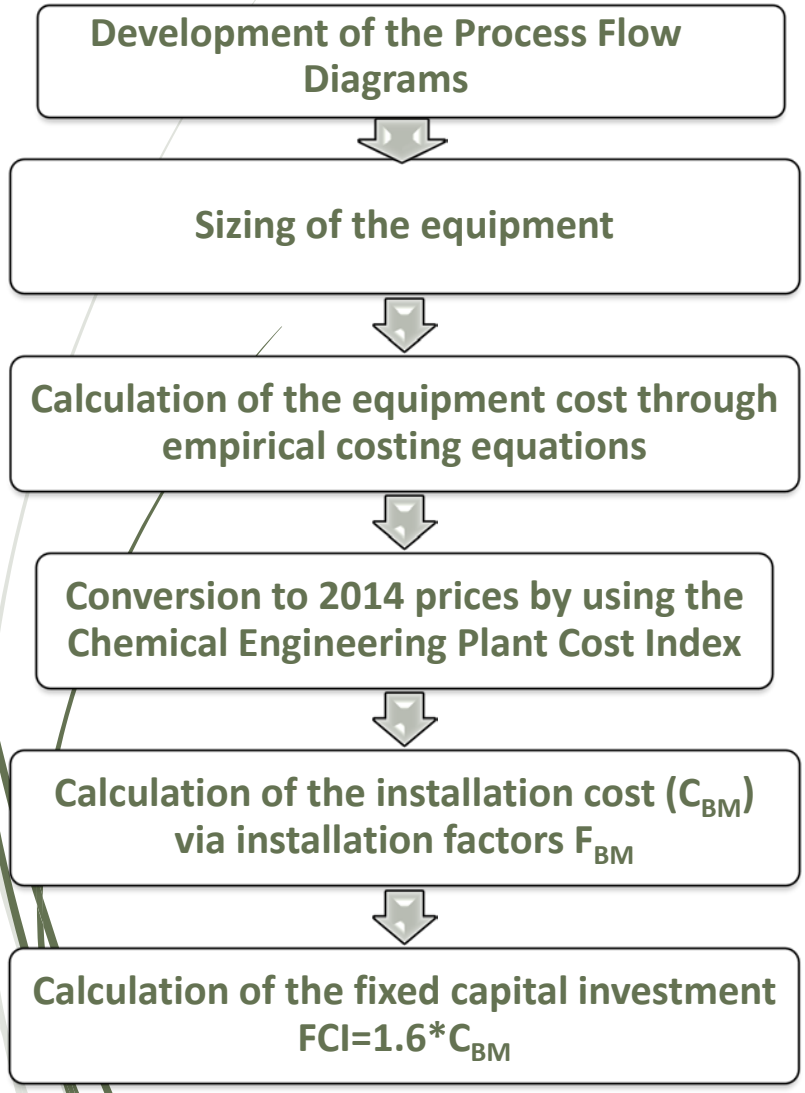
PFD for Microbial Oil Production via fermentation



PFD of Microbial Oil Pro

Ref: A.A. Koutinas et al., Fuel 116 (2014)

Constructing a Techno-economic Analysis



Also the total manufacturing cost is estimated

- Cost of Raw materials
- Utilities Cost
- Labor Cost
- Wastewater treatment cost

$$COM_{woD} = 1.23(C_{RM} + C_{UT} + C_{WT}) + 2.73C_{OL} + 0.18FCI$$

Ref: Peters M.S., Timmerhaus K.D, West R.E., Plant Design & Economics for Chemical Engineers, 2003, NewYork, USA

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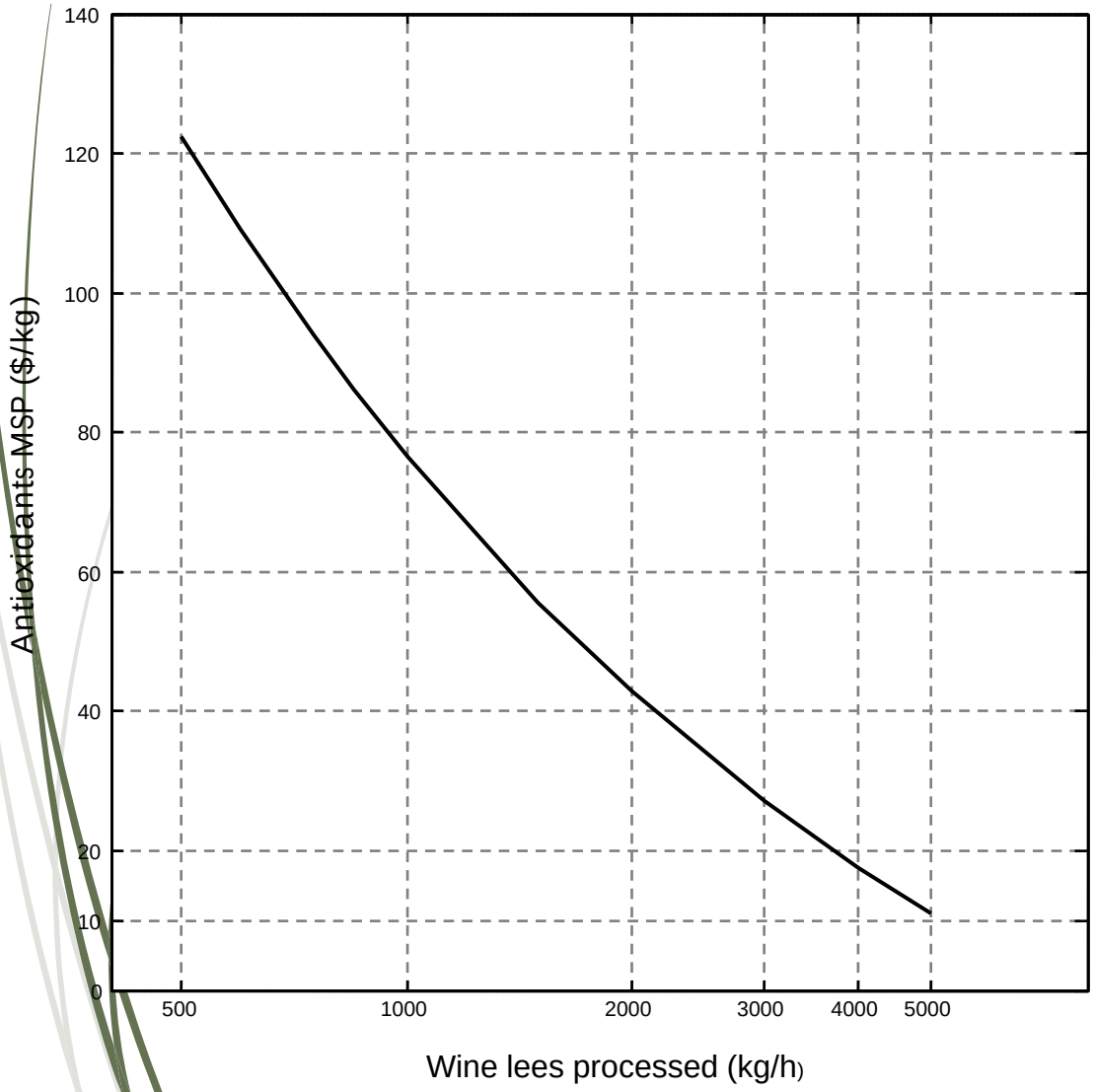
Minimum selling price (MSP) of antioxidants as function of the amount of wine lees processed



- The MSP of the extracted antioxidants is 122 $/kg when 500 kg/h of wine lees are processed.
- **The MSP is reduced to 11 $/kg when 5000 kg/h of wine lees are processed.**
- The proposed process is feasible even in local level in countries like France, Italy or Spain.
- Centralised development is required in countries like Greece as the total production of wine lees is around 27,000 t/yr.

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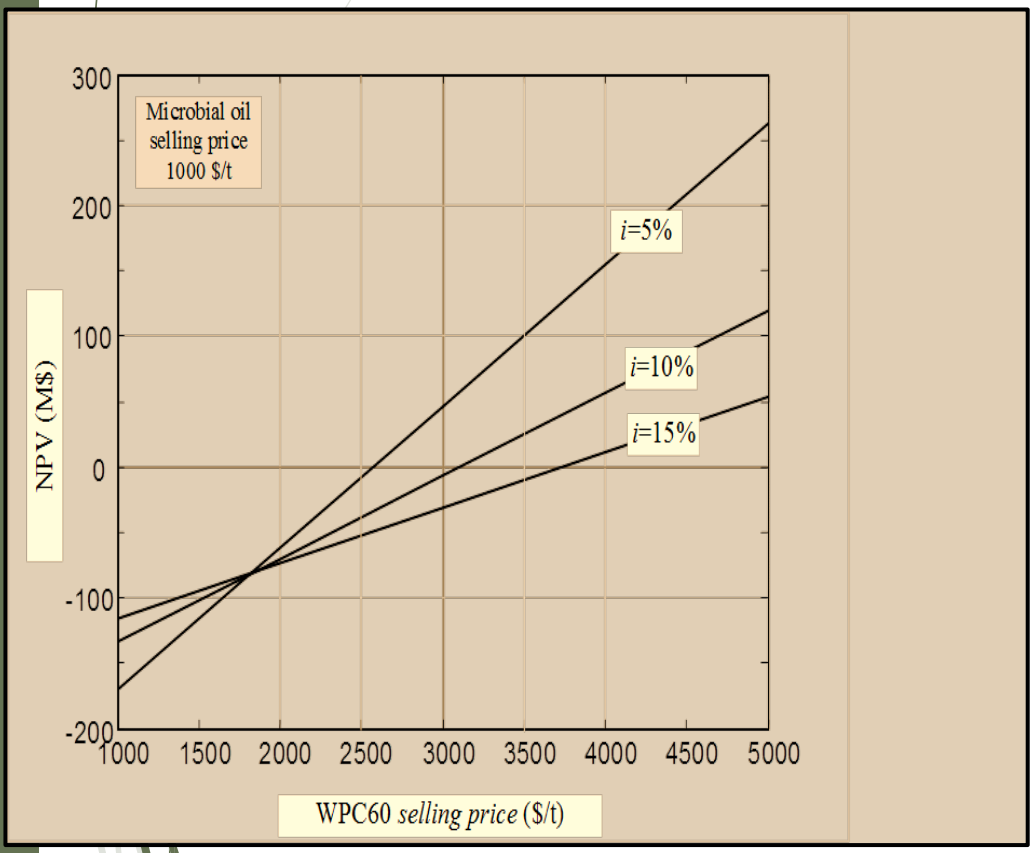
Sensitivity analysis of the WPC60 selling price



- **The unitary production cost of microbial oil is ca. 2.1 $/kg when the plant produces 10,000 t of MO per year** (the required input is 1.2 million t of cheese whey)
- The process can be developed in major EU cheese producing countries, e.g. Germany, France and Italy
- This cost is higher than the selling price of several vegetable oils (1-1.6 $/kg in the last 5 years).
- The selling price of vegetable oils is constantly increasing.
- The production of MO from cheese and winery wastes could be feasible in the future

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Conclusions and Future recommendations

- Extraction of high added value products is necessary to ensure the economic viability of biorefineries
- Fermentation performance (yields, concentrations and productivities) play a crucial role in the development of cost-competitive processes
- Optimum conditions of fermentation should be examined in order to reduce the microbial oil production cost
- Life cycle assessment for the calculation of carbon footprint of the proposed biorefinery

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Thank you for your attention

This work is part of the "Valorization of cheese dairy and winery wastes for the production of high added-value products" project (19SMEs2009)

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