



Integrated biorefinery development for the extraction of value-added components from orange peel waste streams

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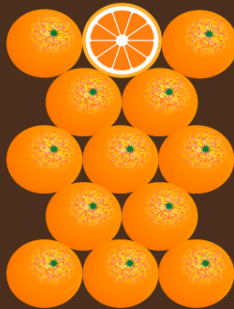
Objectives



- Valorisation of orange peel residues
- Biorefinery development for the production of value-added products
- Extraction of phenolic compounds at different solid to liquid ratios
- Extraction of pectin with different acids
- Bioprocess development for microbial oil production with the yeasts *Lipomyces starkeyi* and *Cryptococcus curvatus*

Production of oranges in the EU (2018)

EU
6.5 million tonnes
274 000 ha



SPAIN
3.6 million tonnes (56%)
140 000 ha



ITALY
1.6 million tonnes (24%)
83 000 ha



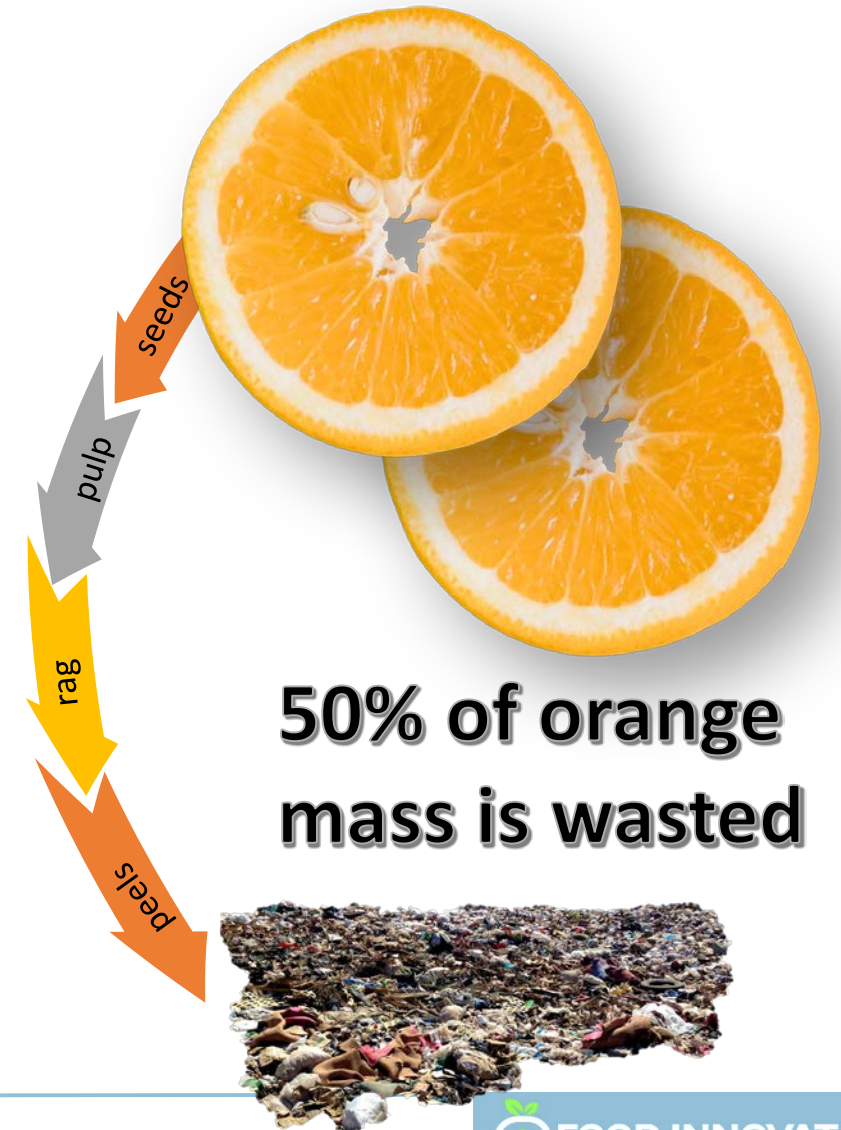
GREECE
0.9 million tonnes (14%)
32 000 hectares



ec.europa.eu/eurostat

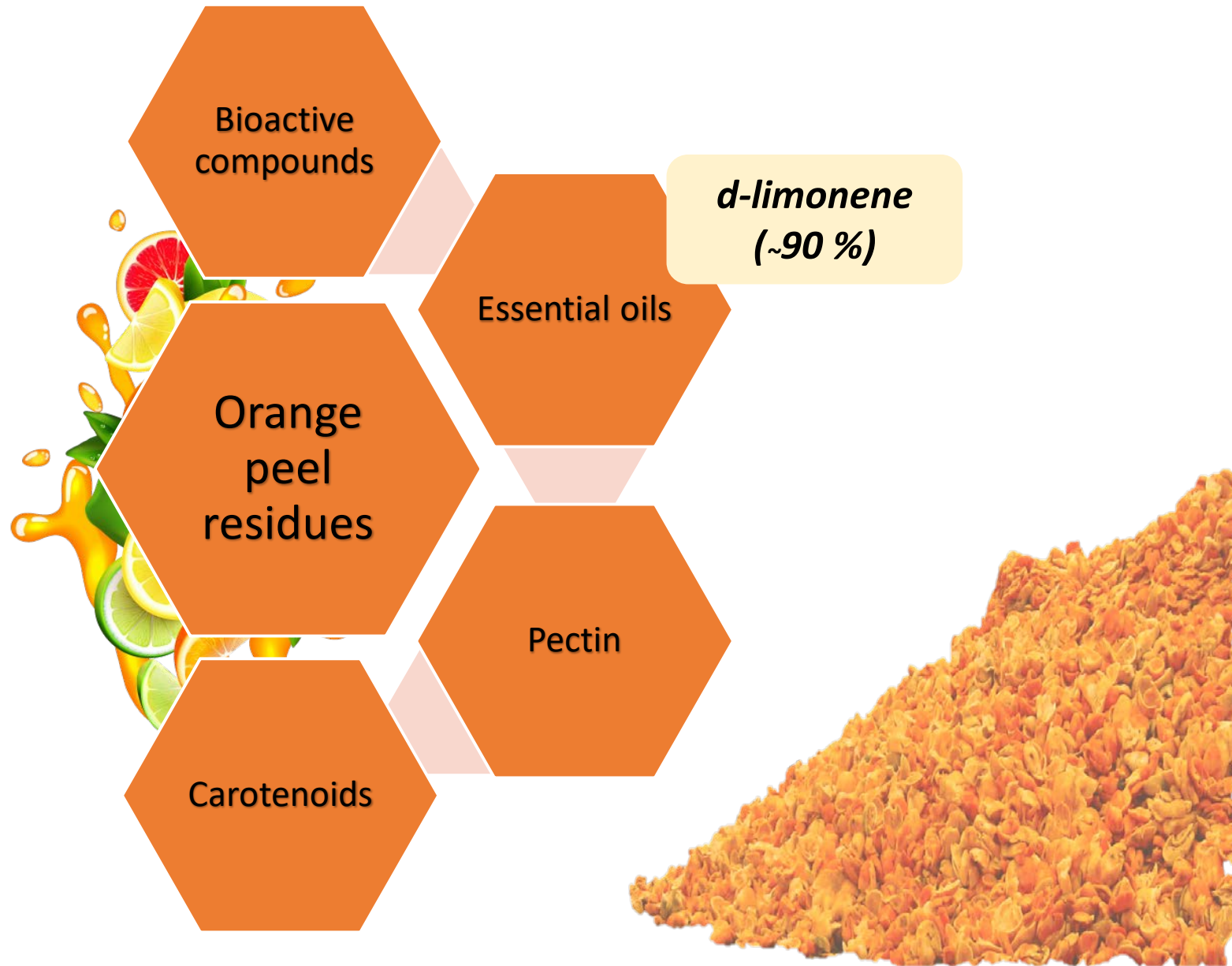
- Worldwide production of oranges in 2019/2020 was 46 million t
- Annual production in Europe was 6.5 million t in 2018
- Juice production from catering services results in generation of 24.3 million t of waste per year
- Orange waste is also disposed from open markets

Orange peel residues

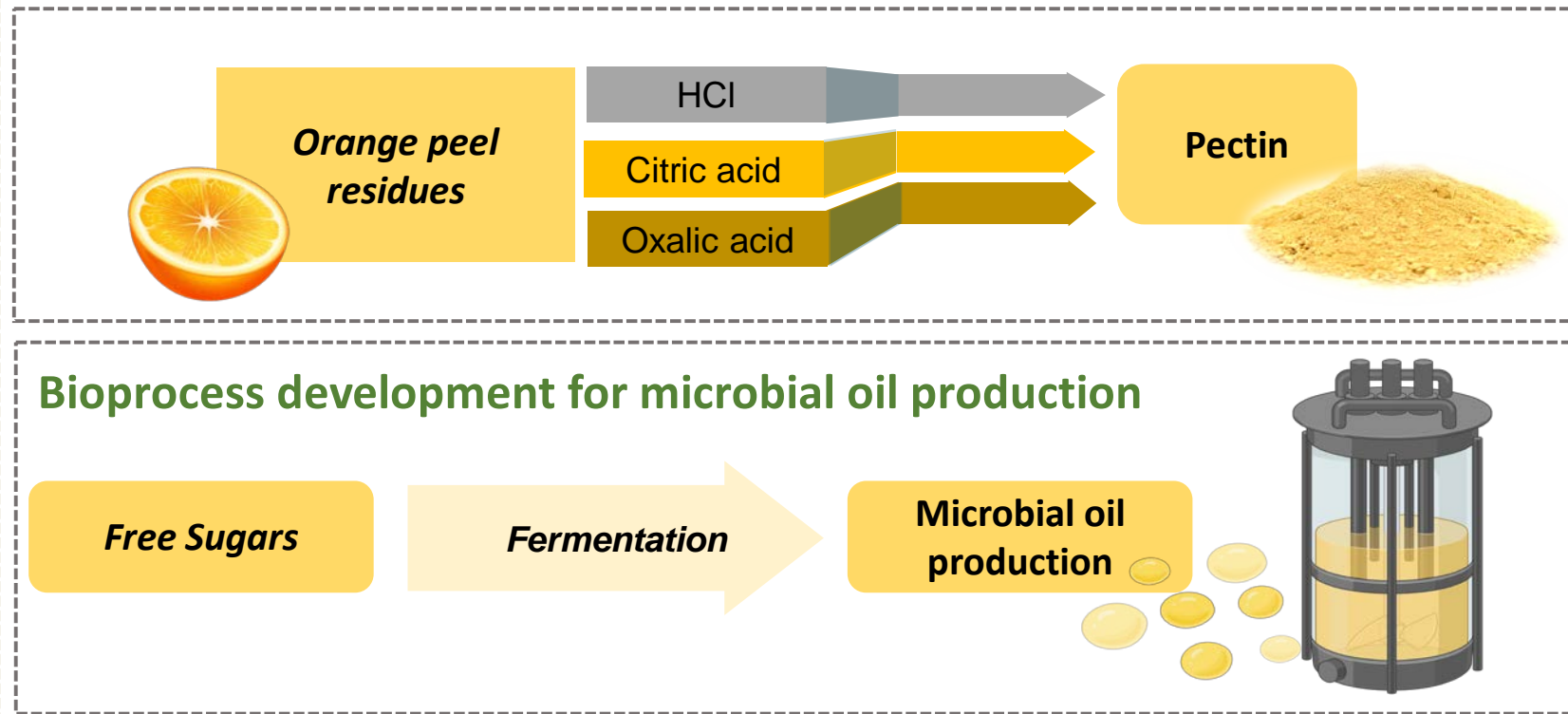
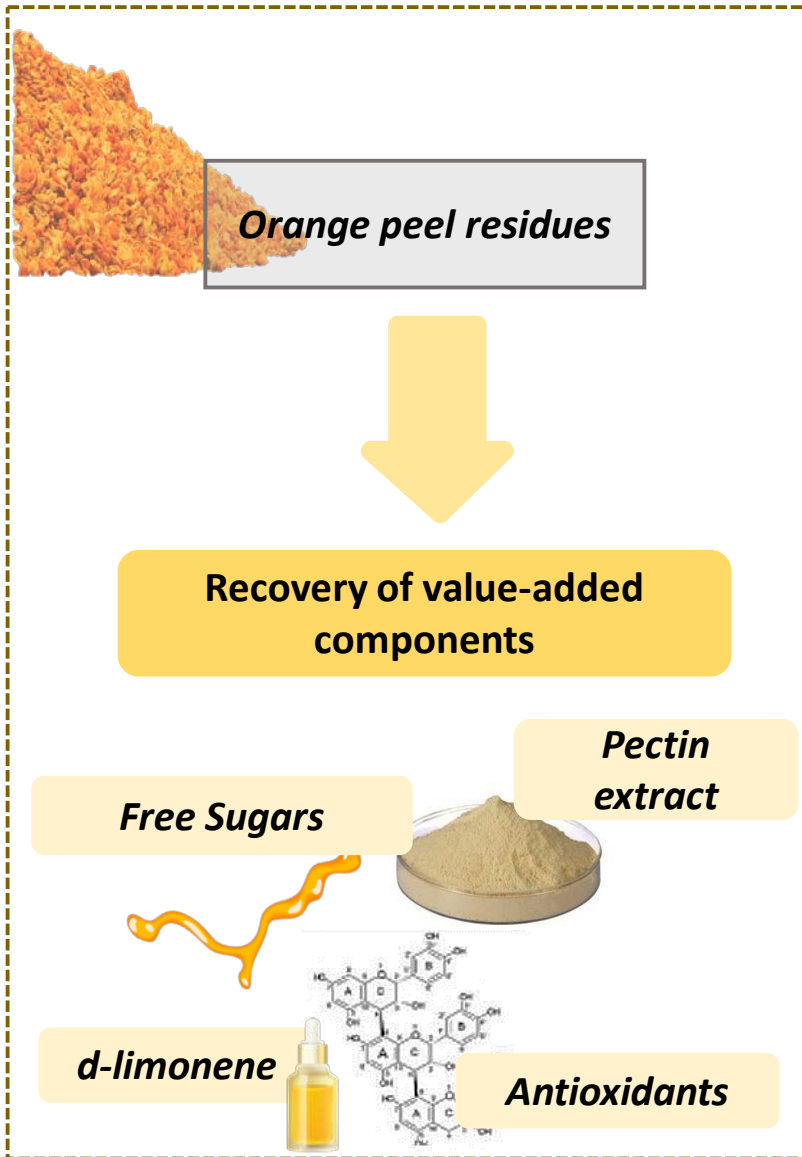


Orange peel residues

- Orange peels contain value-added components
- Rich in carbohydrates (free sugars, cellulose and hemicellulose)
- Orange peels is an ideal feedstock for biorefinery development



Experimental set up

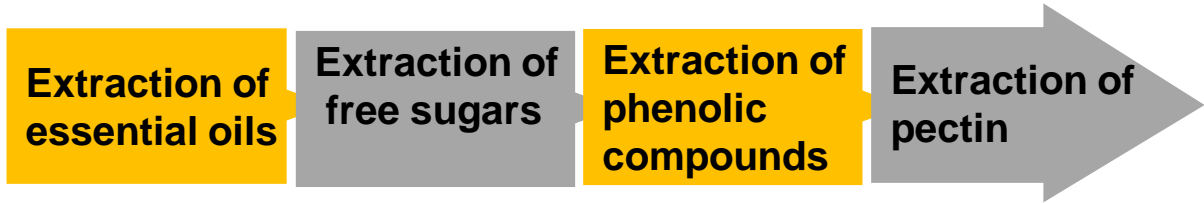


Composition of orange peel residues

Composition (% dry basis)	This study	Literature
Ash	4.0	1.7 – 4.2
Protein	6.4	1.8 – 9.1
Free sugars	31.3	15.0 – 47.8
Oil	2.1	0.5 – 4.0
Pectin	17.6	14.1 – 25.0
Phenolics	0.96	
Glucan	23.1	8.1 – 37.1
Hemicellulose	3.6	5.7 – 11.1
<i>Arabinan</i>	1.7	1.8
<i>Mannan</i>	0.5	0.5
<i>Galactan</i>	1.8	2.0
<i>Xylan</i>	0.8	1.1
Lignin	5.1	0.6 – 7.2



Extraction of value-added co-products from orange peels

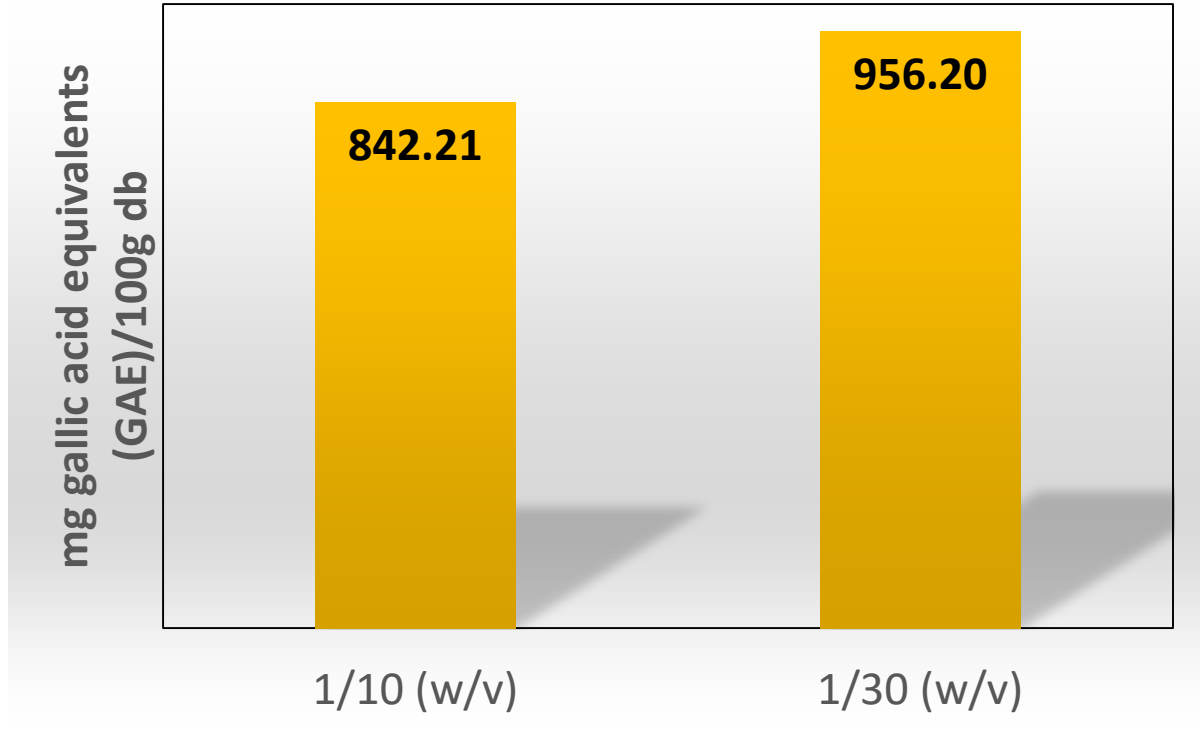


Hydrodistillation of essential oils



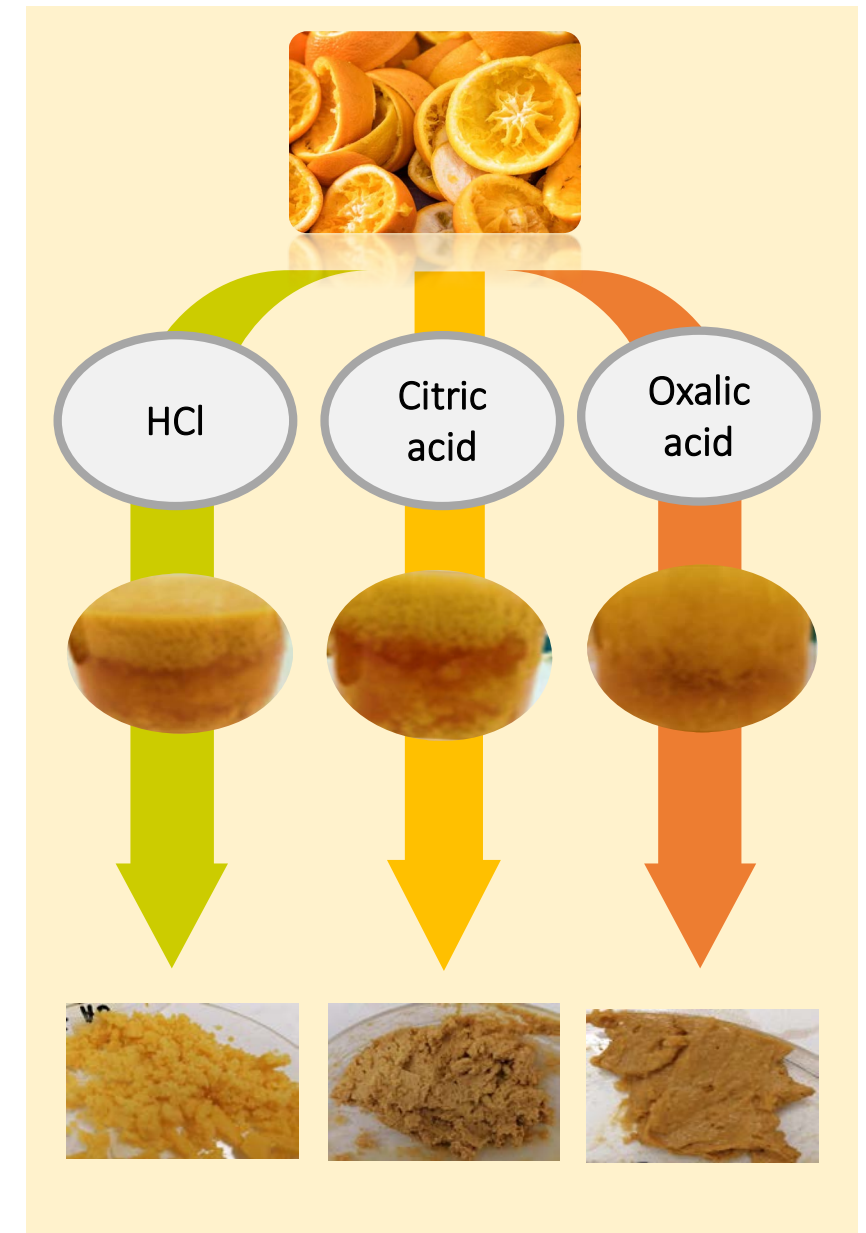
- Extraction of phenolic compounds
- Solid to liquid ratio 1:10
 - Solid to liquid ratio 1:30

Extraction conditions
70% EtOH
Ultrasound 20 min, x 3

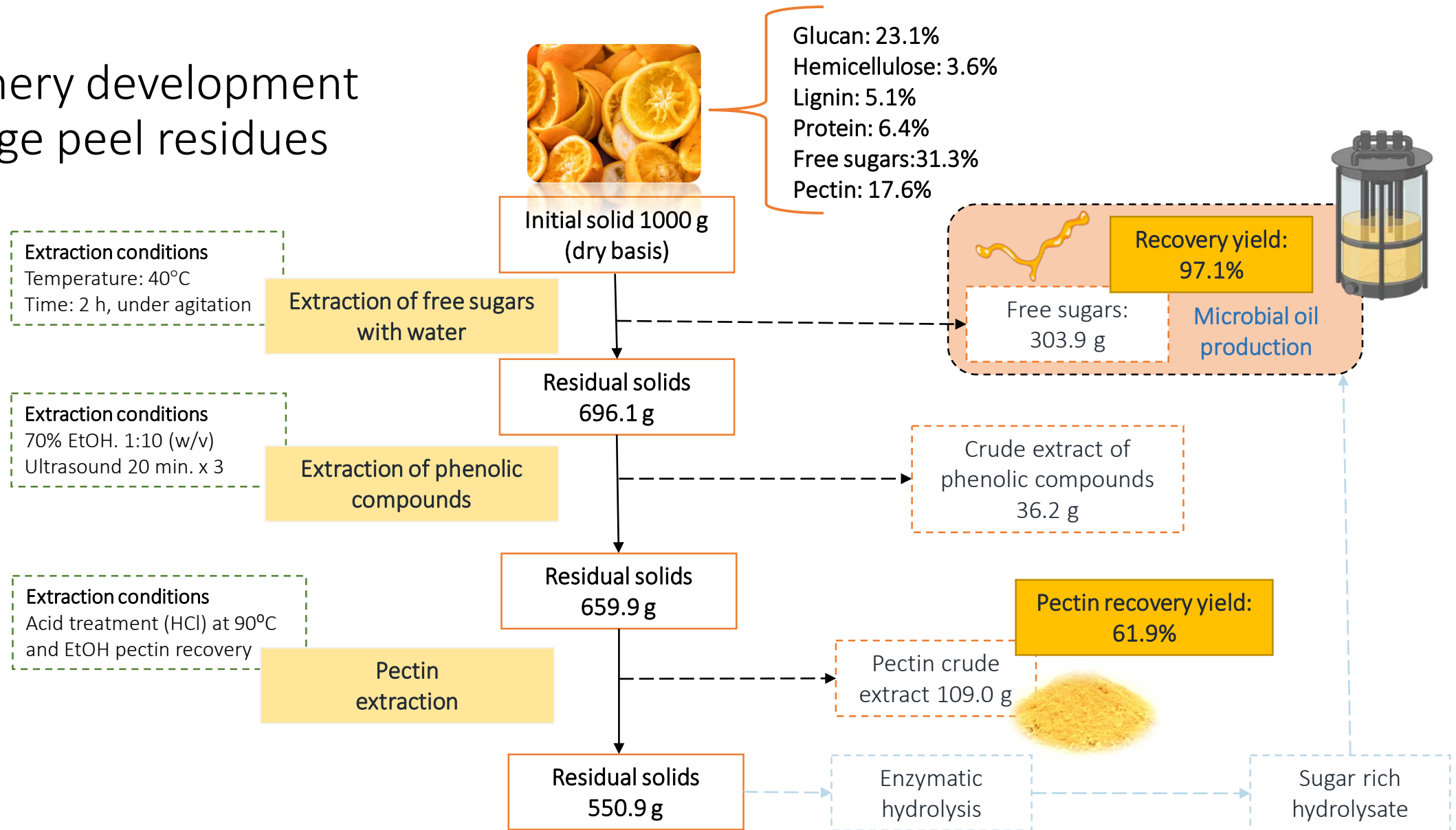


Pectin extraction and characterization

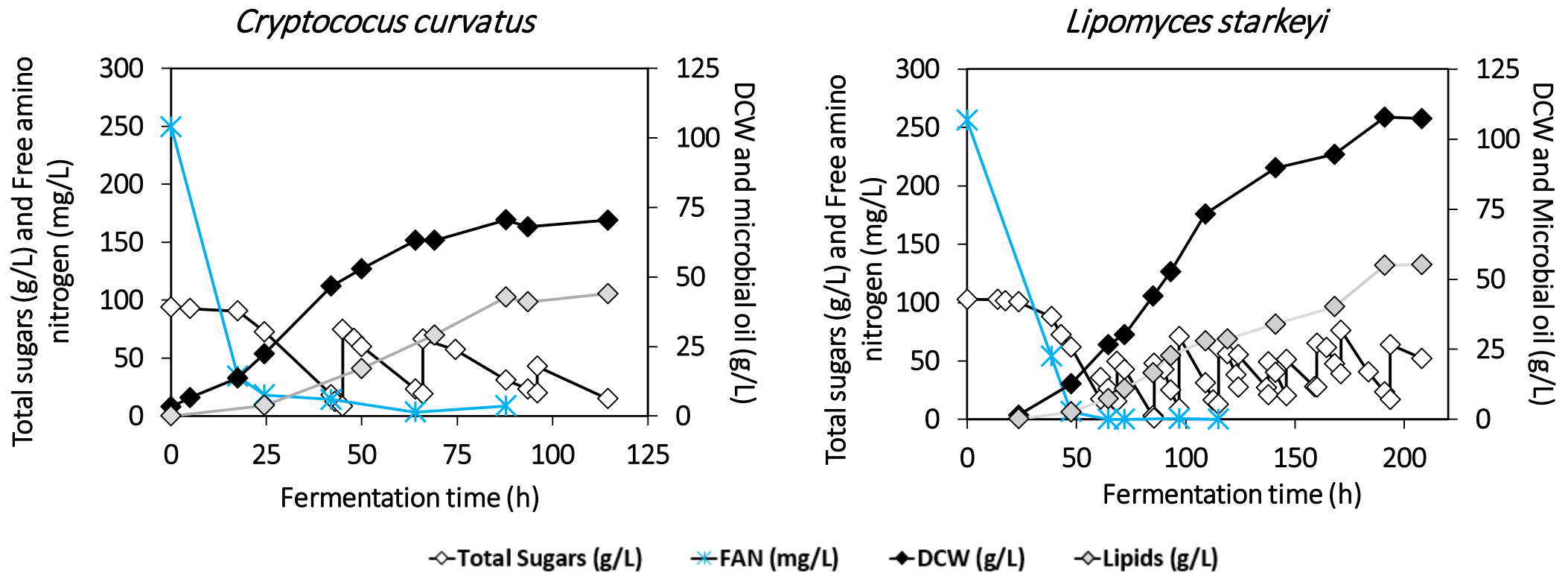
	HCl	Citric	Oxalic
Crude pectin yield (%)	17.6	21.6	46.7
Galacturonic acid (%)	69.4	48.6	28.1
Esterification Degree (%)	79.66	42.85	55.56
Ash (%)	11.11	11.26	11.35
Free sugars (%)	10.24	3.06	1.72



Biorefinery development of orange peel residues



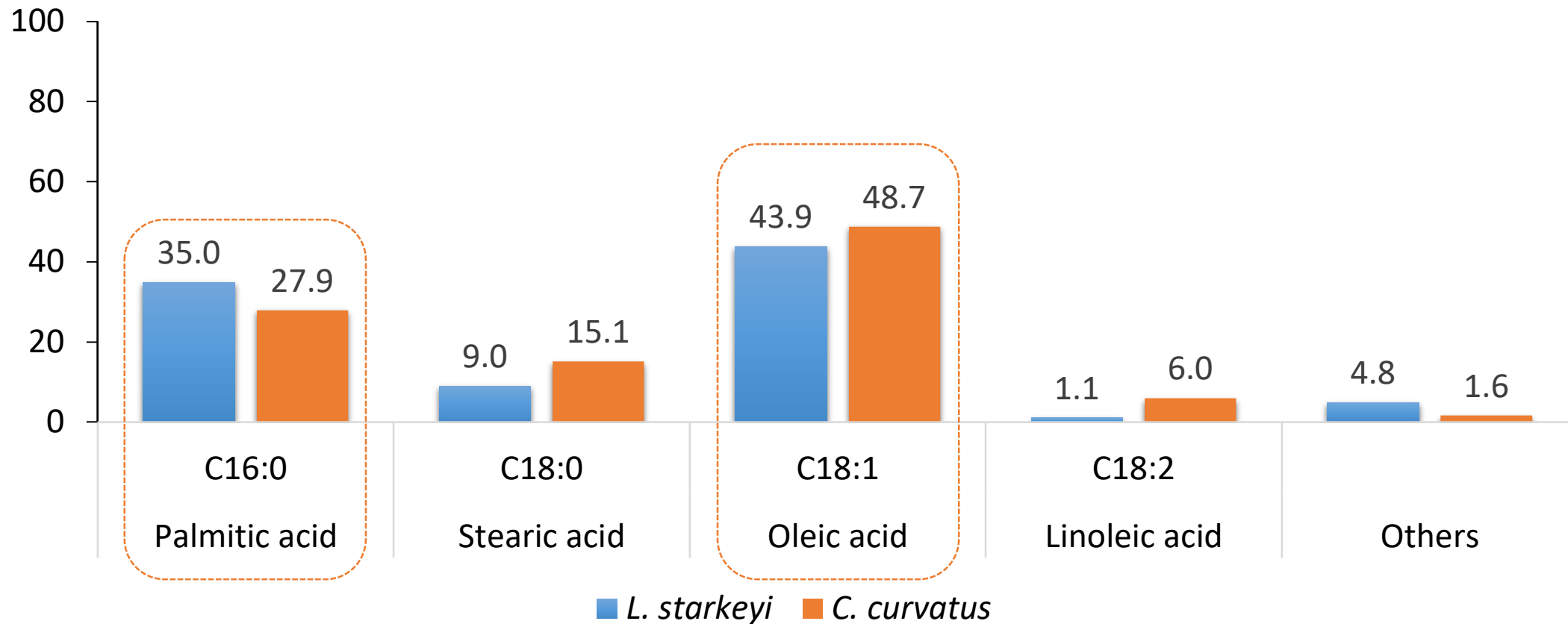
Free sugars fermentation



Yeast strain	Fermentation time (h)	DCW (g/L)	Oil content (%)	Microbial oil (g/L)	Yield (g/g)	Productivity (g/(L·h))
<i>C. curvatus</i>	88	70.5	60.6	42.7	0.24	0.49
<i>L. starkeyi</i>	191	107.8	51.5	55.0	0.12	0.27

Methyl ester fatty acid determination

% Oil Composition



Conclusions

- Development of a novel biorefinery is a promising way to ensure sustainable orange peel residues utilisation, with the recovery of value-added products
- Hydrochloric acid led to the extraction of a pectin extract with higher purity
- Fermentation of orange peel free sugars with *Lipomyces starkeyi* resulted in 107.8 g/L DCW with 51.5% oil content
- Fermentation of orange peel free sugars with *Cryptococcus curvatus* resulted in 70.5 g/L DCW with 60.6% oil content

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