



# Extracting polyphenolic compounds from orange peel: A comparison between solid-liquid and supercritical fluid extraction.

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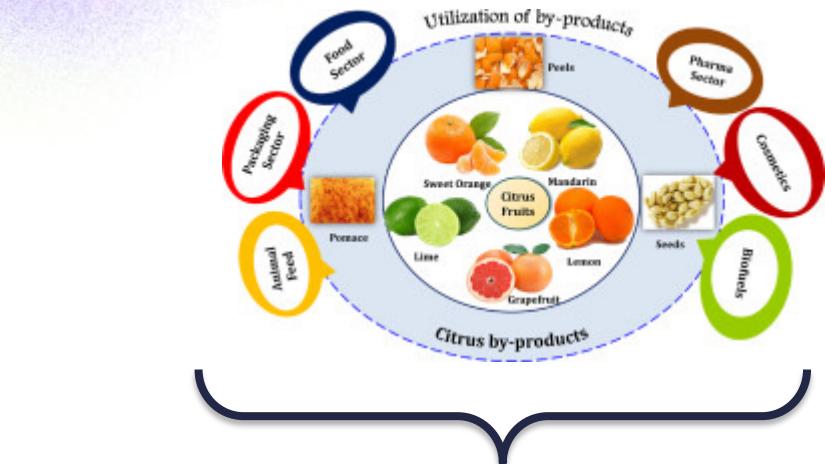
Orange peel and its applications

Definition of extraction conditions and simulation considerations (technical and economic)

Experimental and simulations results (technical and economic)

Is the Orange peel from Colombia a potential raw material to obtain an extract rich in flavanoids like the hesperidin?

# INTRODUCTION



143 million tons in 2019 of citrus fruits was produced in 2019 (FAO)

15 and 25 million tons of citrus wastes are produced by the citrus processing industries

After its consumption three wastes are generated

Peel

Seeds

Exhausted pulp

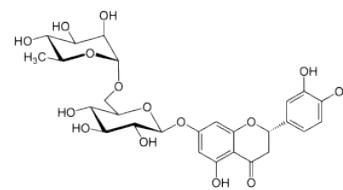
Orange peel



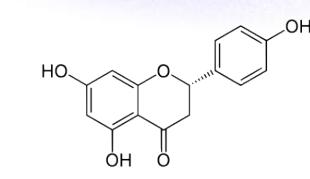
## FLAVONOIDS

### Flavanones

Hesperidin

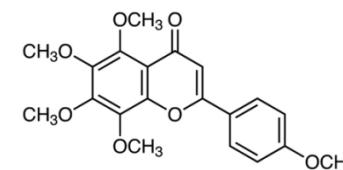


Naringenin

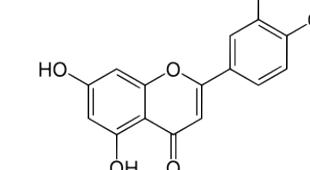


### Flavone

Tangeretin

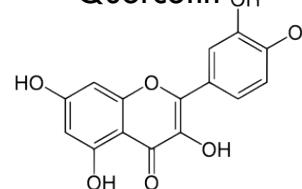


Luteolin

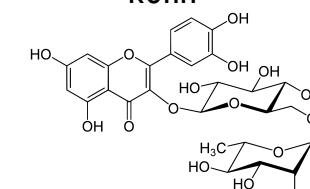


### Flavonols

Quercetin

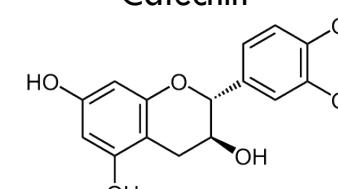


Rutin

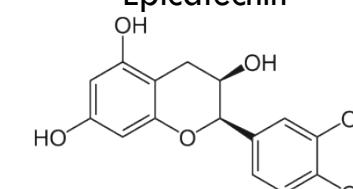


### Flavanols

Catechin



Epicatechin



# INTRODUCTION

## Conventional technology

### Solid:Liquid extraction (SE)

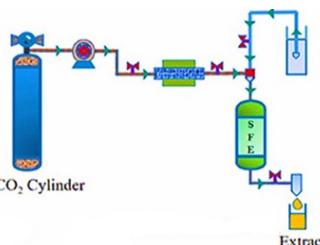
Principle: combining the solid with a **solvent** in which the metabolite is soluble.



## Non-conventional technology

### Supercritical Fluid Extraction (SFE)

Principle: combining the solid with a **solvent (supercritical fluid)** in which the metabolite is soluble. The metabolite solubility in the solvent is modified by the addition of a **co-solvent**.



The yield extraction is influenced for:

- ① Solvent – Water, Ethanol, Ethanol solutions
- ② Technology – SE, SFE
- ③ Raw material – cultivation zone

Parameter	SE	SFE
Investment cost	↓	↑
Selectivity	↓	↑
Pressure	↓	↑
Time	↑	↓
Energy consumption	↓	↑



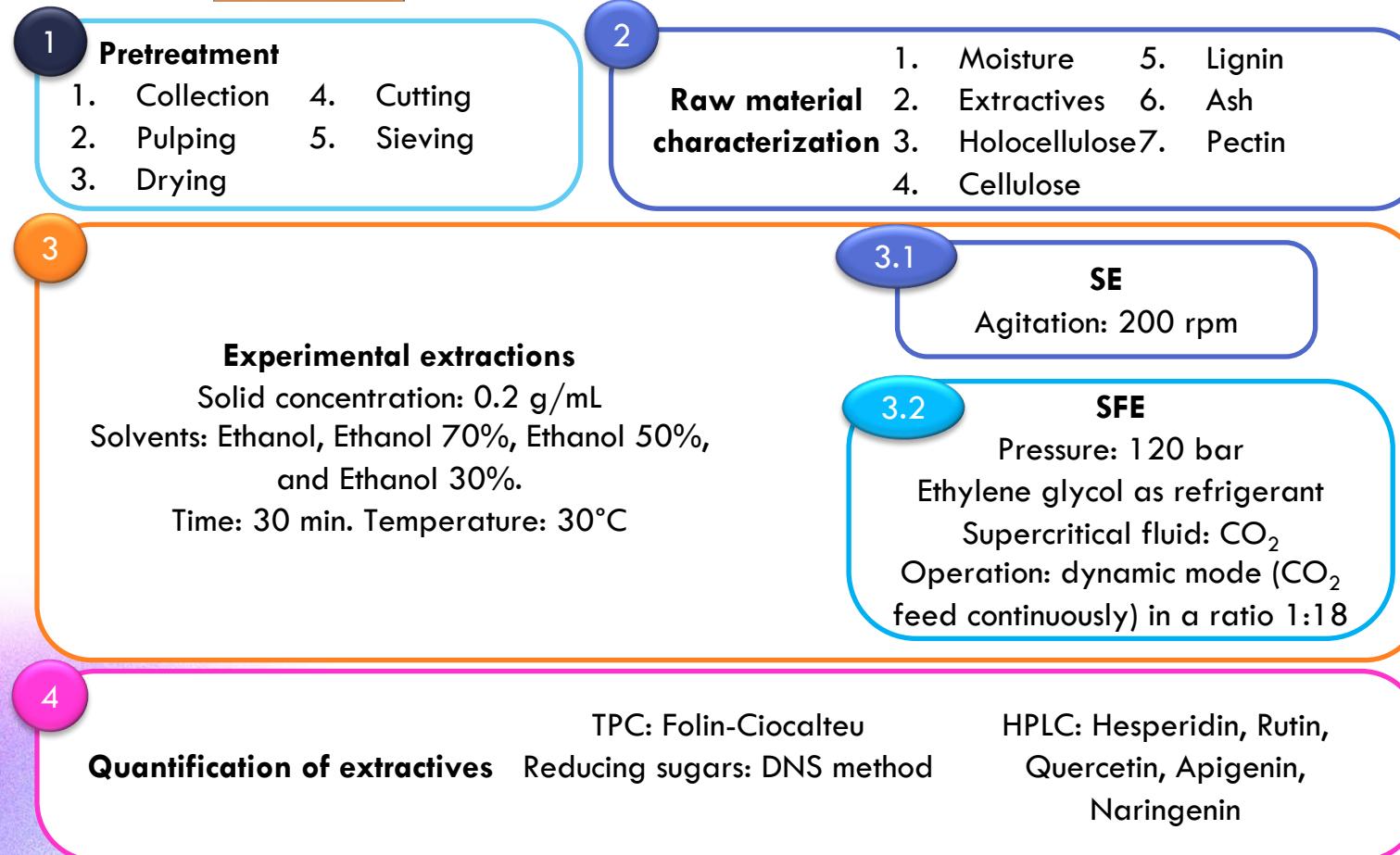
### Objective:

- To identify the most appropriate technology for the extraction of flavonoids from Orange peel.

# METHODOLOGY: EXPERIMENTAL



## Orange peel (*Citrus sinensis* var. *Valencia*)



## Raw material characterization



Extractives (NREL/TP – 510 – 42619)



Holocellulose (ASTM D1104)



Cellulose (T203 os-74 AST 1695-77)



Lignin (NREL/TP – 510 – 42618)



Ash (NREL/TP – 510 – 42622)



Pectin (Yu et al., 1996)



Moisture (NREL/TP - 510-42621)

# METHODOLOGY: SIMULATION



**Software:** Aspen Plus v.9

- Mass flow:** 19 kg/h
- Thermodynamic models:** The Predictive Soave-Redlich-Kwong (PSRK) for the SFE process and the Non-Random Two-Liquid (NRTL) for the SE process
- Solid properties:** Database of National Renewables Energy Laboratory (NREL)
- Dead time:** 15 min for the SE, and 10 min for the SFE.
- All the process considered the solvent recirculation and the extract concentration using evaporation.**



## Technical evaluation

- Yield
- Process Mass Intensity Index
- Mass Loss Index
- Renewability Material Index
- Solvent Intensity Index



## Economic evaluation

- Production cost (USD/kg)
- Profit margin (%)
- CapEx (USD)
- OpEx (USD)
- Payback period (years)
- Net Present Value (USD)
- Minimum selling Price (USD/kg)
- Minimum Processing Scale for Economic Feasibility (MPSEF)

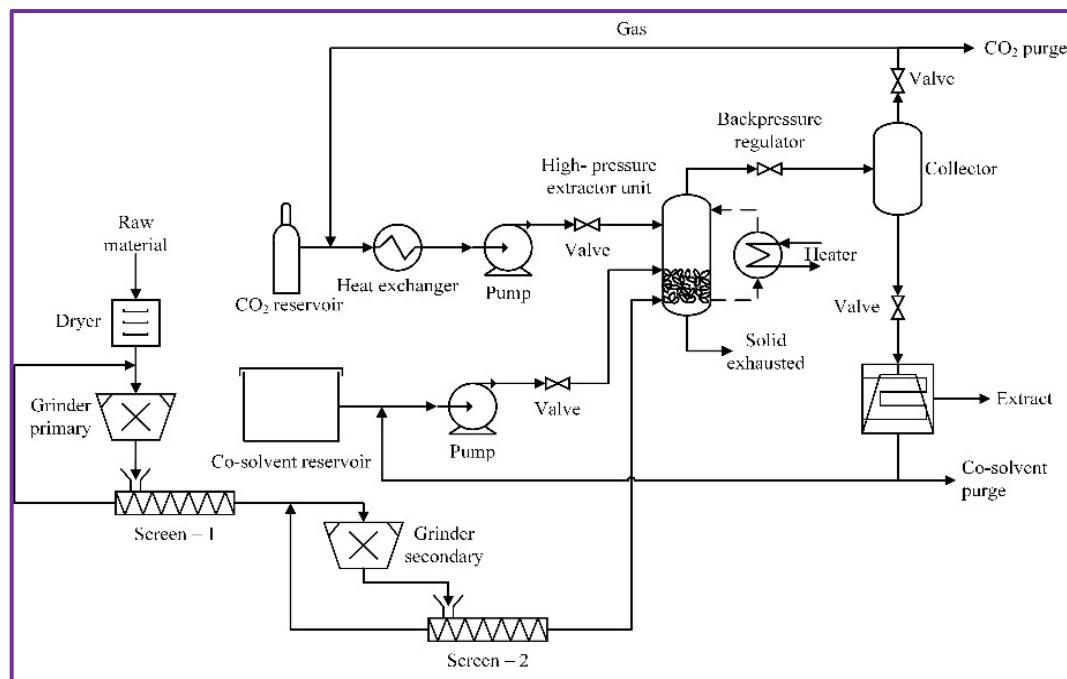


Figure 1. Simulation flowsheet for the SE

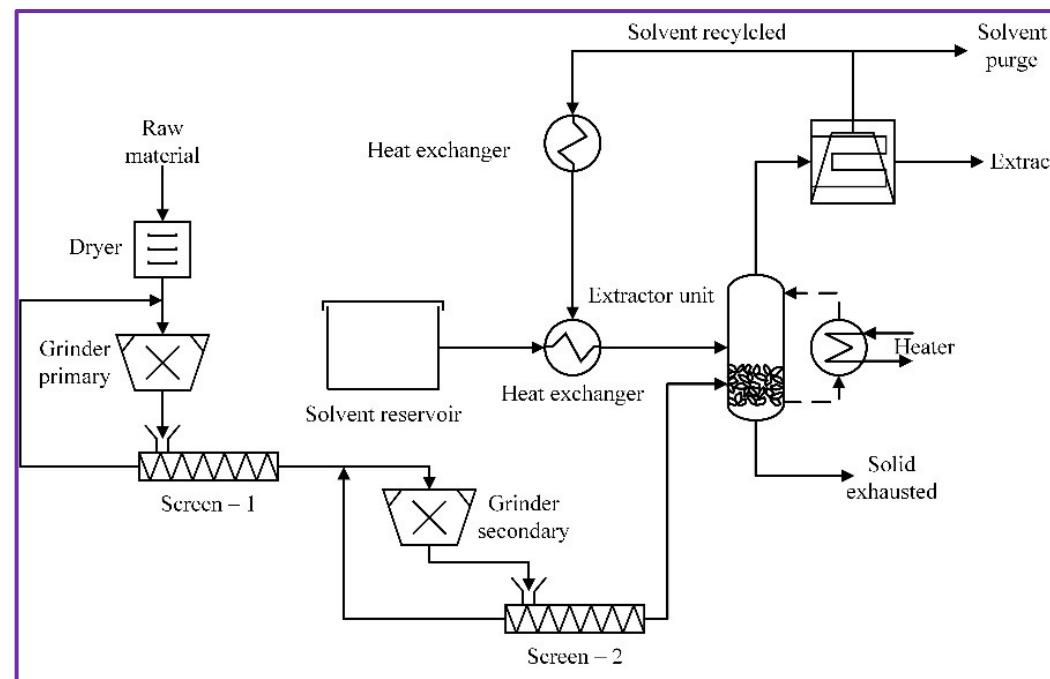
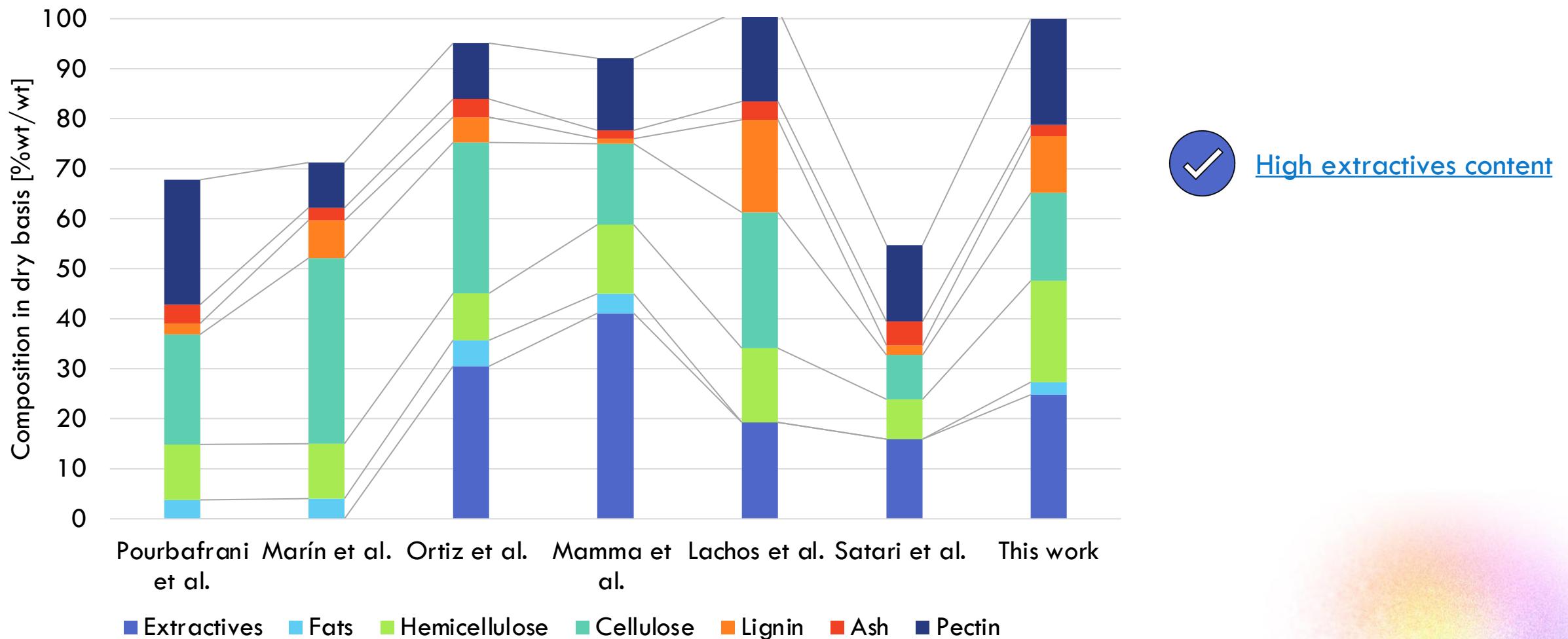


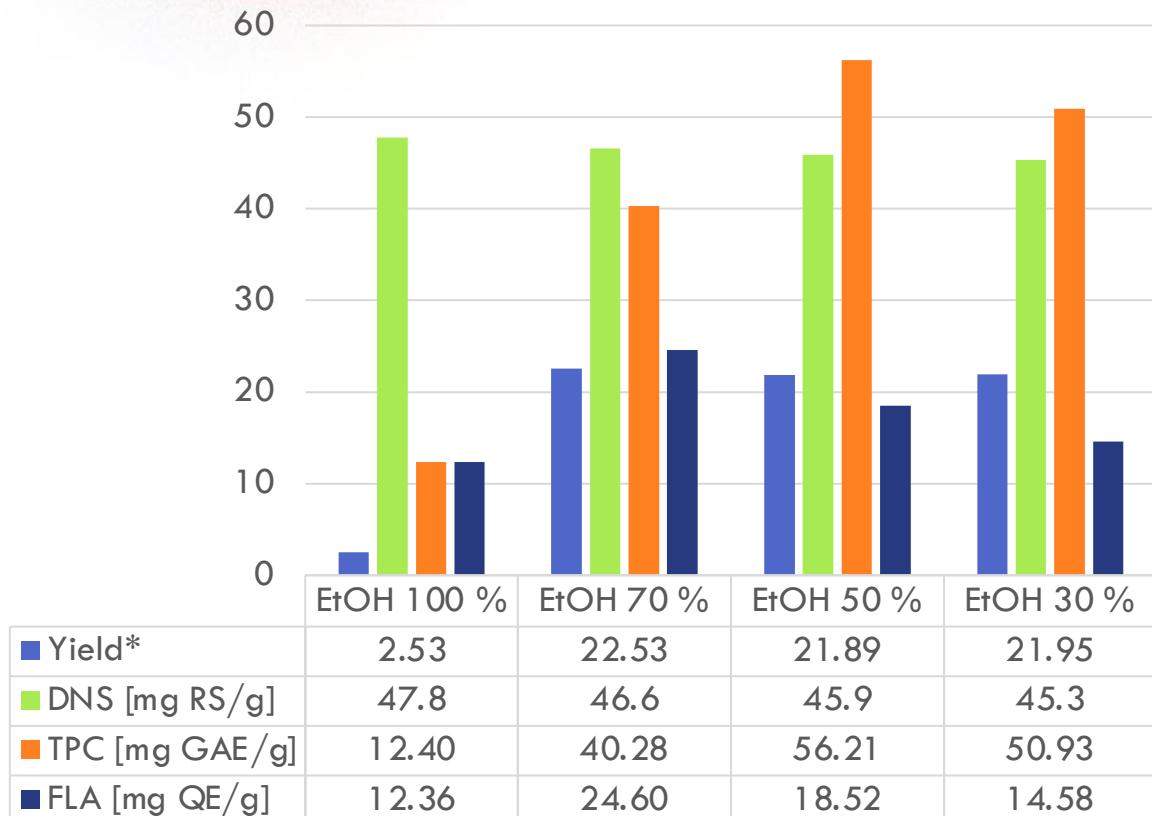
Figure 2. Simulation flowsheet for the SFE process.

# RESULTS: CHARACTERIZATION



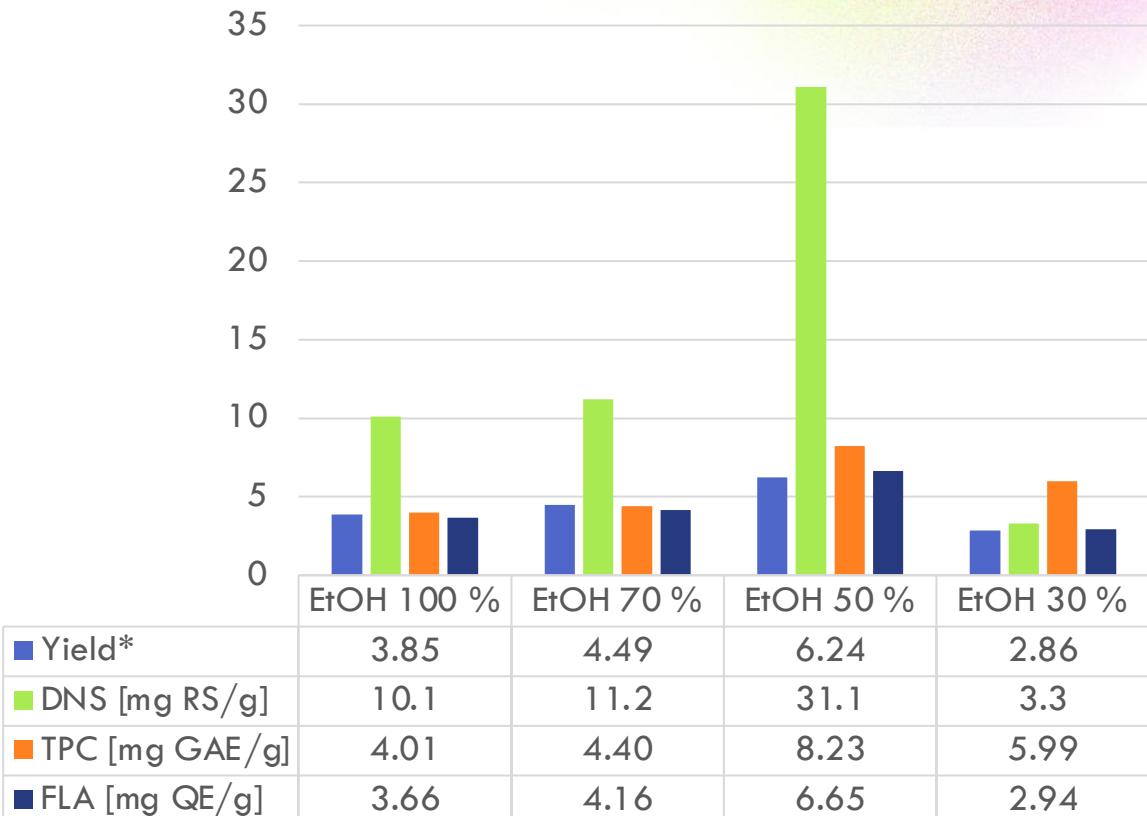
**Figure 3.** Physic-chemical characterization of orange peel and results reported in the literature.

# RESULTS: EXTRACTIONS



\* kg/100 kg OP

**Figure 4.** Quantification in the extracts from Orange Peel using SE

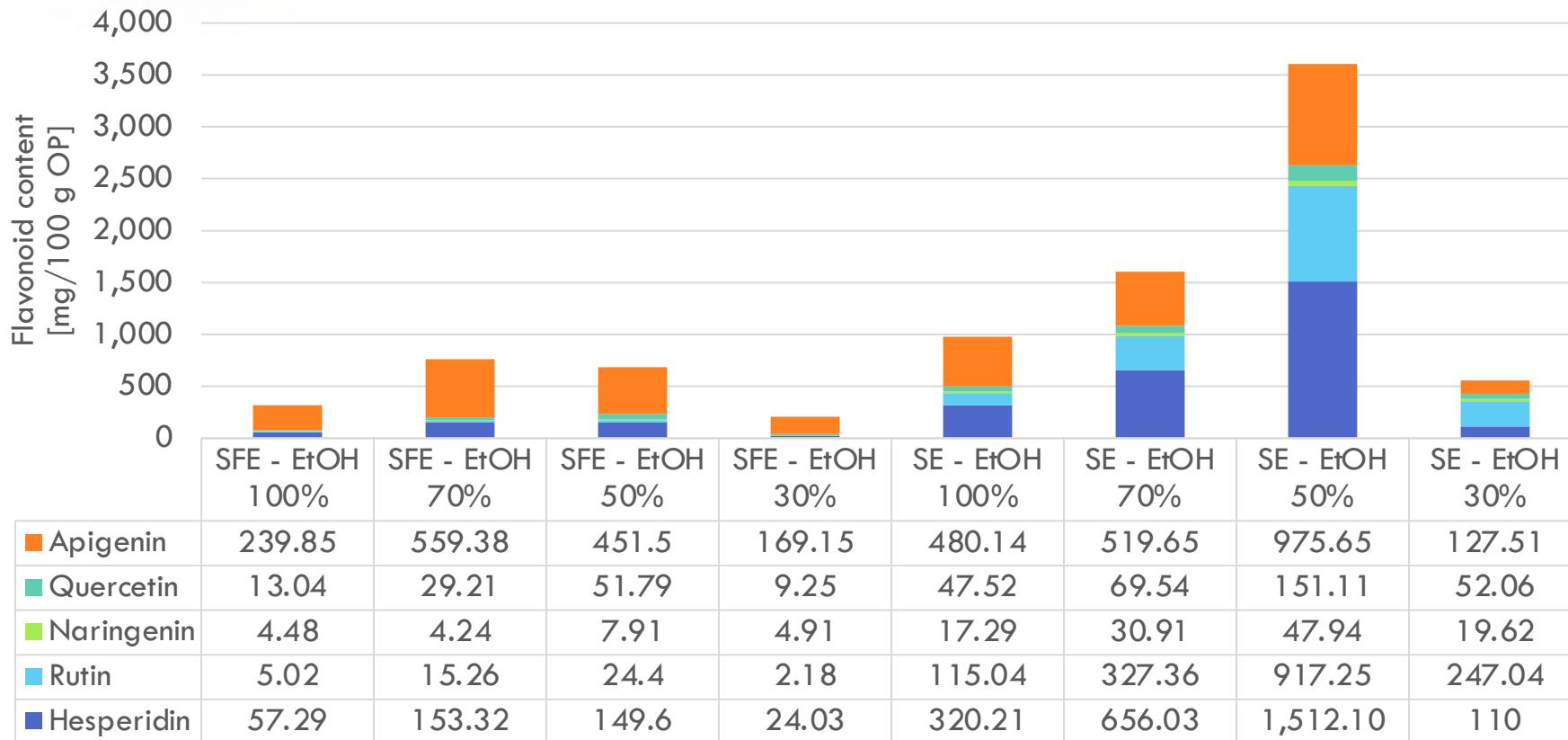


\* kg/100 kg OP

**Figure 5.** Quantification in the extracts from Orange Peel using SFE

Nishad et al. reported a TPC of 16.32 mg GAE/g using an EtOH 70% in UAE, with a flavonoid content of 1.06 mg QE/g

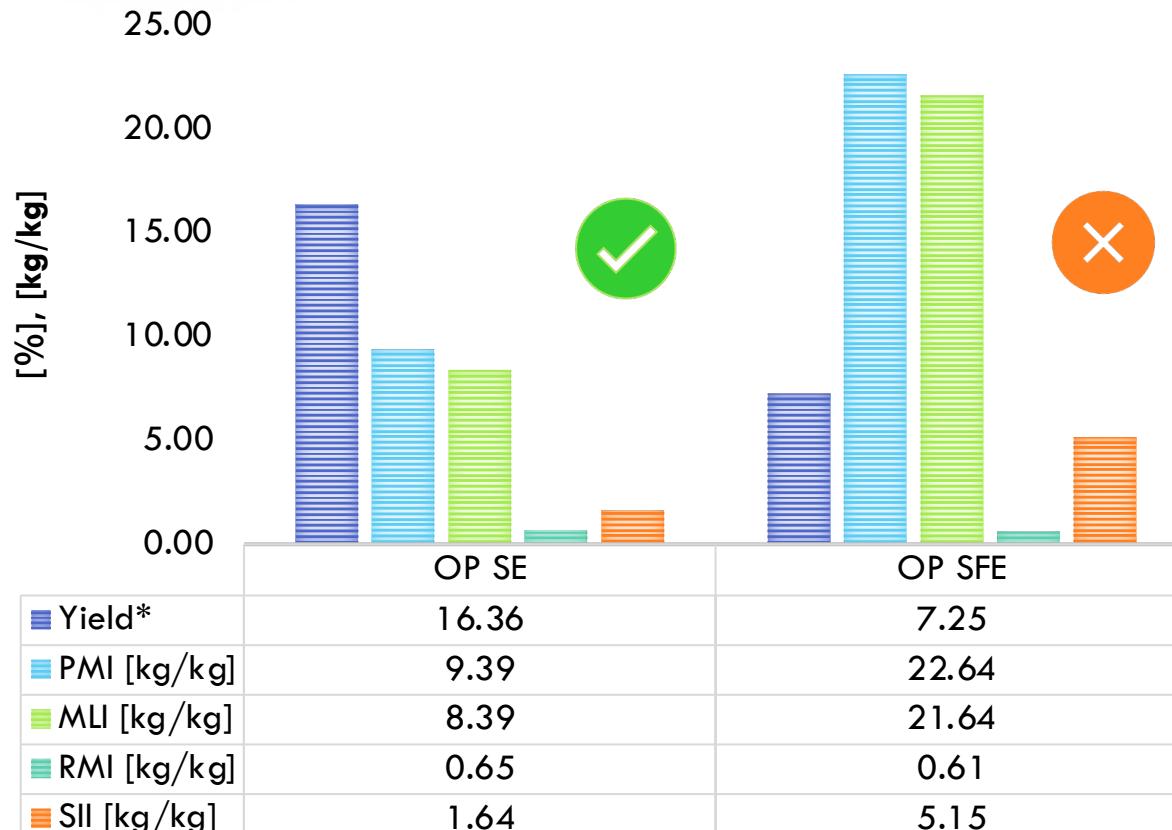
# RESULTS: EXTRACTIONS



**Figure 7.** Flavonoids identified in the extract from orange peel using SE and SFE

- ❑ The grapefruit peel presents a hesperidin content of 0.74 mg/g.
- ❑ Garcia-Castello et al. report a hesperidin content for grapefruit of 0.58 mg/g
- ❑ Iglesias-Carres et al. report a hesperidin concentration of 17.93 mg/g in the orange peel

# RESULTS: SIMULATION



\* kg/100 kg OP

Figure 8. Technical indicators obtained from the simulations

- ✓ The SE requires less solvent than the SFE
- ✓ Low PMI values (<25,000): low waste generation
- ✓ The SE present the lowest mass loss (MLI)
- ✓ Similar values of renewability was obtained (RMI)

PMI (Process Mass Intensity)  
MLI (Mass Loss Index)  
RMI (Renewability Material Index)  
SII (Solvent Intensity Index).

# RESULTS: SIMULATION

Table 1. Economic indicators estimated in this work.

Item	Units	SE	SFE
Production cost	USD/kg	<b>7.68</b>	32.35
Profit margin	%	<b>45.16</b>	-130.38
CapEx	USD	<b>318,823.02</b>	1,000,327.37
OpEx	USD/year	<b>200,453.74</b>	373,431.54
Payback period	years	<b>2.16</b>	-
NPV in 10 years	USD	<b>970,649.29</b>	-1,442,251.55
MPSEF	tonne/day	<b>0.10</b>	13.45
Minimum selling price	USD/kg	<b>7.63</b>	<u><b>31.92</b></u>



Extract sale price:  
14 USD/kg



# CONCLUSIONS

-  Technically the solid:liquid extraction is better than the SFE. The use of ethanol as solvent with a concentration of 50% improve the flavonoid extraction
-  The low extraction yields and metabolite concentration influence significantly the SFE economic feasibility. As result, the SFE is not a good alternative to obtain an extract from the Orange Peel under the conditions analyzed in this work.

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## Plan Bienal de Convocatorias

Más conocimiento, mayor desarrollo y mejores oportunidades para todos.

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Thank you for your attention

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