



Politecnico
di Torino



**8TH INTERNATIONAL CONFERENCE
ON SUSTAINABLE SOLID WASTE MANAGEMENT
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**Conventional and ultrasound-assisted extraction of rice bran oil
with isopropanol as solvent**

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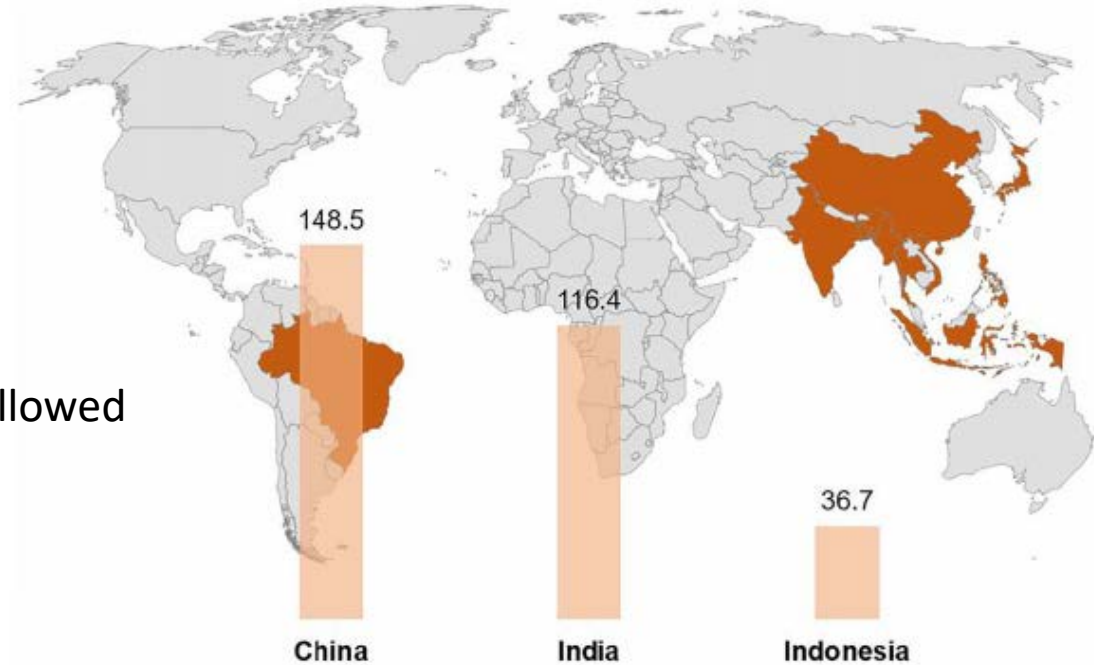


Introduction

Rice represents around **20% of the dietary energy intake** of the global population

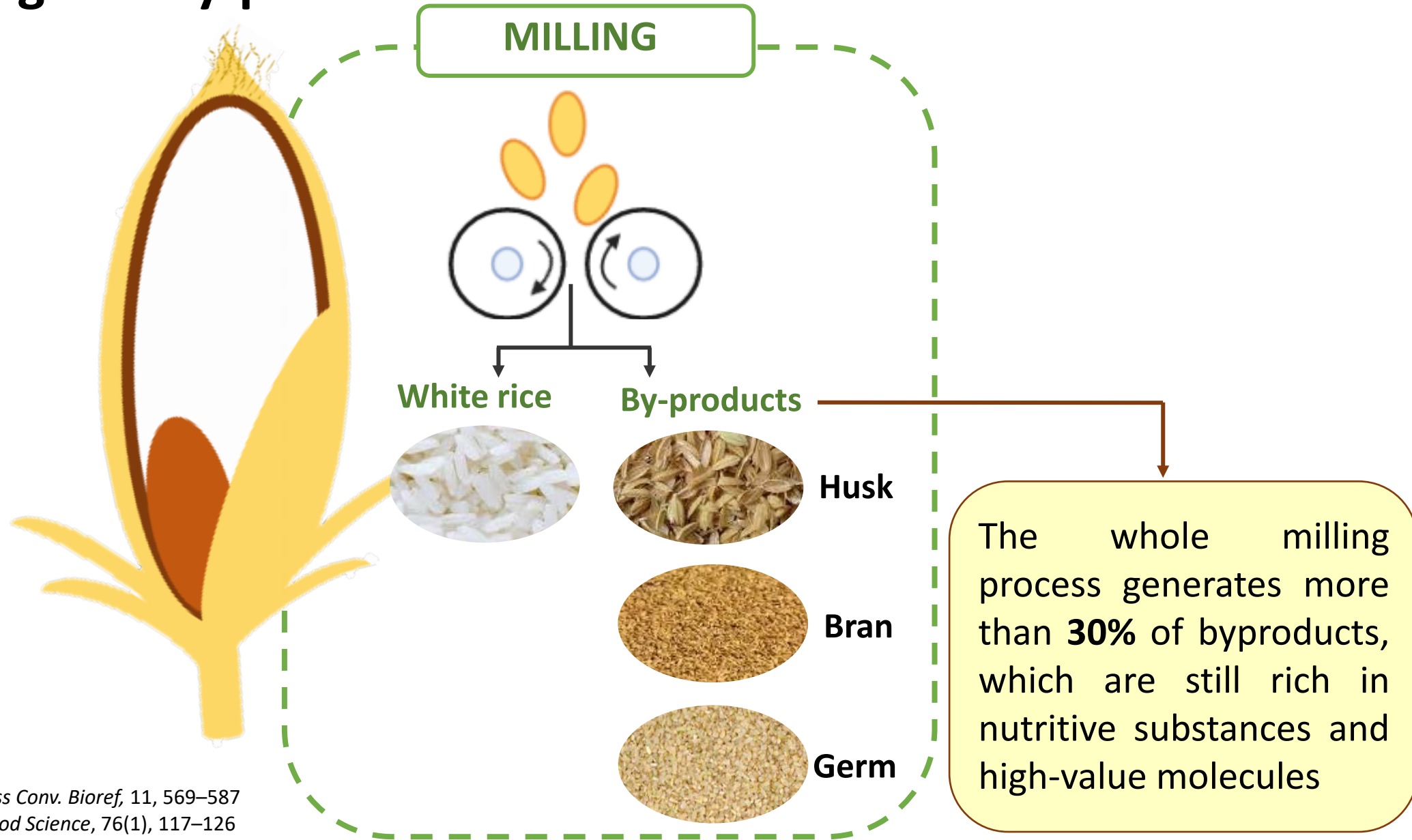


According to estimations, the world's rice production reached **499.31 million metric tons** over the 2019–2020 period



The primary producer and consumer of rice is **China**, followed by **India and Indonesia**

Rice milling and by-products



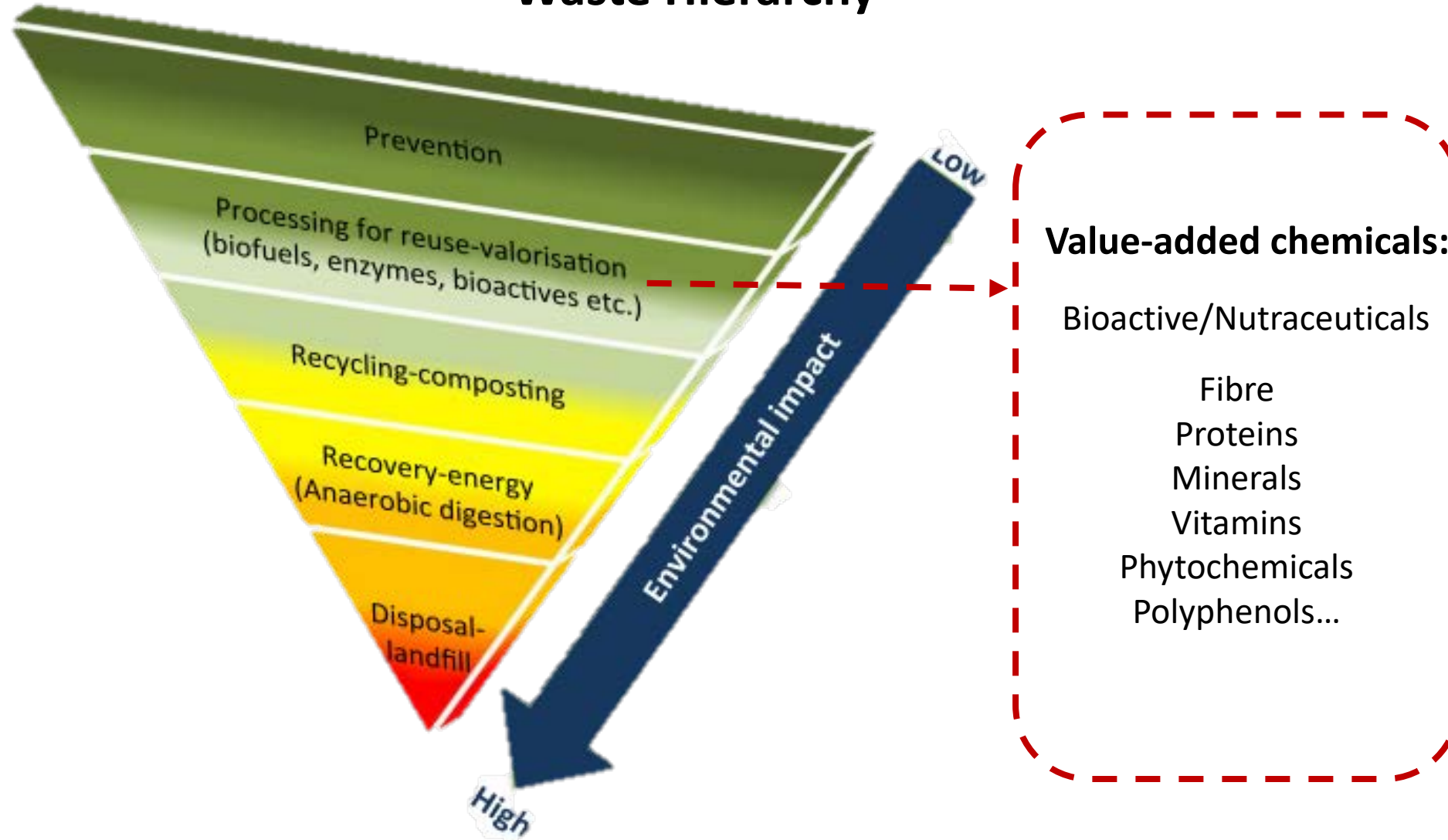
Fraterrigo et al., 2020, *Biomass Conv. Bioref*, 11, 569–587

Min et al., 2011, *Journal of Food Science*, 76(1), 117–126

Andreola et al., 2015, Conference of European Ceramic Society (ECERS)

Introduction

Waste Hierarchy



Directive (2008/98/EC), 2008, *Official Journal of the European Union*, 3–30.
Ravindran et al. 2016, *Trends in Biotechnology*, 34(1), 58–69.

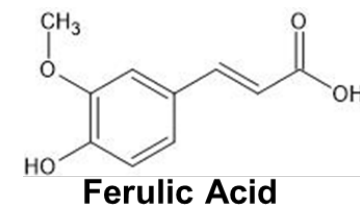
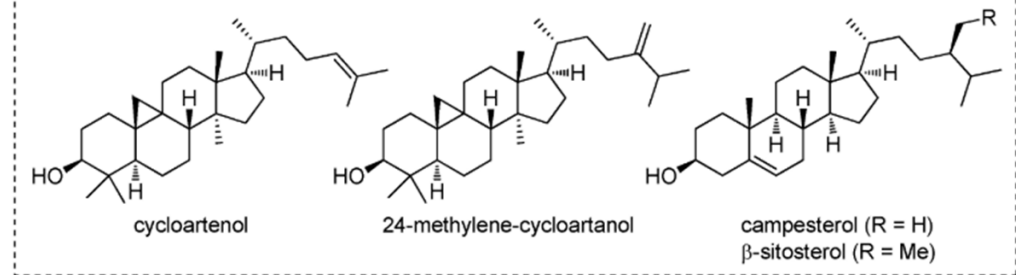
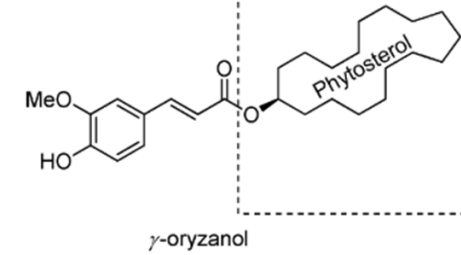
Rice milling and by-products



9% Bran:

- Protein
- Fat
- Fiber
- Vitamins
- Minerals
- Phenolic compounds
- Lipophilic antioxidants:
 - Tocopherols
 - Tocotrienols
 - **γ-oryzanol**

- lowering cholesterol
- antioxidant effect
- inducing apoptosis cancer cells



Phytosterols

Fraterrigo et al., 2020, *Biomass Conv. Bioref*, 11, 569–587
 Lesma, G. et al., 2018, *Journal of Natural Products*, 81(10), 2212–2221.

Rice Bran Oil (RBO)



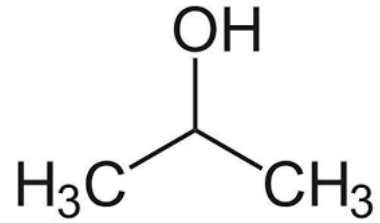
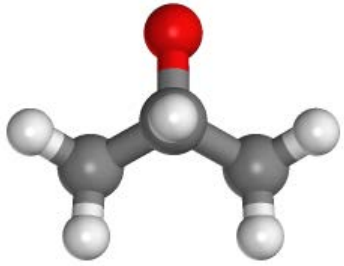
The World Health Organization (WHO), the American Heart Association (AHA), and other international food and health organizations have recognized RBO as a “**healthy oil**,” because of its well-balanced fatty acid content.

Conventional **solvent extraction** using non-polar solvents, such as **hexane**



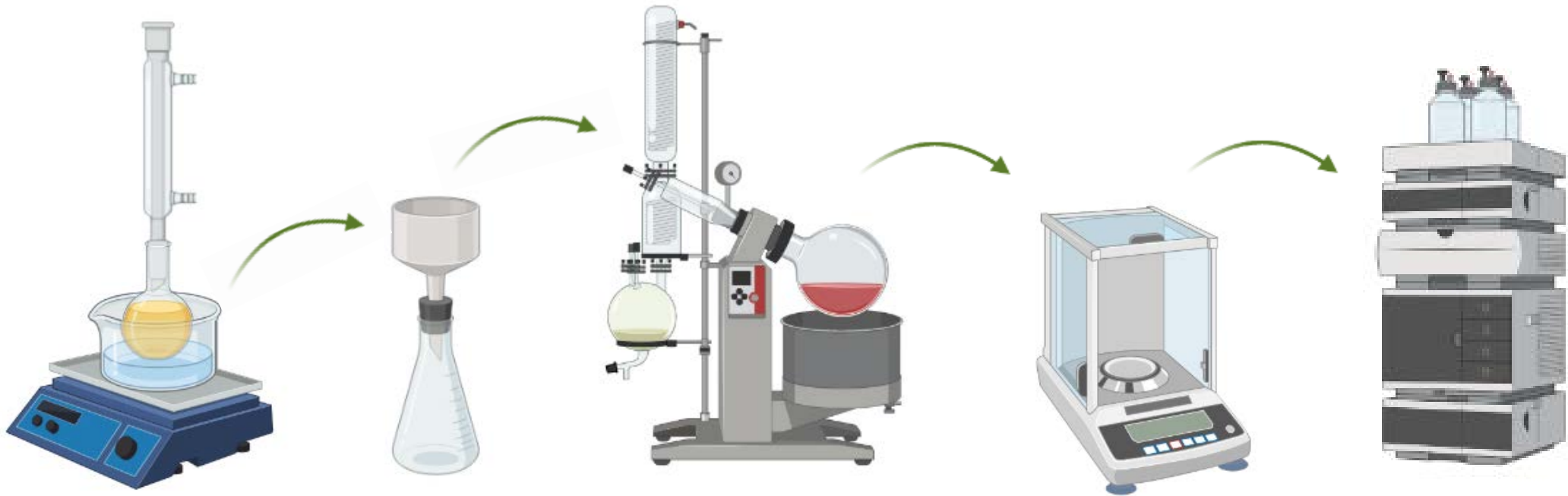
Rohman A, 2014, *Wheat and Rice in Disease Prevention and Health*. Academic Press, 481–490
Fraterrigo et al., 2020, *Biomass Conv. Bioref*, 11, 569–587

Isopropanol Solvent extraction



- DECRETO 4 agosto 2011, n. 158
- Green Solvent Selection Guide
- Low cost

- Sanofi guides
- The CHEM21
- AstraZeneca...

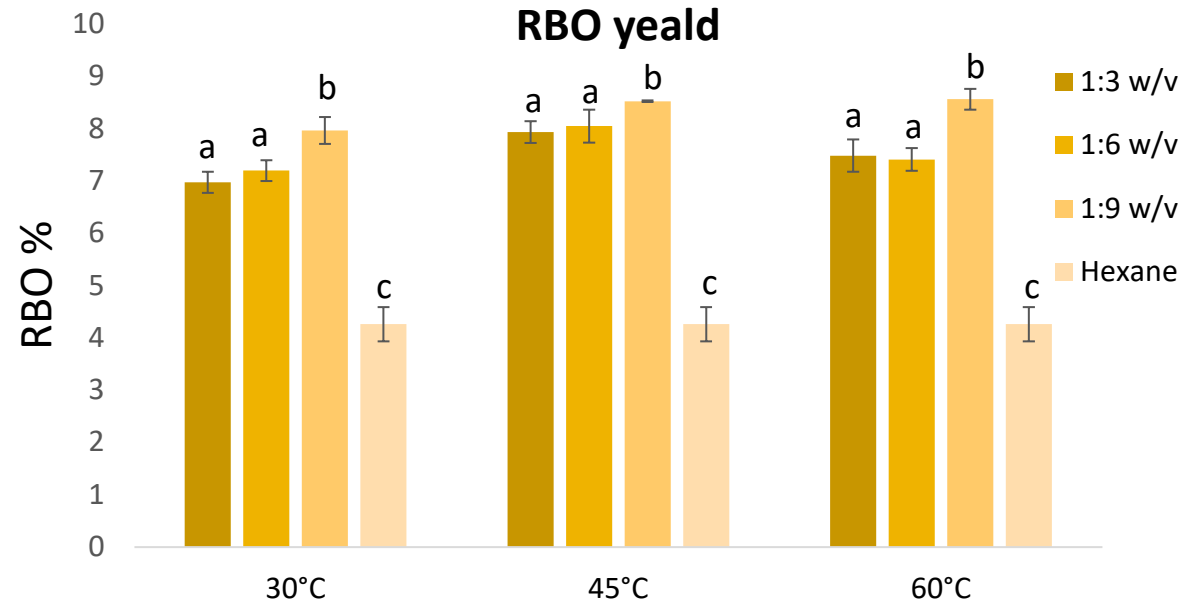


Prat et al., 2013, *Org. Process Res. Dev.* 17 (12), 1517–1525

Prat et al., 2014 *Green Chem.* 16 (10), 4546–4551.

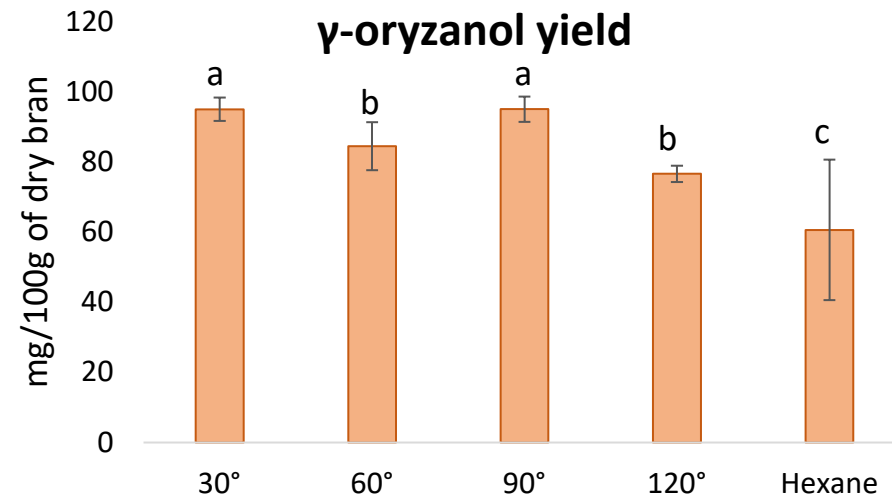
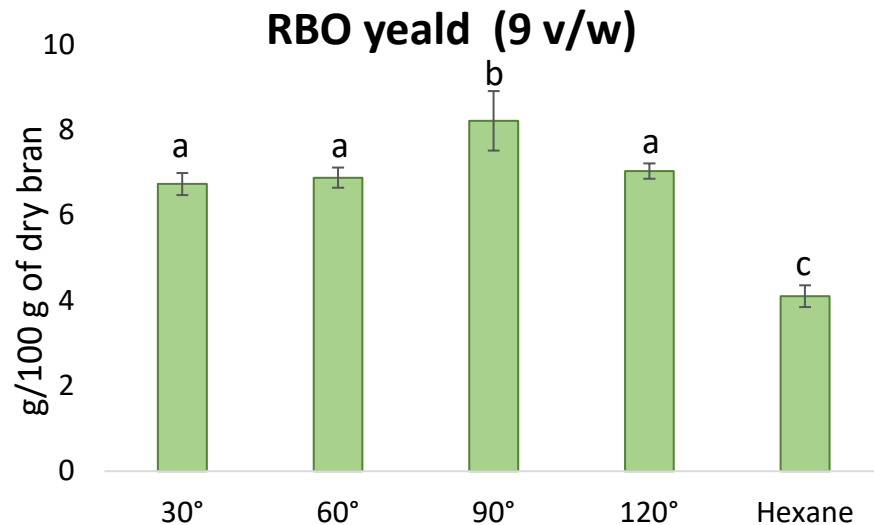
Prat et al., 2015, *Green Chem.* 18 (1), 288–296

Isopropanol Solvent extraction



Hexane is used as standard extraction technique (Pengkumsri et al.2015)

All the values are represented as mean ± SD of triplicate experiments
ANOVA $p < 0.01^{***}$
Different letters mean different group Tukey Test



Pengkumsri et al., 2015, *Food Sci Technol*, 35:493–501.

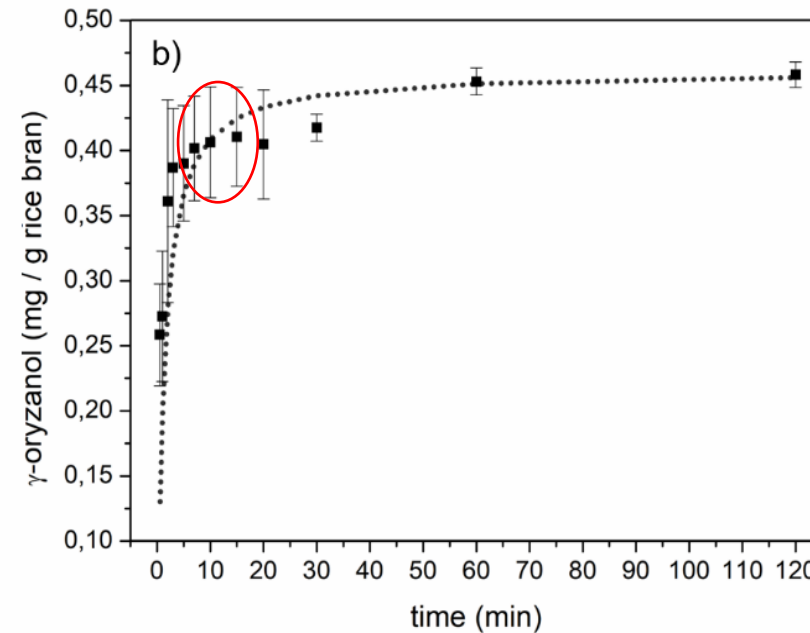
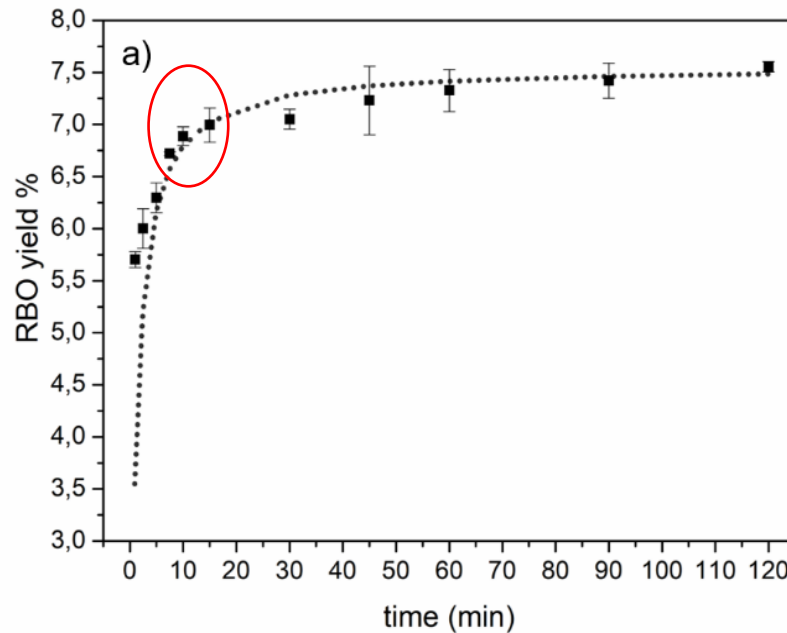
Isopropanol Solvent extraction

Chan et al., 2014, *Chem Eng Res Des* 92:1169–1186
 Peleg, 1988, *J Food Sci*, 53:1216–1217
 Karacabey et al., 2013, *J Food Process Eng*, 36:103–112

Peleg's model

$$y(t) = y_0 + \frac{t}{k_1 + k_2 t}$$

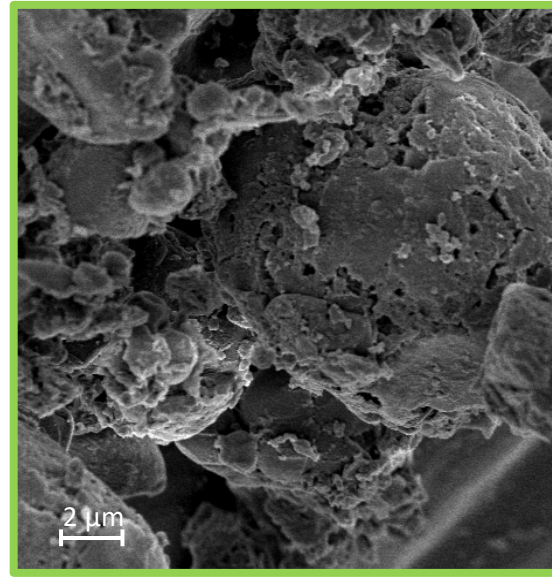
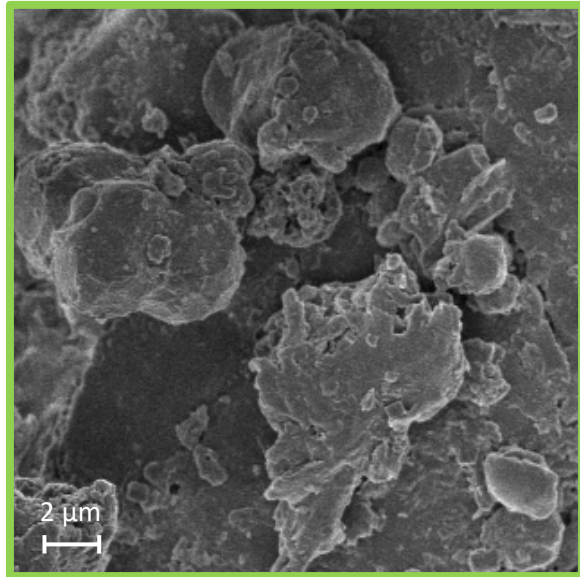
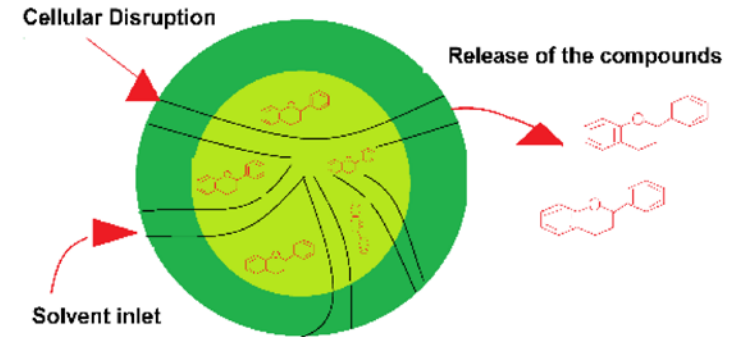
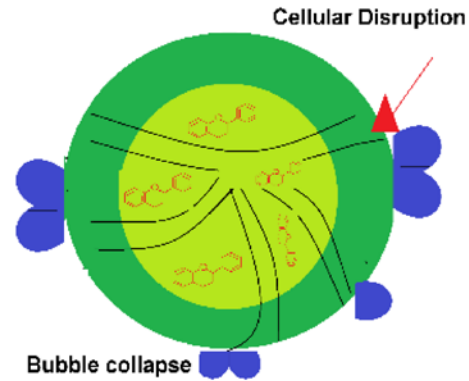
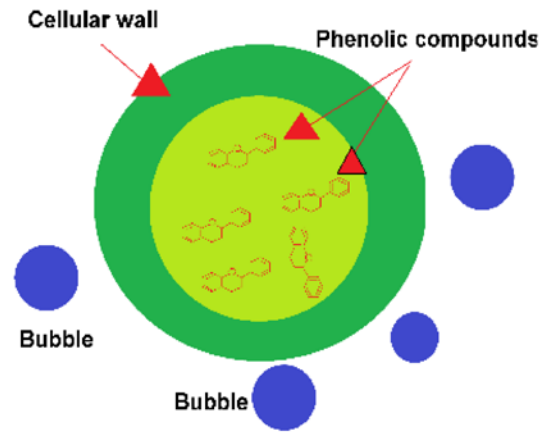
k_1 Peleg's rate constant
 k_2 Peleg's capacity constant
 $y_0=0$



t = 15 min

	K_1 [min g bran / g RBO · 100 or min g bran / mg γ -oryzanol]	K_2 [g bran · 100 / g RBO or g bran / mg γ -oryzanol]	B_0 [g RBO · 100 / min g bran or mg γ -oryzanol / min g bran]	C_e [g RBO / g bran · 100 or mg γ -oryzanol / g bran]	R^2	RMSD
RBO	0,1506	0,1324	6,6401	7,5529	0,9302	0,0534
γ -oryzanol	2,7668	2,1712	0,3614	0,4606	0,8919	0,7076

Ultrasound-assisted extraction



- Room Temperature
- Shorter Time

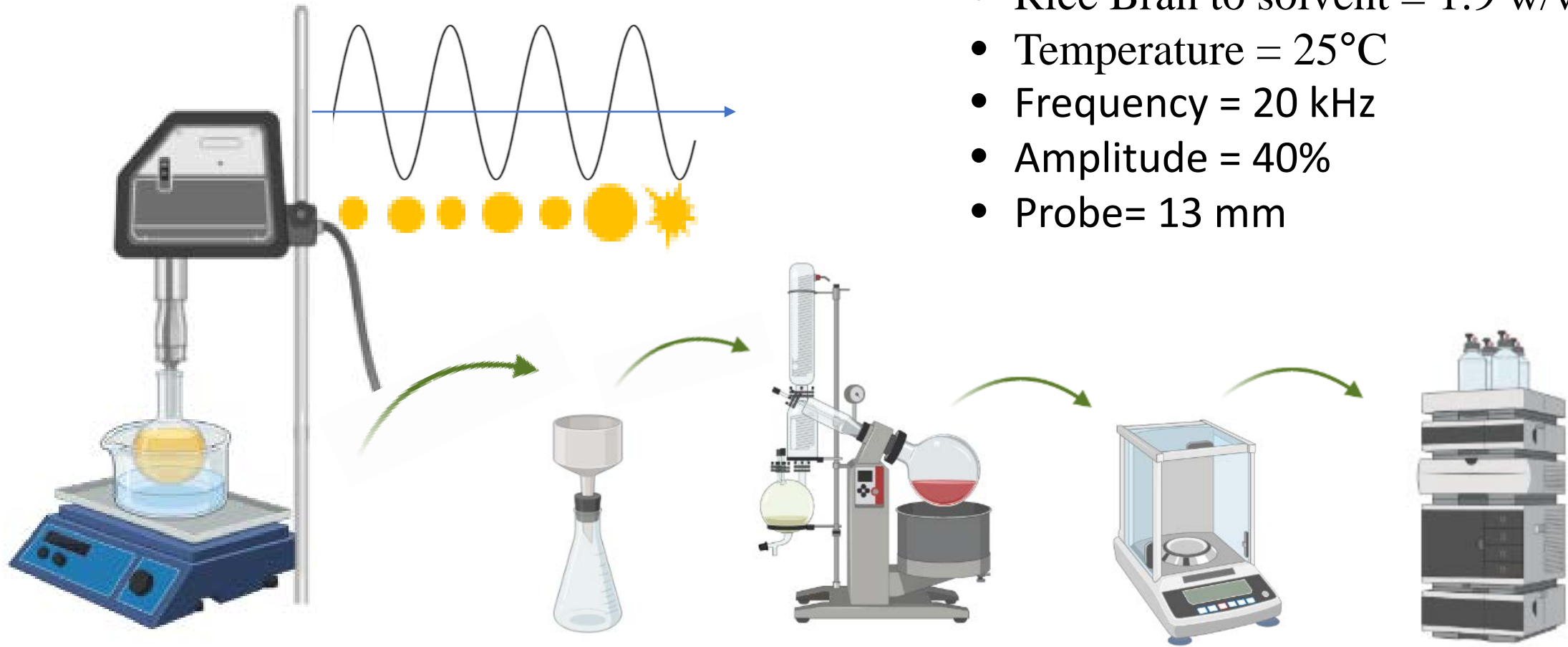


Medina-Torres et al., 2017, *Agronomy*, 7(3)

Niño-Medina et al., 2016 *Phenolic Grape and Wine Biotechnology*, (October)

Ultrasound-assisted extraction

- Solvent = isopropanol
- Rice Bran to solvent = 1:9 w/v
- Temperature = 25°C
- Frequency = 20 kHz
- Amplitude = 40%
- Probe = 13 mm

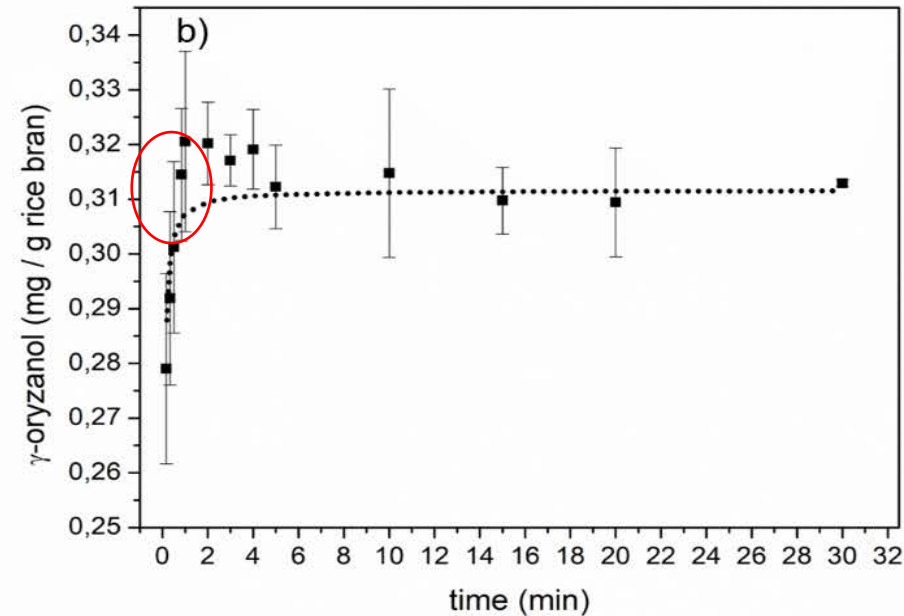
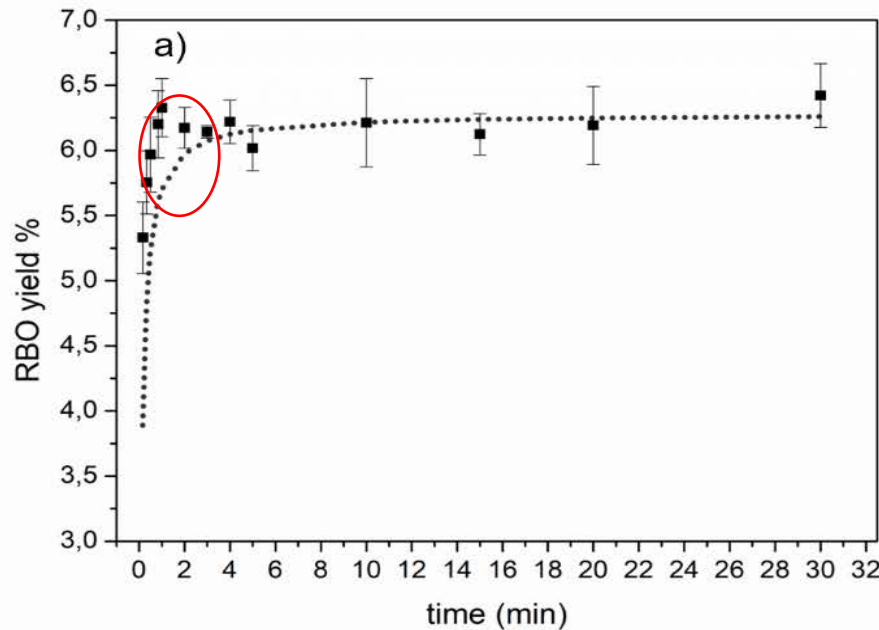


Ultrasound-assisted extraction

Peleg's model

$$y(t) = y_0 + \frac{t}{k_1 + k_2 t}$$

k_1 Peleg's rate constant
 k_2 Peleg's capacity constant
 $y_0=0$



t = 1 min

	K_1 [min g bran / g RBO · 100 or min g bran / mg γ -oryzanol]	K_2 [g bran · 100 / g RBO or g bran / mg γ -oryzanol]	B_0 [g RBO · 100 / min g bran or mg γ -oryzanol / min g bran]	C_e [g RBO / g bran · 100 or mg γ -oryzanol / g bran]	R^2	RMSD
RBO	0,0175	0,1577	57,1429	6,3412	0,7743	0,6070
γ -oryzanol	0,0442	3,2091	22,6244	0,3116	0,7947	0,0070

Life cycle assessment

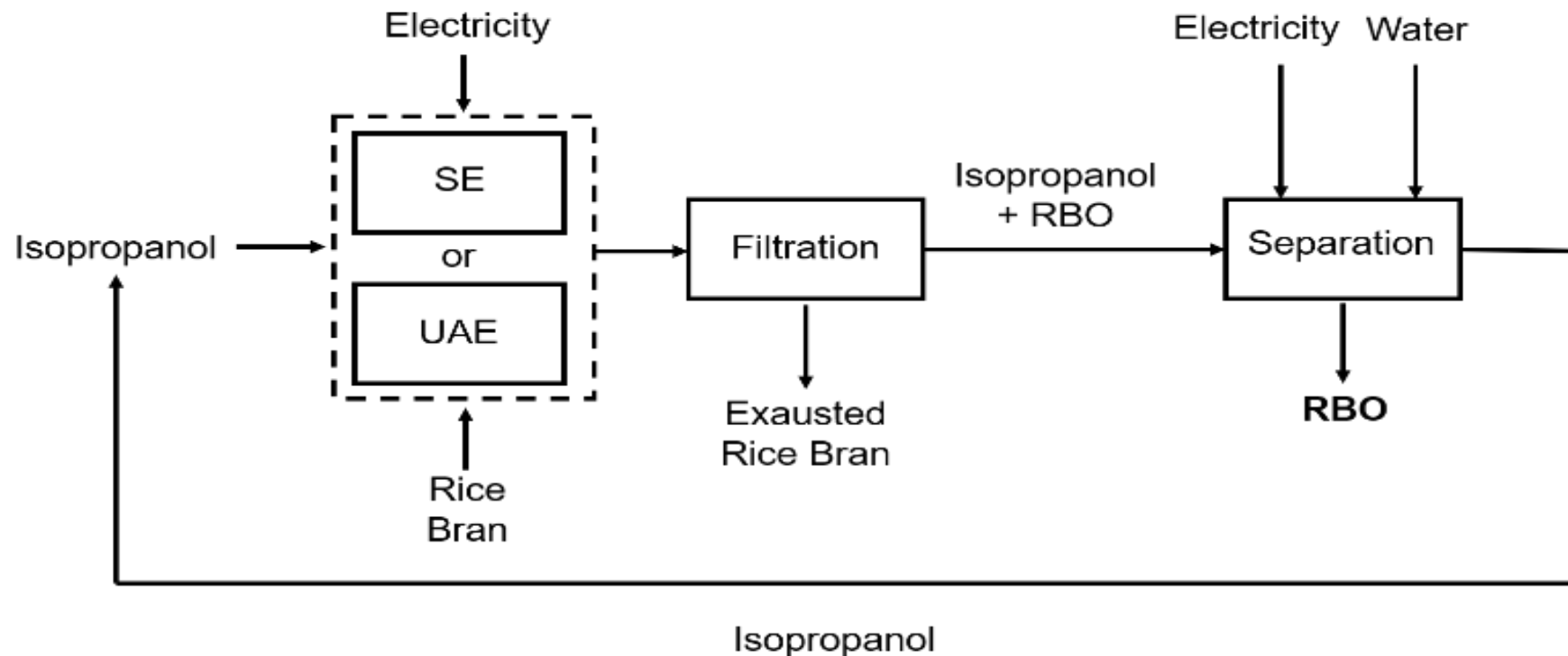
To choose the best extraction process from an environmental sustainability point of view

The functional unit (FU) was 1 g of RBO produced.

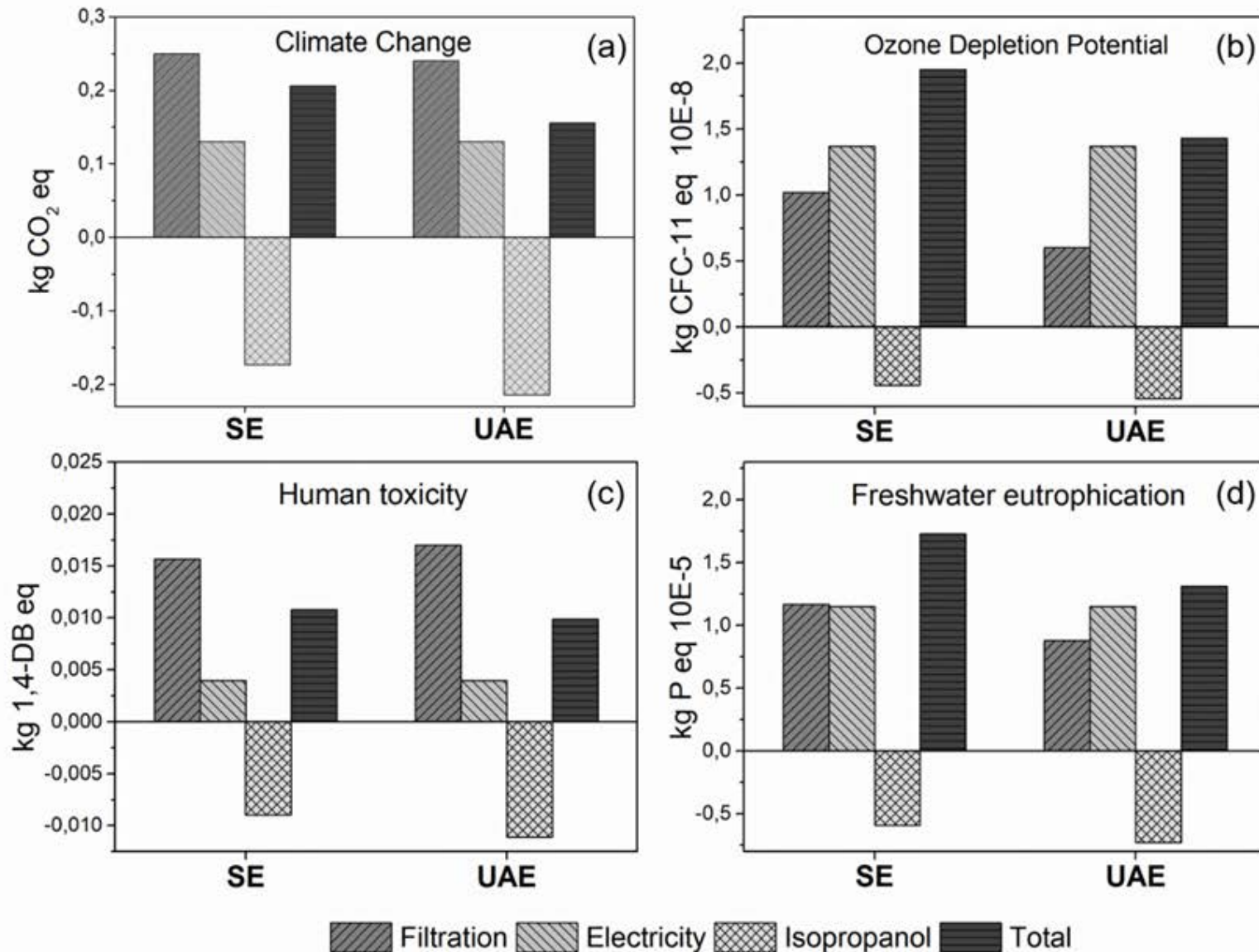
Software: SimaPro 9.0.48

Database: Ecoinvent 3.0

The boundary conditions:



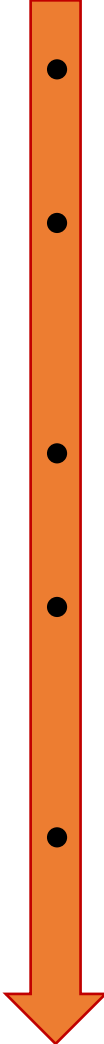
Life cycle assessment



Impact category:

- Climate change (kg CO₂ eq)
- Ozone depletion (kg CFC-11 eq)
- Human toxicity (kg C1,4-DB eq)
- Freshwater eutrophication (kg P eq)

Conclusions

- 
- SE and UAE are suitable to extract RBO instead of conventional extraction with hexane
 - The extraction kinetics of RBO and γ -oryzanol fit with the model proposed by Peleg both for SE and UAE
 - The maximum recovery is reached after 15 minutes using isopropanol at 90°C
 - It is possible to reduce this time to only one minute using isopropanol and ultrasound at room temperature
 - UAE allows reducing the emission contribution to climate change, ozone depletion, and freshwater eutrophication compared to SE

A close-up photograph of rice stalks in a field, with the grain heads in focus and the background slightly blurred. The overall color palette is green and yellowish-green.

Thanks for your attention