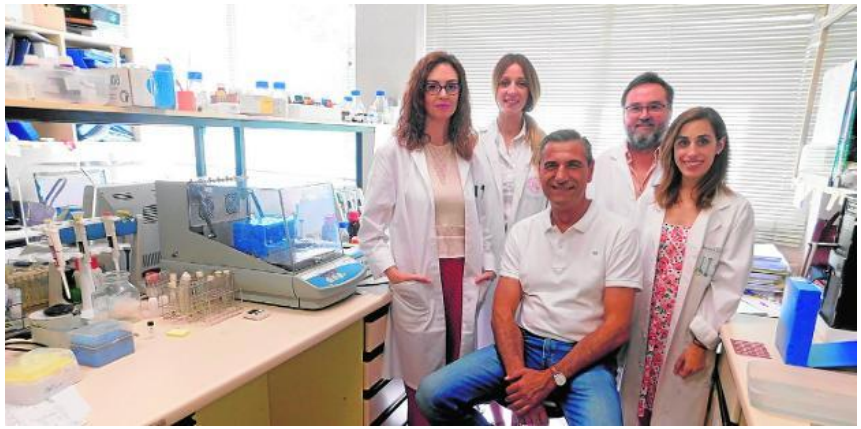
GREEN SYNTHESIS OF COSMETICS INGREDIENTS

Grupo de Investigación

QUÍMICA SOSTENIBLE – UMU / E-060-10



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E060-10 QUÍMICA SOSTENIBLE

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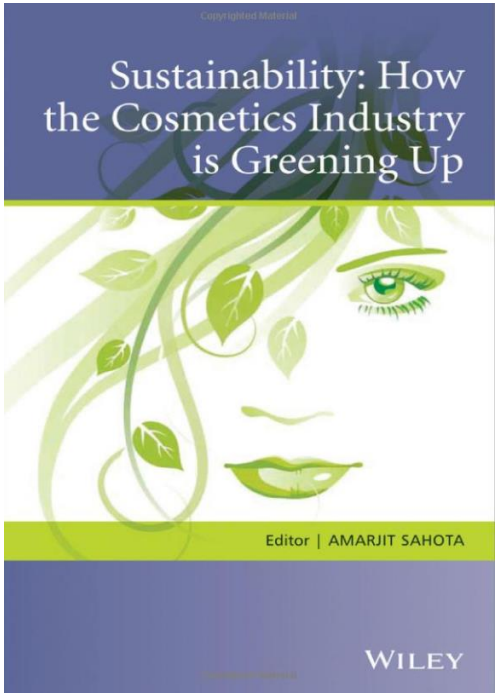
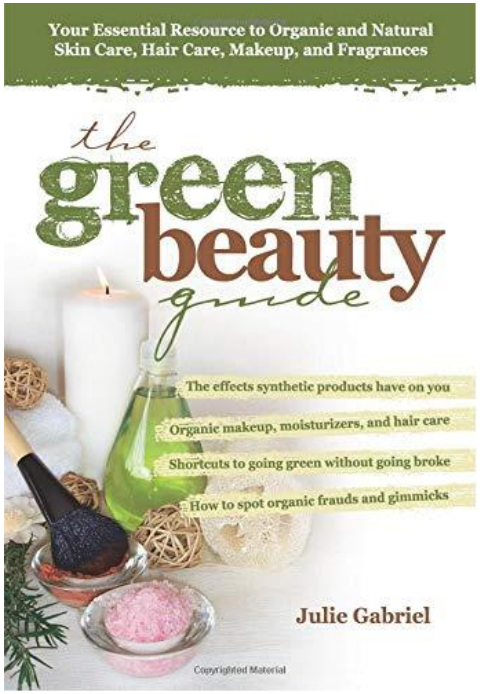
(AS) ASOCIADO, (CO) CONTRATADO, (COL) COLABORADOR, (CU) CATEDRATICO DE UNIVERSIDAD, (TU) TITULAR DE UNIVERSIDAD

http://www.um.es/sustainablechemistry/

GREEN AND SUSTAINABLE COSMETICS





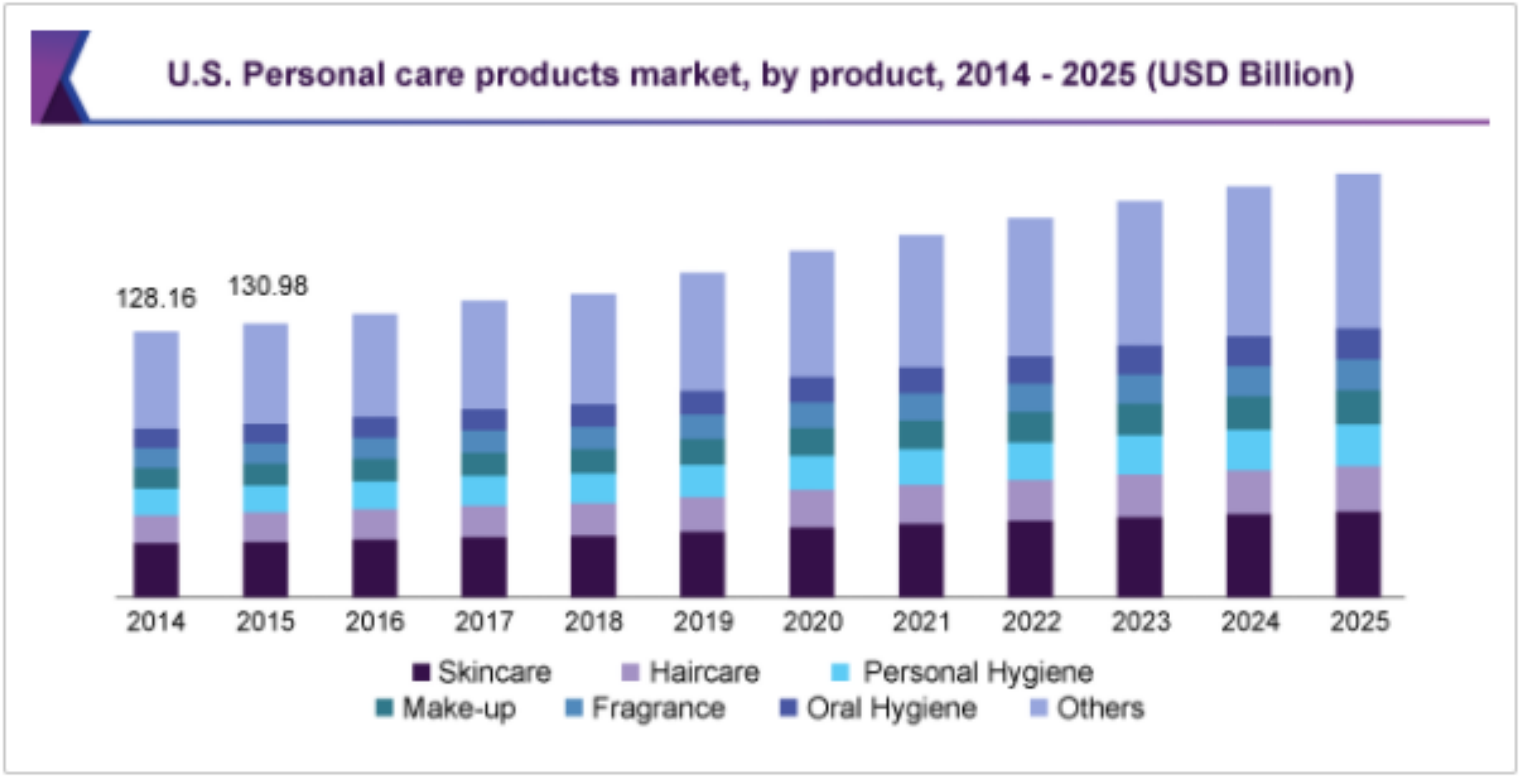
PDF

Market Analysis Report

U.S. Personal Care Products Market Size, Share & Trends Analysis Report By Product (Skincare, Haircare, Personal Hygiene, Make-up, Fragrances, Oral Hygiene), Competitive Landscape, And Segment Forecasts, 2018 - 2025

Published Date: Jan, 2018 | Base Year for Estimate: 2016 | Report ID: GVR-2-68038-301-0

Format: Electronic (PDF) | Historical Data: 2014 - 2015 | Number of Pages: 74



What does Green Cosmetics mean ….?

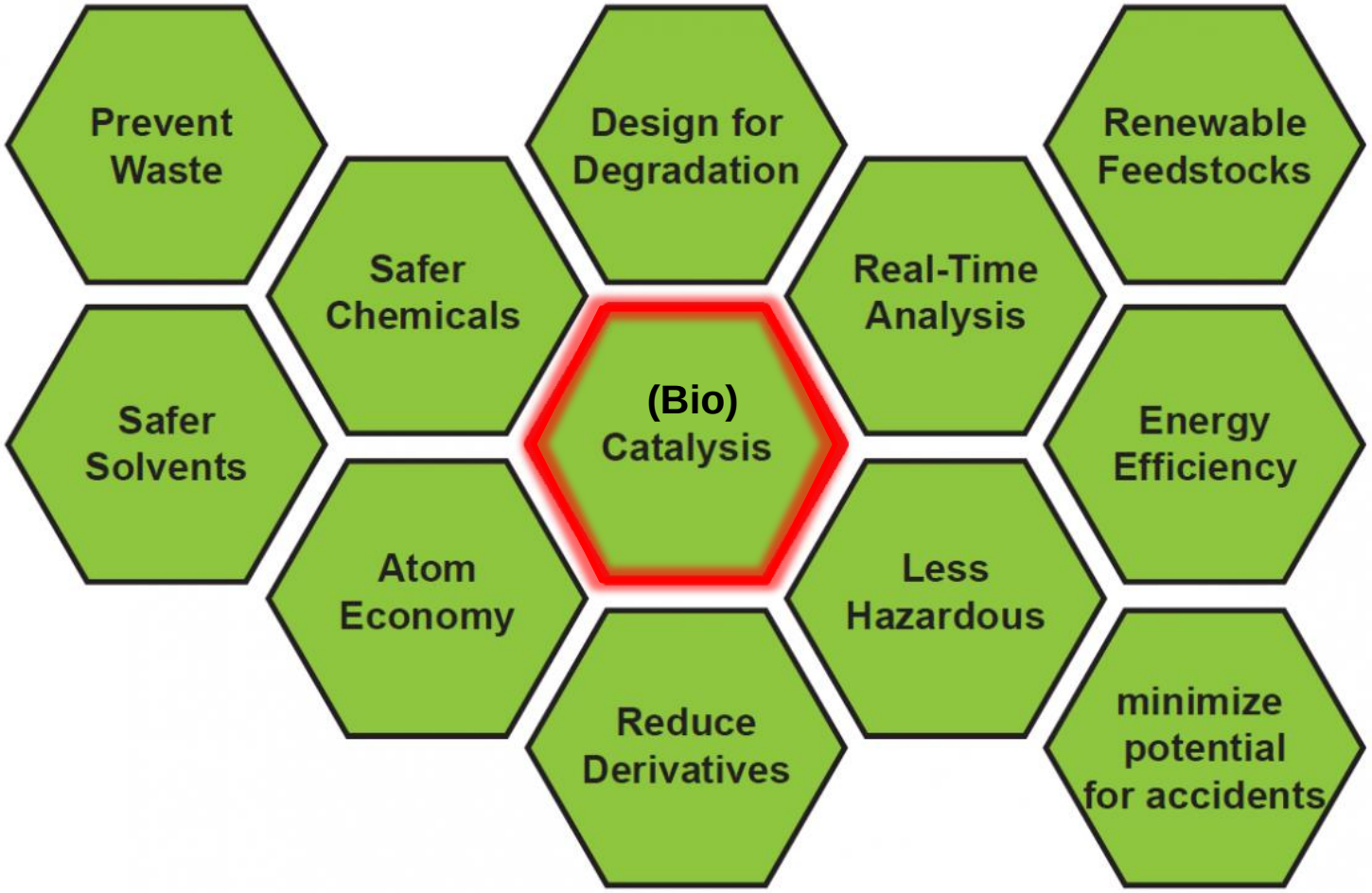
- Natural products / ingredients
- Renewable resources
- Solvent-free process and products
- Biotechnological transformations
- ……

"Natural" flavours can only be prepared by physical processes (*e.g.* extraction) from natural sources, or by enzymatic or microbial transformation of precursors isolated from nature.

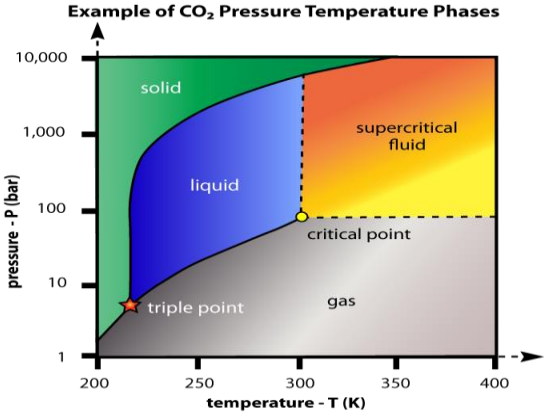
The use of petrochemical solvents, like hexane, is not permitted

1. EC Council, Council Directive 88/388/ EEC, 1988.

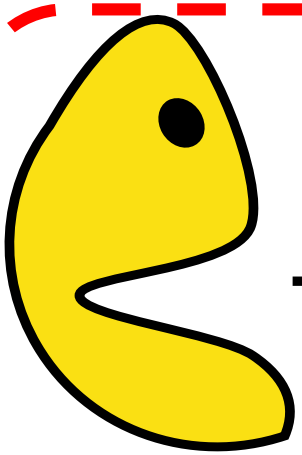
Twelve Principles of Green Chemistry



HOW WE TRY TO WALK TOWARDS "GREEN /DREAM" CHEMISTRY?



Supercritical Fluids



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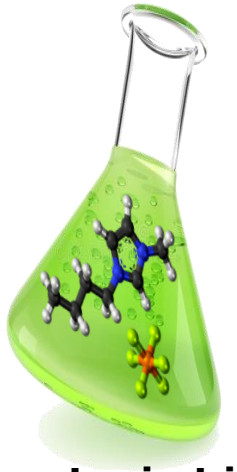
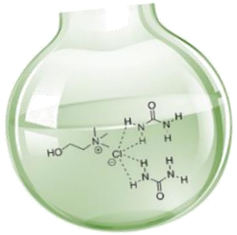
Chemical Catalyst



Ionic Liquids

(Bio)catalysts



Deep Eutectic Solvents

WITHOUT ORGANIC SOLVENTS

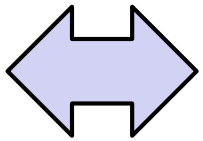
Ultrasonic Irradiation
Solvent-free

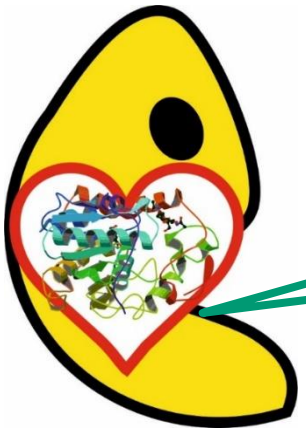
AIMS

- No by-products
- No air emissions
- No wastes
- Direct release of nearly pure products
- Full recovery and reuse of the reaction system

…. LIKE MAGIC

Biocatalysts are Magic Wands for Chemists!!!

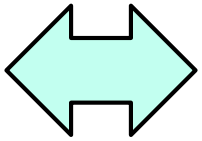




- ✓ Full transformation
- ✓ Highest Selectivity

S → **Thousands of Enzymes** / **Thousands of Reactions** → **P**

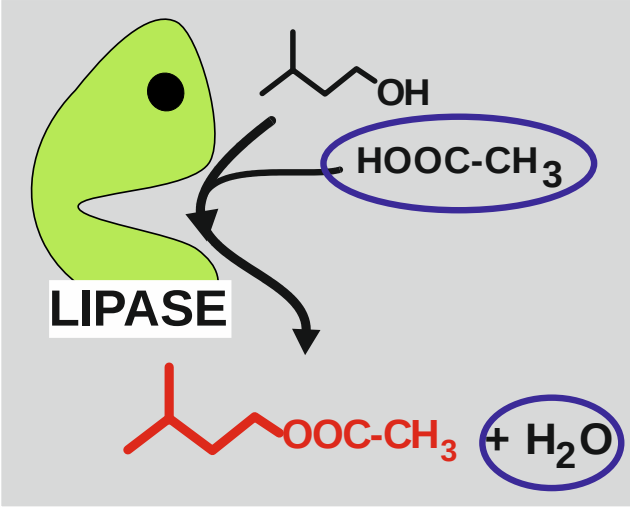
Reaction Systems Engineering for Clean Processes



- ➢ No air emissions
- ➢ No wastes
- ➢ Direct release of pure products
- ➢ Full recovery and reuse

Example 1

Enzymatic synthesis of FLAVOUR ESTERS by direct esterification in IONIC LIQUIDS



PROBLEMS

1. Fast Enzyme deactivation by acetic acid

1 mol AcH (57.4 mL)
+ 1 mol Isoamyl alcohol (111.2 mL)

5.93 M Acetic acid
5.93 M Isoamyl alcohol

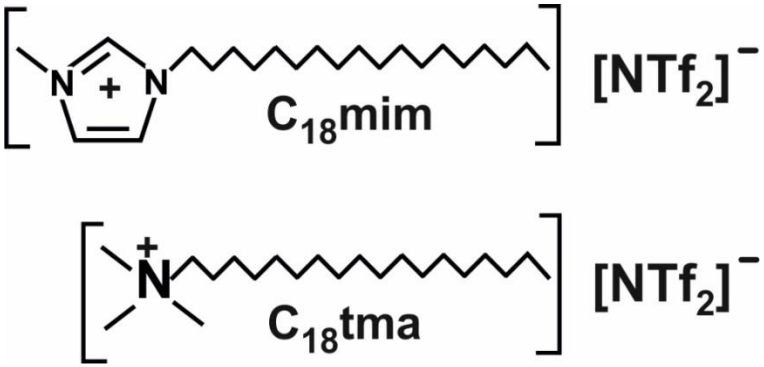
2. Continuous elimination of H_2O from reaction medium

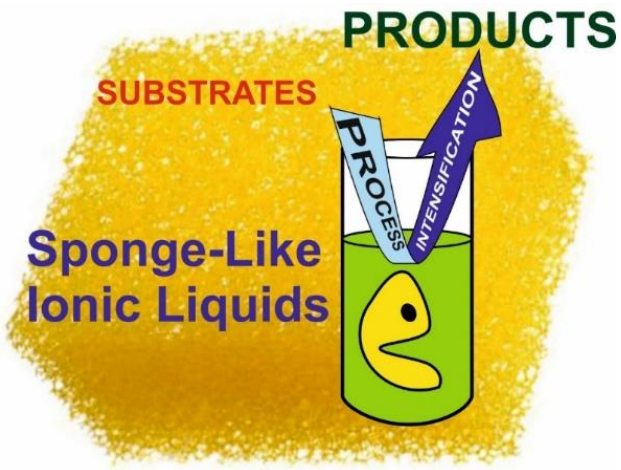
(up to 18 mL H_2O / mol of isoamyl acetate , 10.7% v/v)

Sponge-Like Ionic Liquids (SLILs)

- **Hydrophobic ILs based on LARGE ALKYL SIDE CHAIN in cation, which are <u>solid at room temperature.</u>**

- **NON-VOLATILE, Non-flammable, High thermal stability**

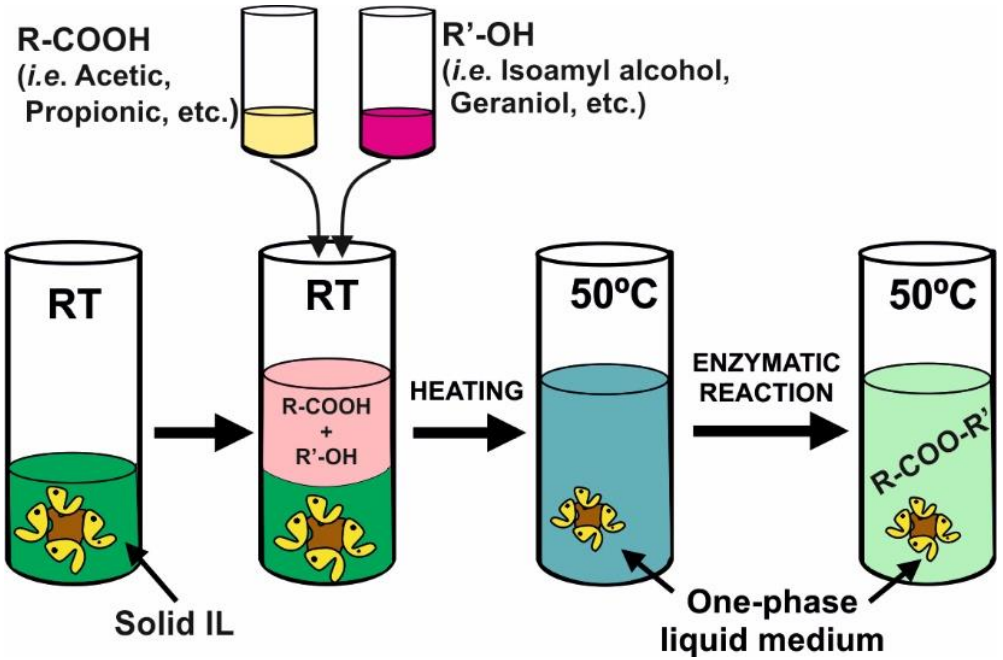




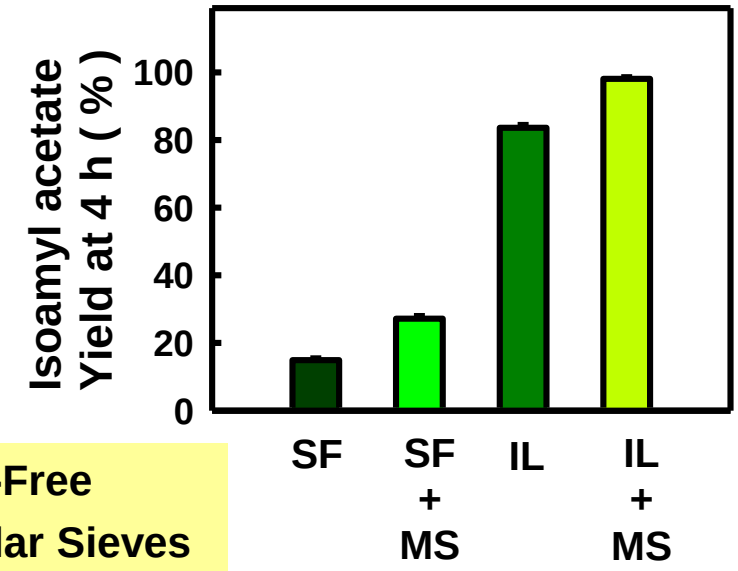
IL	Melting Point (ºC)
[C18tma] $[NTf_2]$	74
[C16tma] $[NTf_2]$	64
[C14tma] $[NTf_2]$	52
[C12tma] $[NTf_2]$	36
[C18mim] $[NTf_2]$	46

Lozano, *et al*. Sponge-like ionic liquids: a new platform for green biocatalytic chemical processes. *Green Chem*., <u>2015</u>, 17, 3706-3717

Examp. 5. Enzymatic synthesis of flavor ester by direct esterification in SLILs



Excellent reaction medium!!!



SF: Solvent-Free
MS: Molecular Sieves

Flavour and IL separation ??

By COOLING AND CENTRIFUGATION !!!

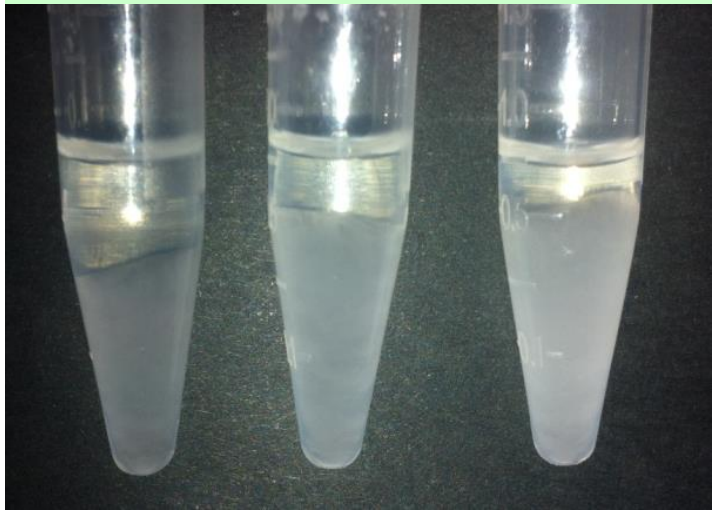
50ºC

RT

4ºC

SLIL (% w/w)

50 60 70



1. Cooling (0ºC)
2. Centrifugation

(**Product yield** > 92%)

Ionic Liquid

Pure Flavour Ester

Cite this: *Green Chem.*, 2012, **14**, 3026

www.rsc.org/greenchem

PAPER

A clean enzymatic process for producing flavour esters by direct esterification in switchable ionic liquid/solid phases†

Pedro Lozano,* Juana M. Bernal and Alicia Navarro

Received 12th July 2012, Accepted 20th August 2012
DOI: 10.1039/c2gc36081k

Table 1 Production of flavour esters by Novozym 435-catalyzed esterification between an aliphatic carboxylic acid (acetic, propionic, butyric or valeric) and a flavour alcohol (isoamyl alcohol, nerol, geraniol or citronellol) in 60% (w/w) $[C_{16}tma][NTf_2]$ after 4 h reaction at 50 °C, using 40 mg immobilized enzyme and 80 mg molecular sieves per mmol of the acid substrate, respectively. Assayed substrate amounts were 3 mmol flavour alcohol and 1 (A), 2 (B) or 3 (C) mmol aliphatic carboxylic acid, respectively

	Product concentration, g mL^{-1} (yield, %)		
Flavour ester	A	B	C
Isoamyl acetate	0.325 (97.0 ± 0.1)	0.572 (98.1 ± 1.7)	0.369 (47.7 ± 6.4)
Isoamyl propionate	0.356 (99.9 ± 0.1)	0.601 (99.9 ± 0.1)	0.738 (94.7 ± 3.7)
Isoamyl butyrate	0.374 (99.9 ± 0.1)	0.613 (99.1 ± 0.9)	0.739 (91.1 ± 6.4)
Isoamyl valerate	0.392 (99.9 ± 0.1)	0.626 (99.8 ± 0.2)	0.741 (86.6 ± 11.5)
Neryl acetate	0.305 (99.9 ± 0.1)	0.540 (96.6 ± 0.3)	0.687 (88.6 ± 2.2)
Neryl propionate	0.314 (98.7 ± 1.3)	0.543 (95.0 ± 0.1)	0.694 (89.2 ± 2.2)
Neryl butyrate	0.330 (99.9 ± 0.1)	0.556 (95.7 ± 0.3)	0.611 (78.4 ± 0.5)
Neryl valerate	0.335 (97.8 ± 0.4)	0.559 (94.5 ± 0.6)	0.650 (85.6 ± 9.3)
Geranyl acetate	0.324 (99.9 ± 0.1)	0.552 (93.4 ± 1.1)	0.702 (86.1 ± 6.8)
Geranyl propionate	0.337 (99.6 ± 0.4)	0.570 (94.6 ± 3.4)	0.680 (83.3 ± 5.8)
Geranyl butyrate	0.350 (99.9 ± 0.1)	0.599 (97.9 ± 0.3)	0.696 (85.4 ± 7.9)
Geranyl valerate	0.355 (97.9 ± 2.1	0.593 (95.5 ± 0.3)	0.757 (93.0 ± 5.3)
Citronellyl acetate	0.301 (99.9 ± 0.1)	0.546 (98.5 ± 1.3)	0.692 (90.1 ± 1.7)
Citronellyl propionate	0.315 (99.9 ± 0.1)	0.537 (94.8 ± 0.8)	0.741 (96.0 ± 2.1)
Citronellyl butyrate	0.327 (99.9 ± 0.1)	0.558 (96.9 ± 3.1)	0.722 (93.4 ± 4.6)
Citronellyl valerate	0.339 (99.9 ± 0.1)	0.570 (97.2 ± 1.5)	0.706 (91.0 ± 9.4)

ACS Sustainable Chemistry & Engineering

Research Article

Cite This: ACS Sustainable Chem. Eng. 2019, 7, 13307−13314

pubs.acs.org/journal/ascecg

Clean Enzymatic Production of Flavor Esters in Spongelike Ionic Liquids

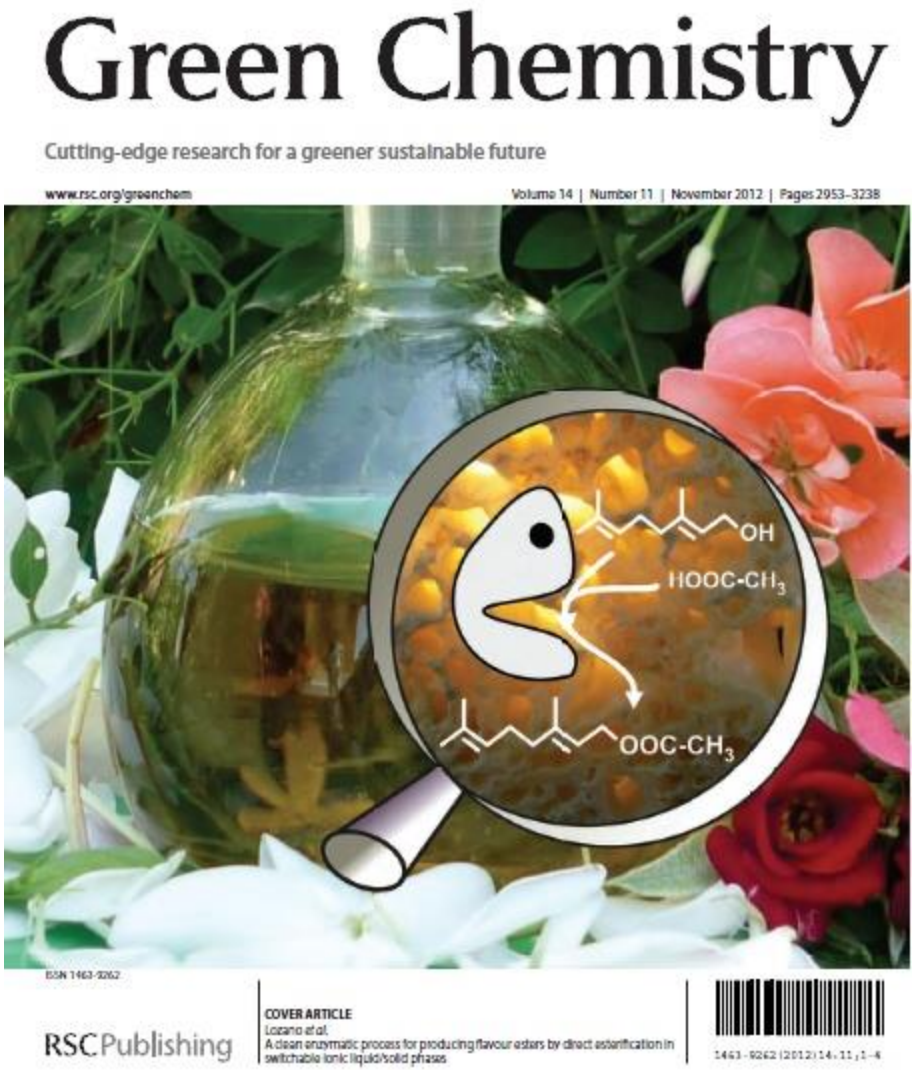
Elena Alvarez,[†] Jose Rodriguez,[†] Rocio Villa,[†] Celia Gomez,[†] Susana Nieto,[†] Antonio Donaire,[‡] and Pedro Lozano*[,†]

Table 1. Flavor Ester Yield Obtained by Novozyme-435-Catalyzed Esterification Reactions in 50% (w/w) SLILs after 4 h at 50 °C[a]

entry	SLIL	flavor ester	yield (%)
1	$[C_{12}tma][NTf_2]$	cinnamyl propionate	98.0
2	$[C_{14}tma][NTf_2]$	cinnamyl propionate	98.4
3	$[C_{16}tma][NTf_2]$	cinnamyl propionate	98.6
4	$[C_{18}tma][NTf_2]$	cinnamyl propionate	99.3
5	$[C_{16}tma][NTf_2]$	cinnamyl acetate	99.0
6	$[C_{16}tma][NTf_2]$	cinnamyl butyrate	96.1
7	$[C_{16}tma][NTf_2]$	cinnamyl valerate	98.9
8	$[C_{16}tma][NTf_2]$	cinnamyl hexanoate	98.5
9	$[C_{16}tma][NTf_2]$	cinnamyl heptanoate	98.5
10	$[C_{16}tma][NTf_2]$	cinnamyl octanoate	98.6
11	$[C_{16}tma][NTf_2]$	benzyl acetate	99.5
12	$[C_{16}tma][NTf_2]$	benzyl propionate	99.8
13	$[C_{16}tma][NTf_2]$	benzyl butyrate	99.6
14	$[C_{16}tma][NTf_2]$	anisyl acetate	99.0
15	$[C_{16}tma][NTf_2]$	anisyl propionate	99.1
16	$[C_{16}tma][NTf_2]$	anisyl butyrate	98.9
17	$[C_{16}tma][NTf_2]$	*R*-1-phenylethyl propionate	49.5 (ee > 99)
18	$[C_{16}tma][NTf_2]$	*R*-sulcatyl propionate	48.9 (ee > 99)
19	$[C_{16}tma][NTf_2]$	*R*-sulcatyl hexanoate	49.7 (ee > 99)

[a]See the Experimental Section for further details.

Green Chemistry or “Dream” Chemistry?



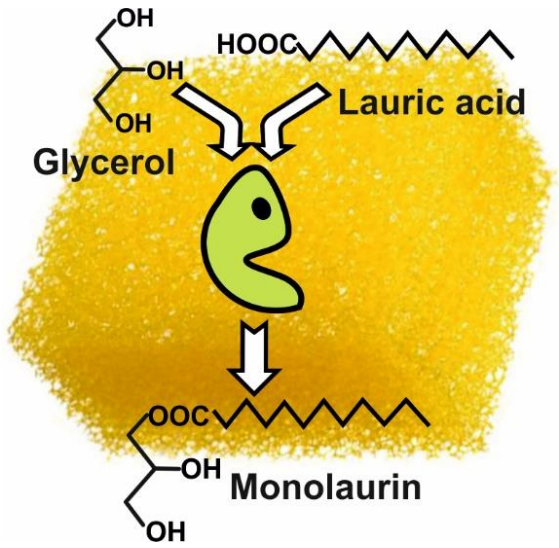
Lozano *et al*. *Green Chem*. 2012, 14, 3026–3033

Example 2

GREEN ENZYMATIC SYNTHESIS OF MONOACYLGLYCERIDES in IONIC LIQUIDS

- Natural non-ionic surfactants
- Nutraceuticals

DIRECT ESTERIFICATION



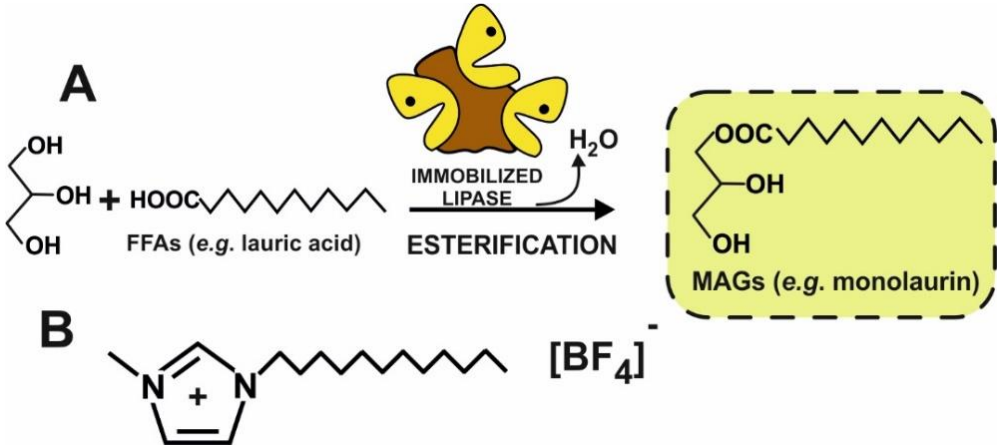
Glycerol + Fatty acid $\rightleftharpoons$ (**Lipase**) **Monoacylglyceride + H_2O**

- **Hydrophilic**
- **Liquid**
- **Highly viscous**

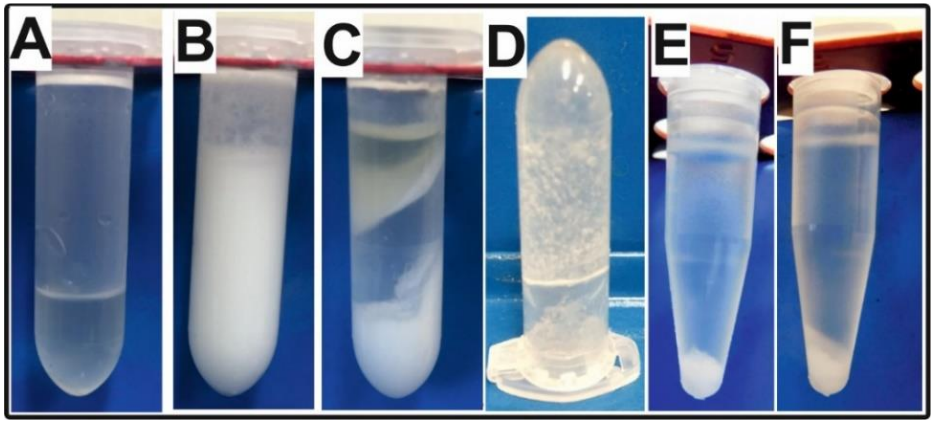
- **Hydrophobic**
- **Solid**
- **Viscous**

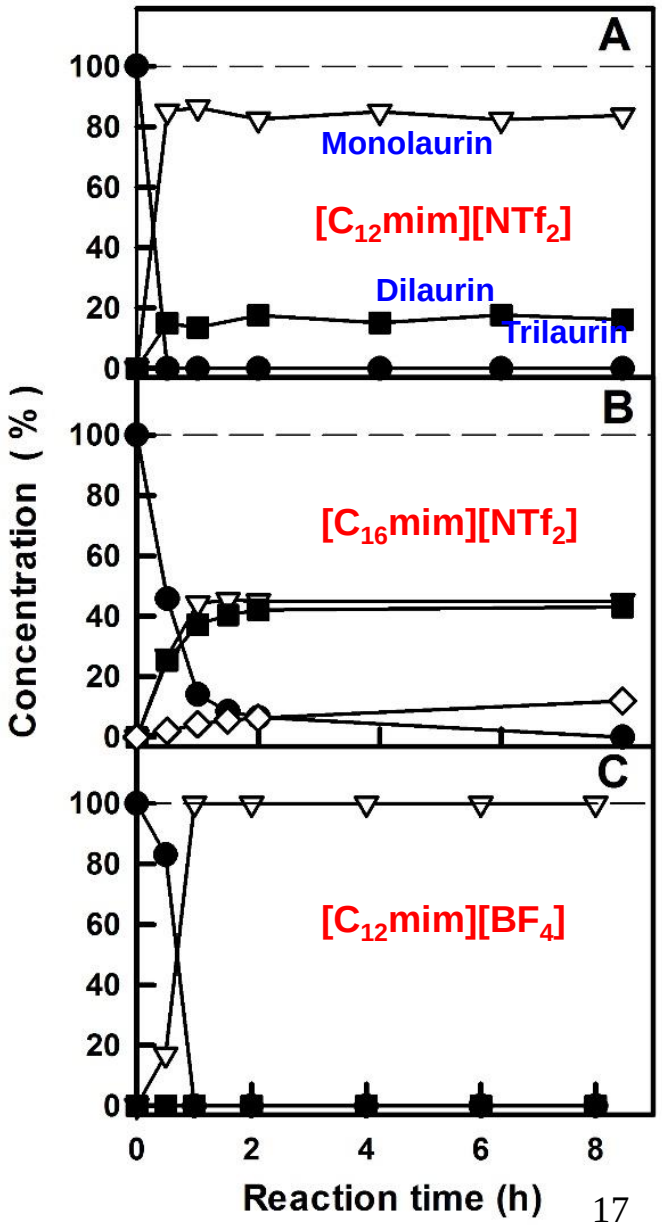
- **Amphipathic**
- **Solid / Liquid**
- **Highly viscous**

Lozano *et al. Green Chem*. **2017**, 19, 390 –396



Monoolein/[C18mim][NTf2] Monolaurin/[C12mim][BF4]





Lozano *et al. Green Chem*. **2017**, 19, 390 –396

Example 3

Green Chemistry

ROYAL SOCIETY OF CHEMISTRY

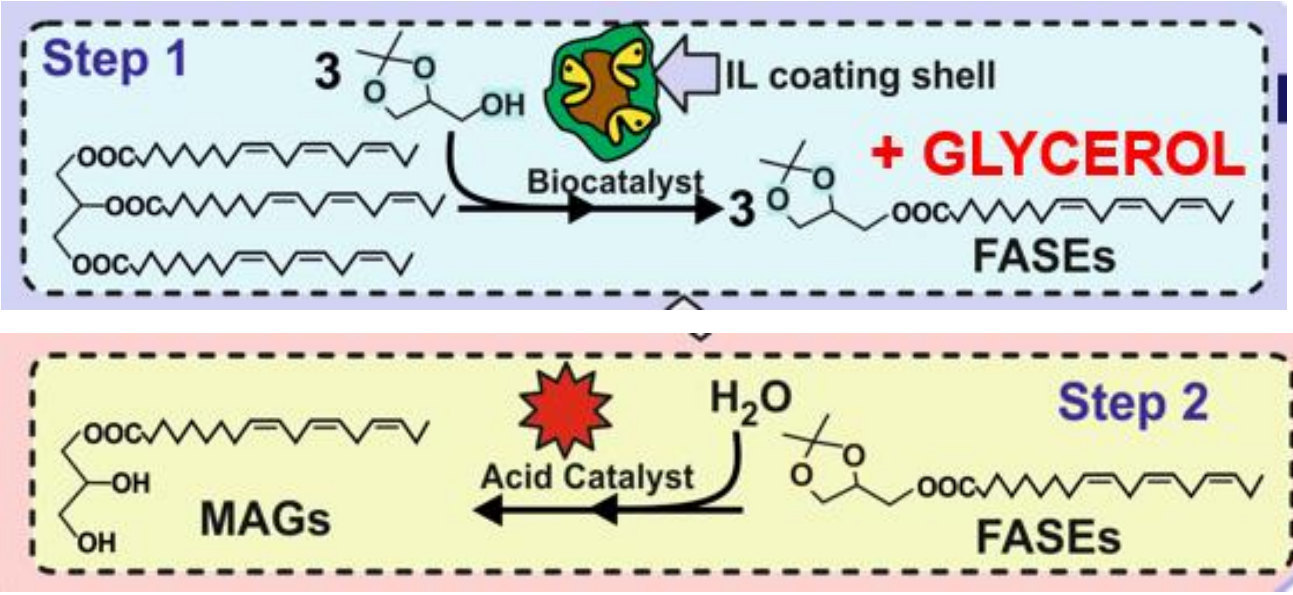
PAPER

Check for updates

Cite this: *Green Chem.*, 2020, **22**, 5701

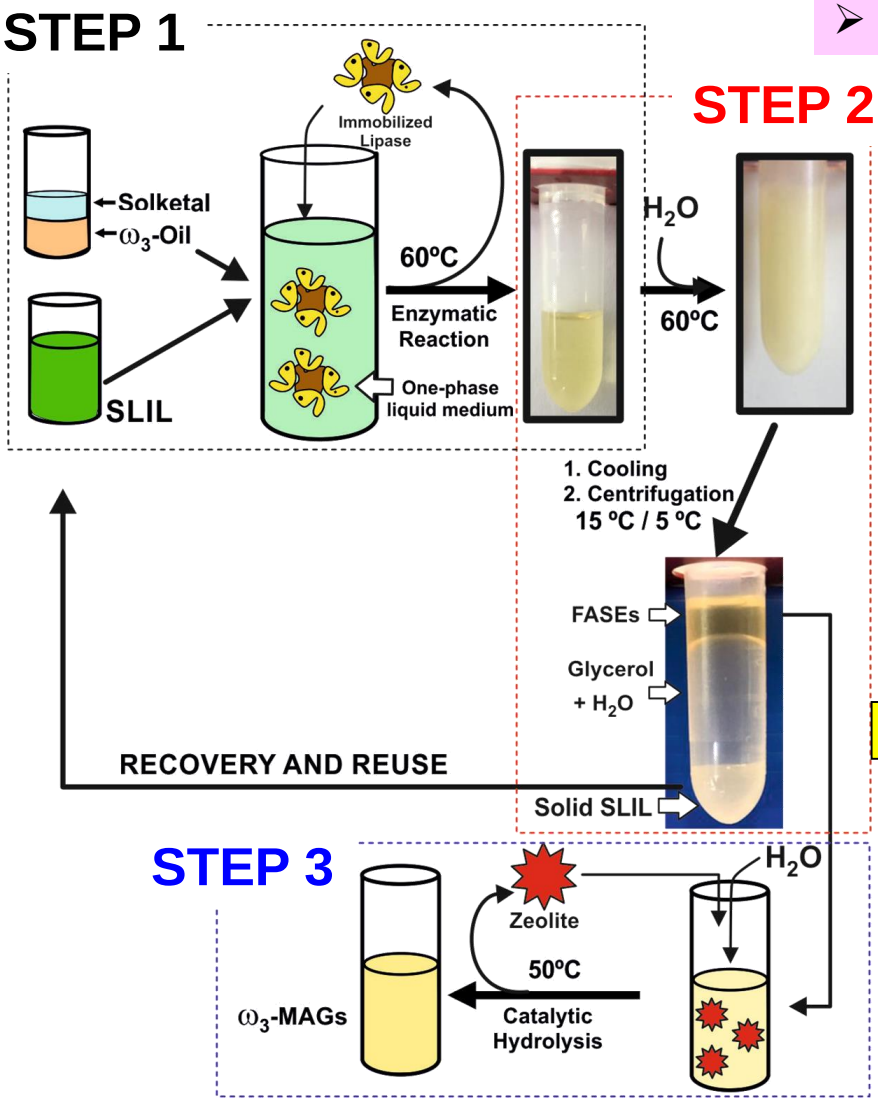
Chemo-enzymatic production of omega-3 monoacylglycerides using sponge-like ionic liquids and supercritical carbon dioxide†

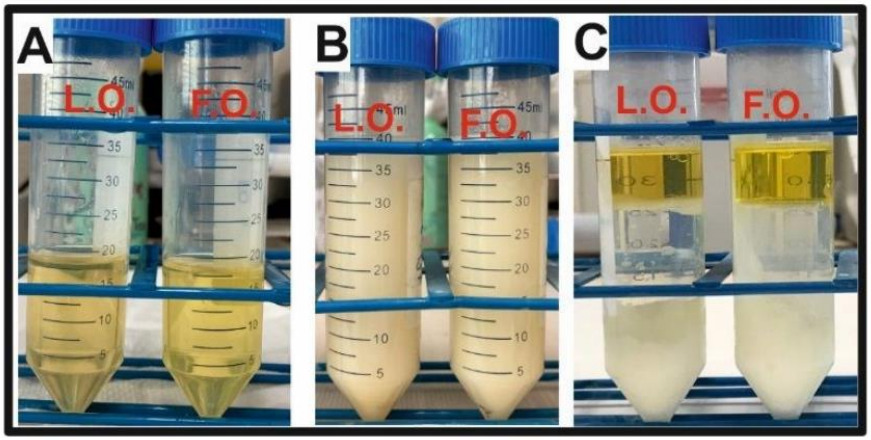
Rocio Villa,[a] Elena Alvarez,[a] Susana Nieto,[a] Antonio Donaire,[b] Eduardo Garcia-Verdugo,[c] Santiago V. Luis[c] and Pedro Lozano *[a]



SLILs in BIOCATALYTIC SYNTHESIS OF OMEGA-3 MONOACYLGLYCERIDES

- Natural non-ionic surfactants
- Nutraceuticals





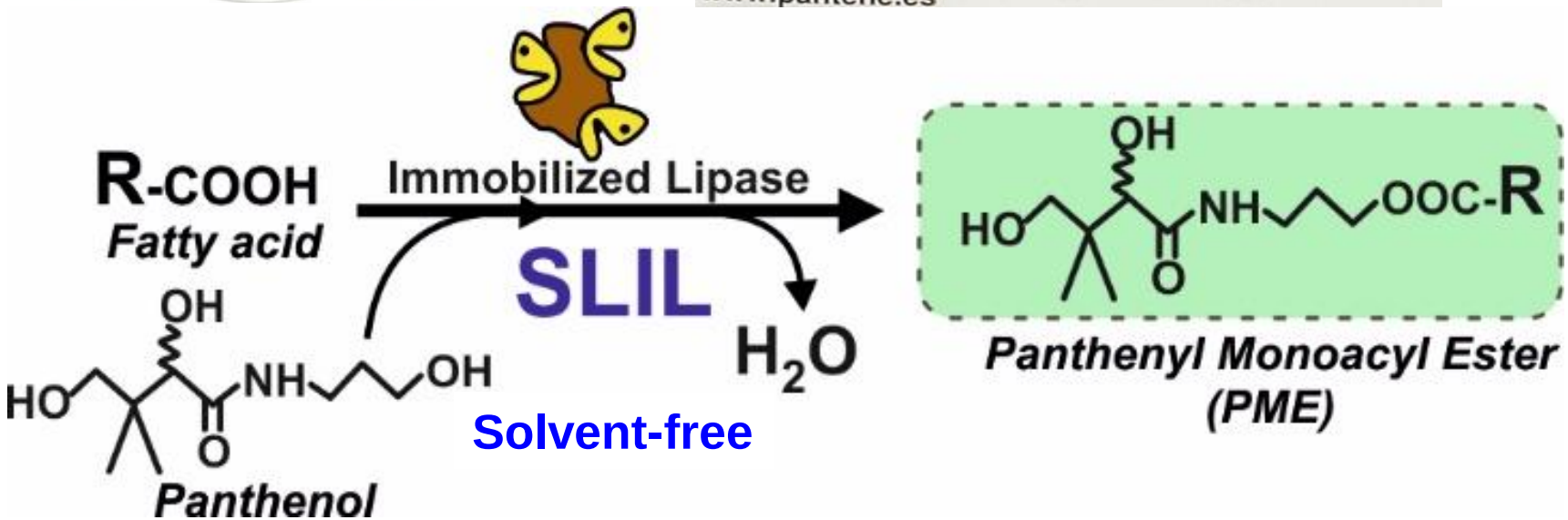
100% yield of IL-free omega-3 monoacylglycerides !!!!

Villa et al. *Green Chem.*, **2020**, 22, 5701-5710.

Example 4

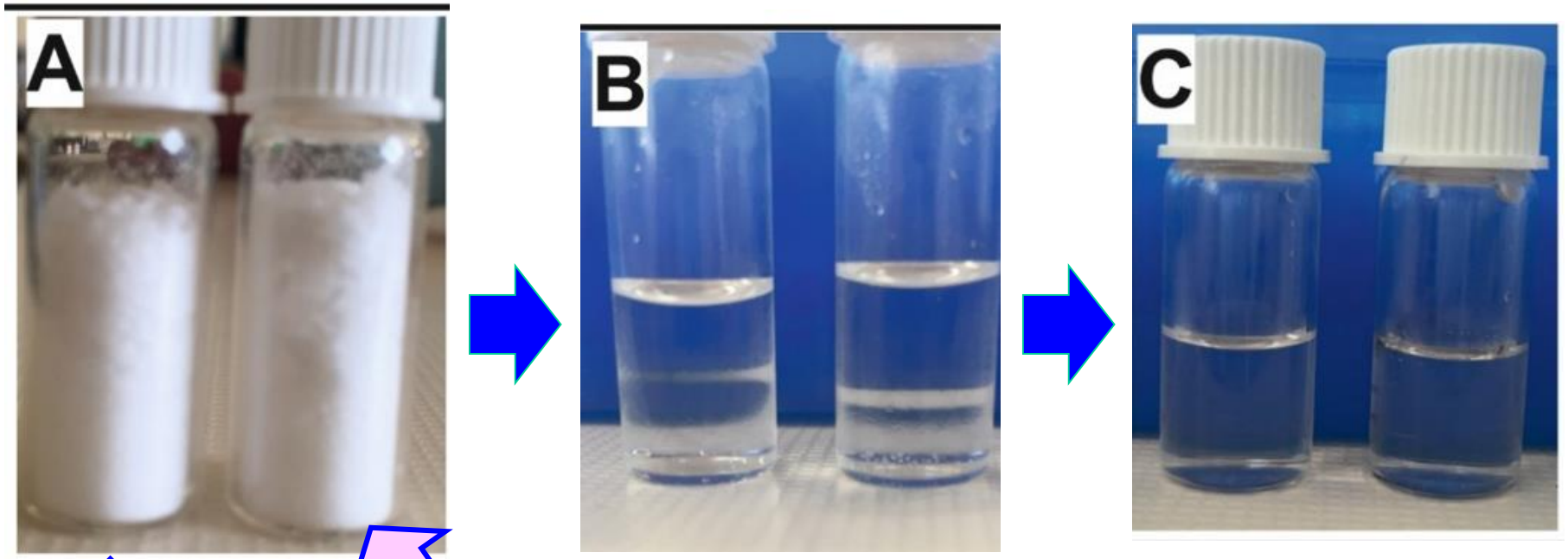
Biocatalytic synthesis of panthenyl monoacyl esters in Deep Eutectic Solvents (DES)

Panthenol: Skin and hair care



DES based on Panthenol + Fatty Acids MIXTURES

R.T. 80 ºC R.T.

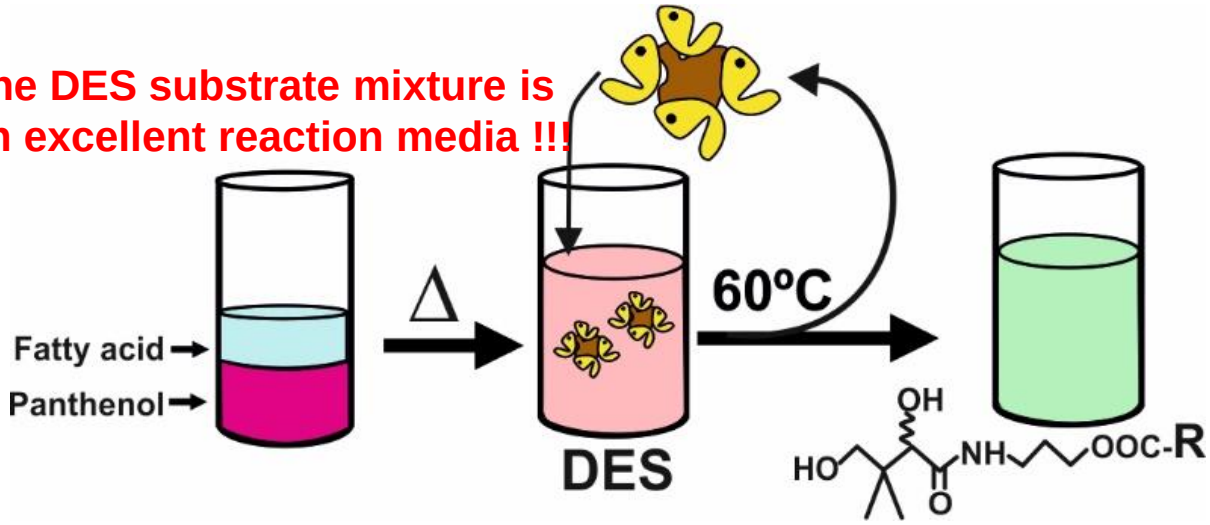


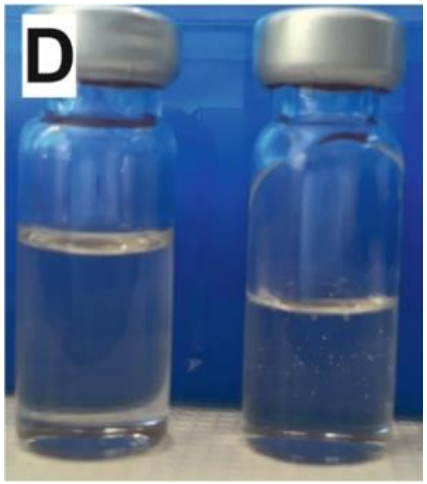
Palmitic acid (m.p. 63ºC
Panthenol (m.p. 69ºC)

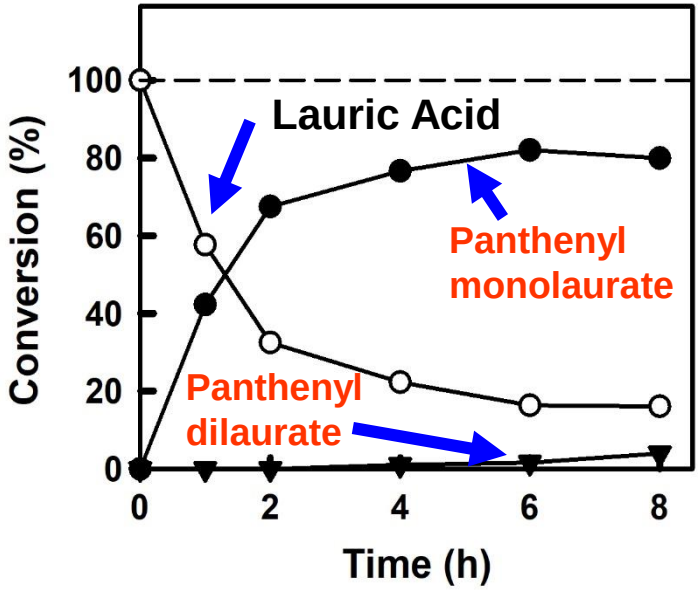
Lauric acid (m.p. 43ºC
Panthenol (m.p. 69ºC)

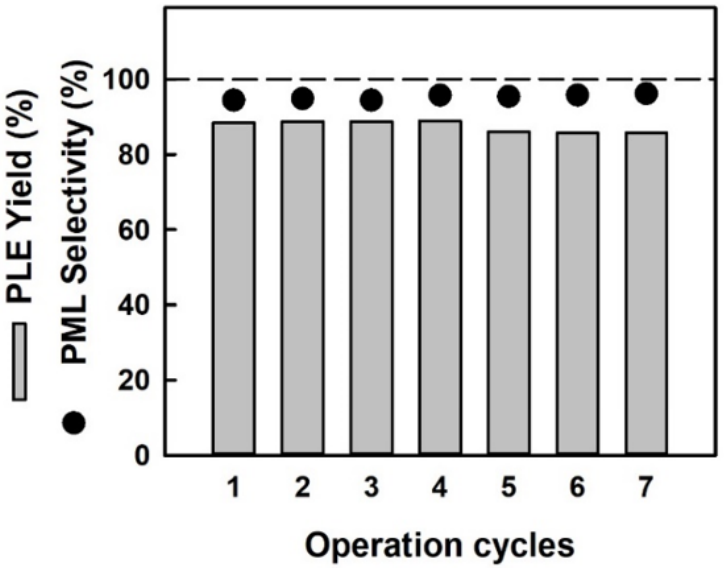
Reaction mixture is ready to be used in food, cosmetic, etc

The DES substrate mixture is an excellent reaction media !!!









Lozano et al. *Green Chem*., **2019**, 21, 3353–3361

Green Chemistry

PAPER

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Cite this: *Green Chem.*, 2019, **21**, 3353

Biocatalytic synthesis of panthenyl monoacyl esters in ionic liquids and deep eutectic solvents†

Pedro Lozano, *[a] Elena Alvarez,[a] Susana Nieto,[a] Rocio Villa,[a] Juana M. Bernal[a,b] and Antonio Donaire[c]

(12) SOLICITUD INTERNACIONAL PUBLICADA EN VIRTUD DEL TRATADO DE COOPERACIÓN EN MATERIA DE PATENTES (PCT)

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(54) Title: METHOD FOR ENZYMATIC SYNTHESIS OF MONOESTERS OF POLYHYDROXYLATED COMPOUNDS

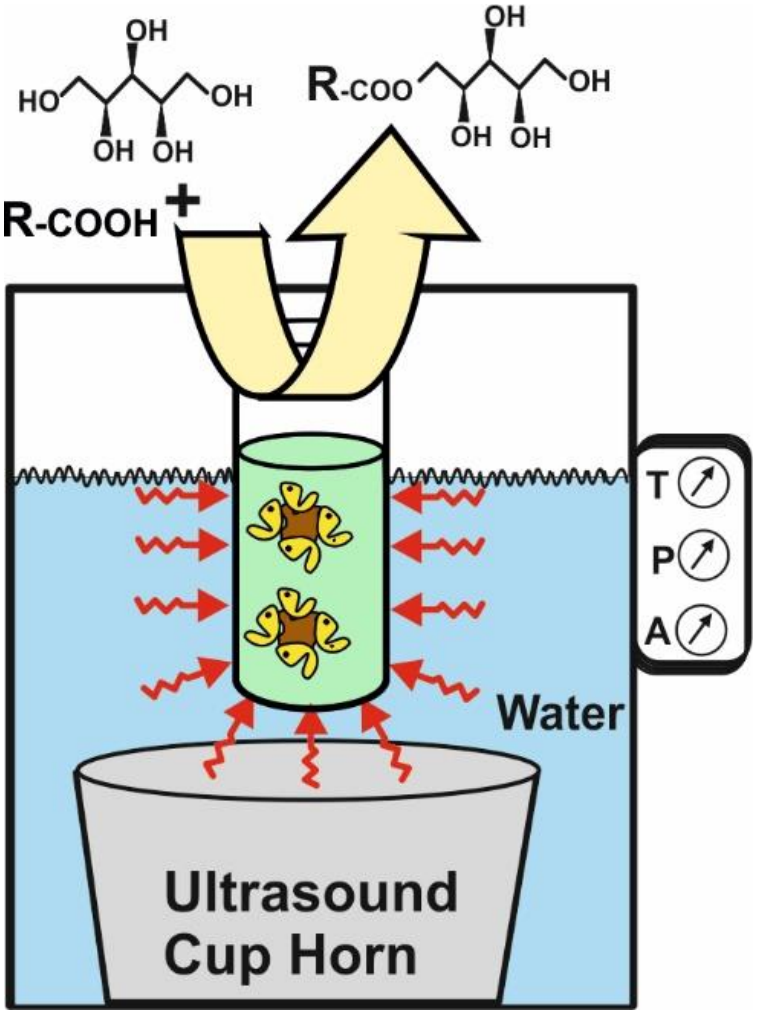
Example 5

Ultrasound-assisted biocatalytic synthesis of xylitol monoacyl esters

- **SOLVENT-FREE APPROACH**
- **SOLID SUBSTRATES NON-FORMING DES**

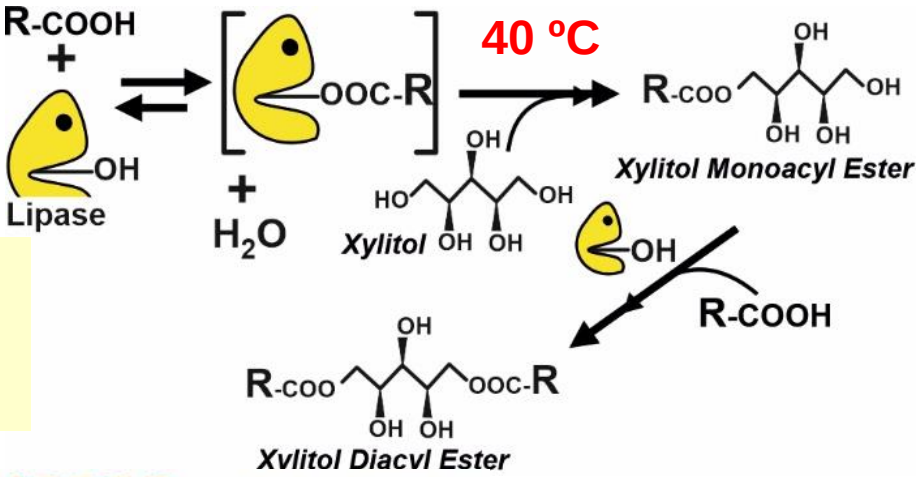
- **Natural non-ionic surfactants**
- **Nutraceuticals**

Xylitol, m.p. 93 ºC
Lauric acid, m.p. 43ºC

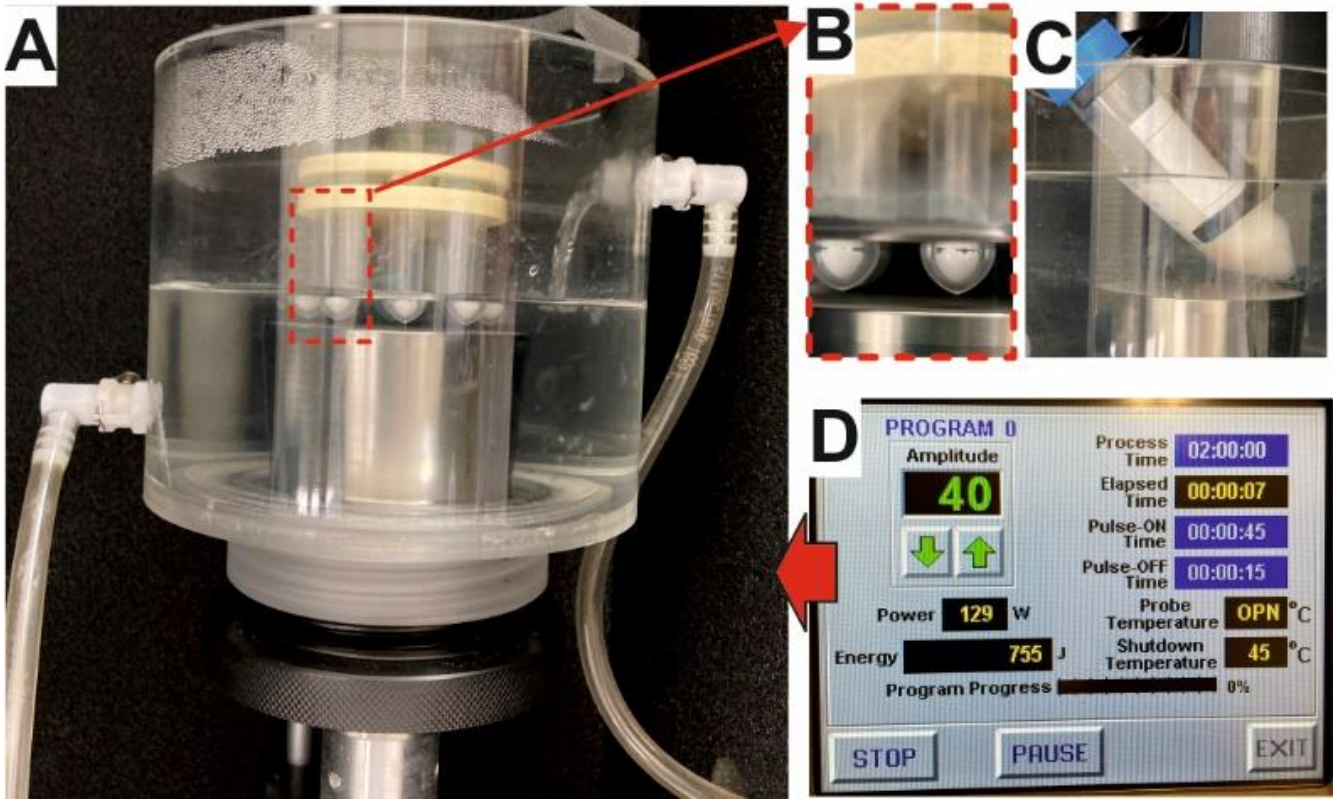


Nieto at al. *Ultrason. Sonochem*. **2021**, 75, Art nº 105606.

Experimental set-up

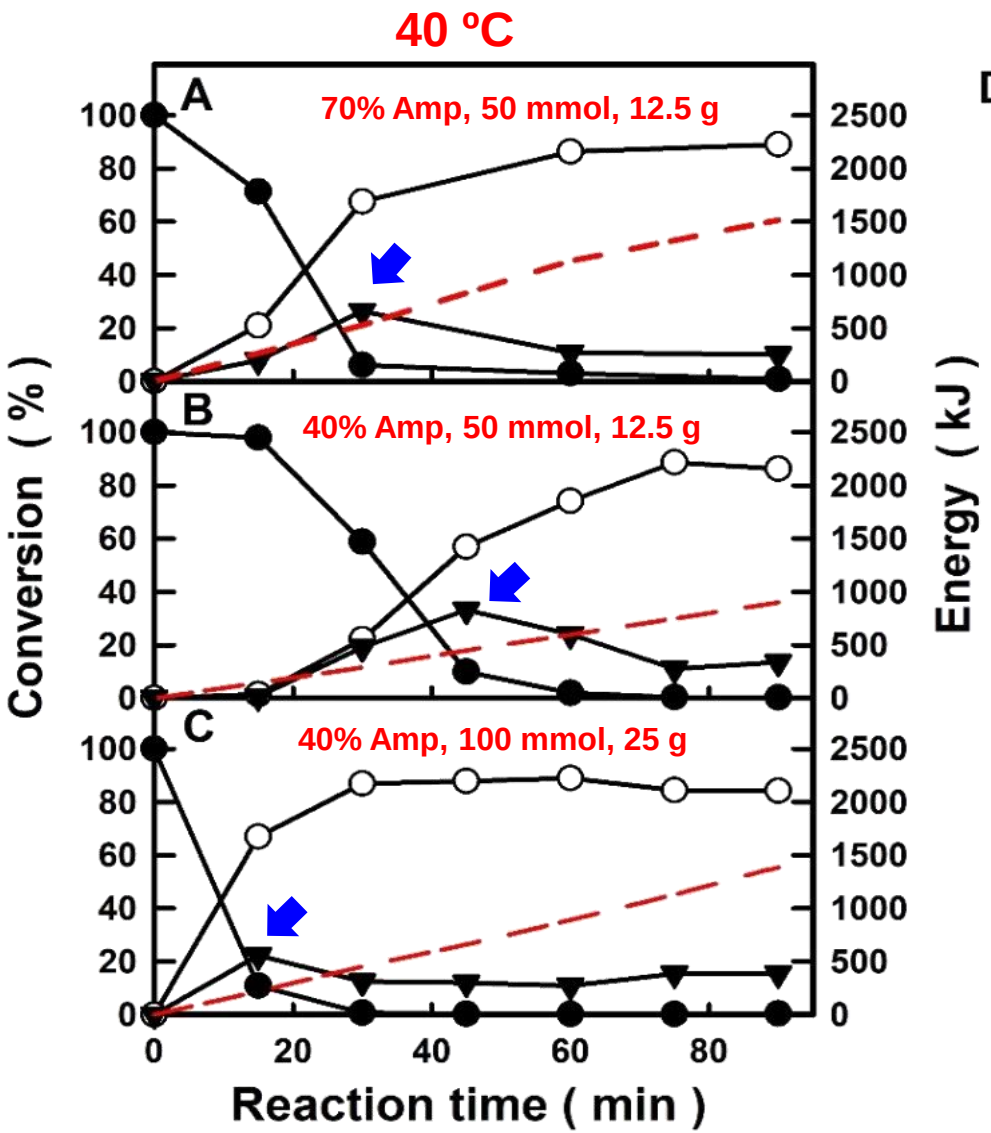


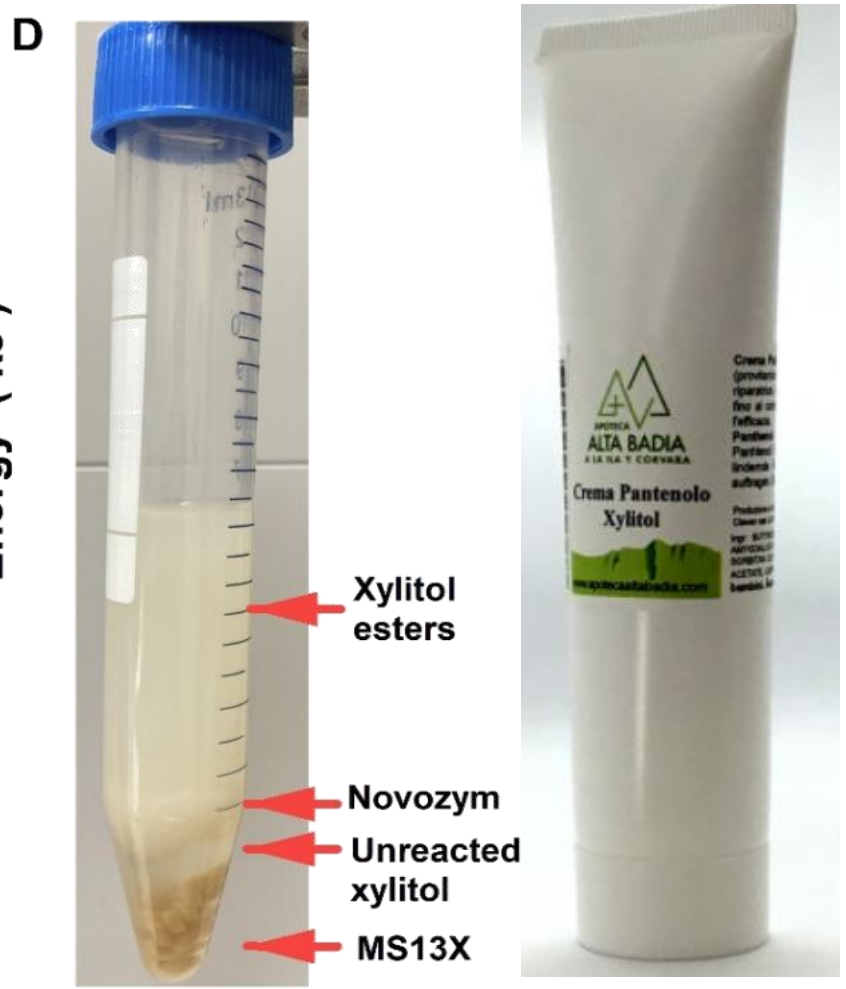
DIRECT ESTERIFICATION BETWEEN A **SOLID** CARBOXILIC ACID WITH A **SOLID** POLYOL **WITHOUT SOLVENT** !!!!



Nieto at al. *Ultrason. Sonochem*. **2021**, 75, Art nº 105606.

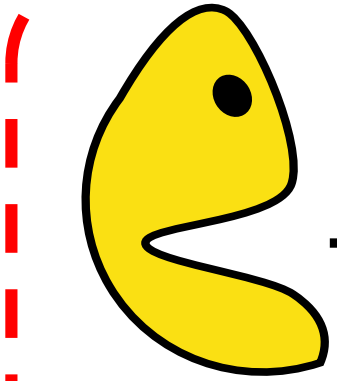
Reaction mixture is ready to be used in food, cosmetic, etc





Nieto at al. *Ultrason. Sonochem*. **2021**, 75, Art nº 105606.

CONCLUSIONS



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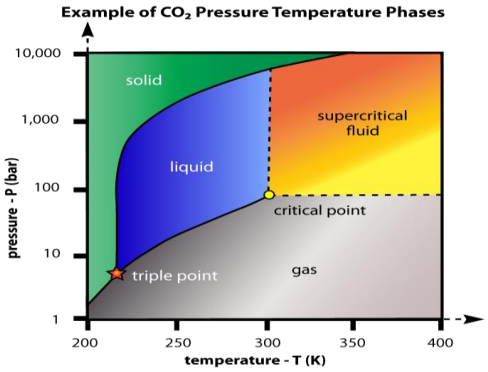
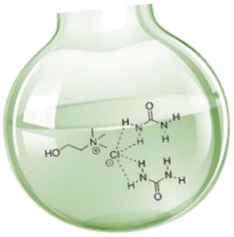
Chemical Catalyst

(Bio)catalysts

Ionic Liquids



Supercritical Fluids

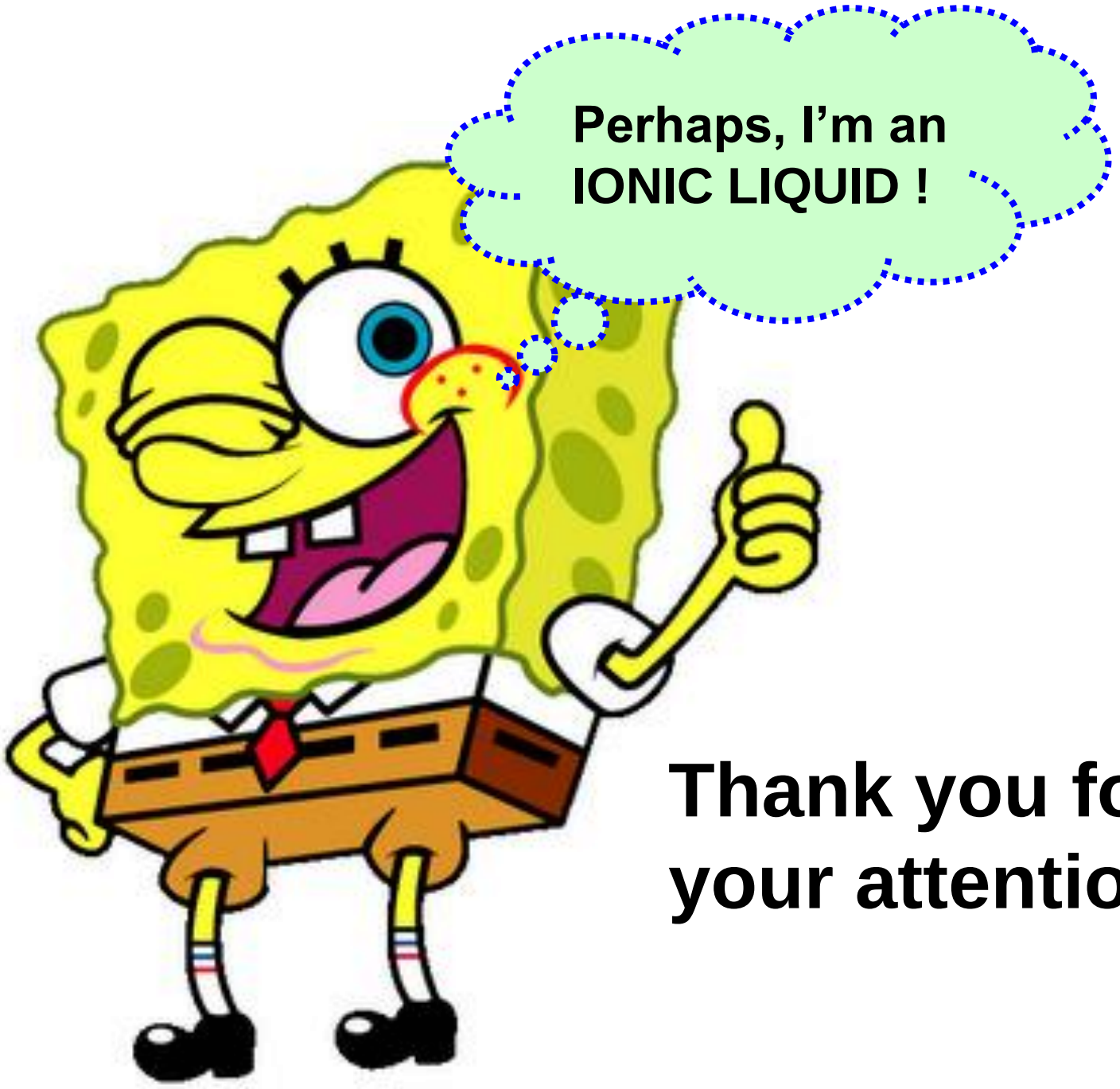


Deep Eutectic Solvents

Ultrasonic Irradiation

Is it possible?..... Do it !!!

Let's go to a Dream Chemistry !!!



Thank you for your attention !