Supplementary data

Deep Eutectic Solvents as Efficient Media for the Extraction and Recovery of Cynaropicrin from Cynara cardunculus L. leaves

Emanuelle L.P. de Faria [1], Rafael S. do Carmo [1], Ana Filipa M. Cláudio [1], Carmen S.R. Freire [1], Mara G. Freire [1] and Armando J.D. Silvestre [1,*]

[1] CICECO – Aveiro Institute of Materials, Chemistry Department, University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal

*Corresponding author: armsil@ua.pt; tel: + 351 234370701; Fax: +351 234370084

Table S1. Prepared DES, HBD:HBA ratio and physical state at room temperature (ca. 25^{0}C).

Hydrogen bond donor	Hydrogen bond Acceptor	HBD:HBA Ratio	Physical state
Decanoic acid	Choline chloride	1:1 / 2:1 / 1:2	Solid
Hexanoic acid	Choline chloride	2:1	Solid
Hexanoic acid	Choline chloride	4:1	Solid
Hexanoic acid	$[N_{2222}]Br$	2:1	Solid
Decanoic acid	$[N_{2222}]Br$	2:1	Solid
Hexanoic acid	$[N_{3333}]Br$	2:1	Solid
Decanoic acid	$[N_{3333}]Br$	2:1	Solid
Butanoic acid	$[N_{4444}]Br$	2:1	Liquid
Butanoic acid	$[N_{4444}]Br$	1:1	Liquid
Butanoic acid	$[N_{4444}]Br$	1:2	Solid
Caprylic acid/ hexanoic	$[N_{4444}]Br$	1:1	Liquid
Caprylic acid/ hexanoic	$[N_{4444}]Br$	2:1	Liquid
Caprylic acid/ hexanoic	$[N_{4444}]Br$	1:2	Solid
Octanoic acid	$[N_{4444}]Br$	2:1	Liquid
Octanoic acid	$[N_{4444}]Br$	1:1	Solid
Octanoic acid	$[N_{4444}]Br$	1:2	Solid
Decanoic acid	$[N_{4444}]Br$	2:1	Liquid
Decanoic acid	$[N_{4444}]Br$	1:1	Solid
Decanoic acid	$[N_{4444}]Br$	1:2	Solid

Lauric acid/ dodecanoic	$[N_{4444}]Br$	2:1	Liquid
Lauric acid/ dodecanoic	$[N_{4444}]Br$	1:1	Solid
Lauric acid/ dodecanoic	$[N_{4444}]Br$	1:2	Solid
Miristic acid/ tetradecanoic	$[N_{4444}]Br$	2:1	Solid
Hexanoic acid	$[N_{2222}]Cl$	2:1	Liquid
Decanoic acid	$[N_{2222}]Cl$	2:1	Liquid
Caprilic acid / hexanoic	$[N_{3333}]Cl$	2:1	Liquid
Caprilic acid/ Hexanoic	$[N_{3333}]Cl$	1:1	Solid
Caprilic acid/ Hexanoic	$[N_{3333}]Cl$	1:2	Solid
Decanoic acid	$[N_{3333}]Cl$	2:1	Liquid
Lauric acid/ dodecanoic	$[N_{3333}]Cl$	2:1	Liquid
Lauric acid/ dodecanoic	$[N_{3333}]Cl$	1:1	Solid
Lauric acid/ dodecanoic	$[N_{3333}]Cl$	1:2	Solid
Butanoic acid	$[N_{4444}]Cl$	2:1	Liquid
Butanoic acid	$[N_{4444}]Cl$	1:1	Solid
Butanoic acid	$[N_{4444}]Cl$	1:2	Solid
Hexanoic acid	$[N_{4444}]Cl$	2:1	Liquid
Hexanoic acid	$[N_{4444}]Cl$	1:1	Solid
Hexanoic acid	$[N_{4444}]Cl$	1:2	Solid
Octanoic acid	$[N_{4444}]Cl$	2:1	Liquid
Octanoic acid	$[N_{4444}]Cl$	1:1	Solid

Octanoic acid	$[N_{4444}]Cl$	1:2	Solid
Decanoic acid	$[N_{4444}]Cl$	2:1	Liquid
Decanoic acid	$[N_{4444}]Cl$	1:1	Liquid
Decanoic acid	$[N_{4444}]Cl$	1:2	Solid
12-hydroxystearic acid	$[N_{4444}]Br$	1:1 / 2:1 / 1:2	Solid
12-hydroxystearic acid	$[N_{3333}]Cl$	1:1 / 2:1 / 1:2	Solid
12-hydroxystearic acid	Choline chloride	1:1 / 2:1 / 1:2	Solid

Table S2. Weight fraction percentage (extraction yield, wt.%) of cynaropicrin from the leaves of *Cynara cardunculus L.* with several DES at different molar ratio and fixed conditions, S/L ratio= 1:10, T = 25°C and t = 120 min.

DES	Cynaropicrin (wt.%)
But. Acid:$[N_{4444}]Br$ (2:1)	1.273 ± 0.003
But. Acid:$[N_{4444}]Br$ (1:1)	0.138 ± 0.003
But. Acid:$[N_{4444}]Cl$ (2:1)	2.216 ± 0.036
But. Acid:$[N_{2222}]Cl$ (2:1)	ND
Pure But. Acid	1.175 ± 0.000
Hex. Acid:$[N_{4444}]Br$ (2:1)	1.405 ± 0.004
Hex. Acid:$[N_{4444}]Br$ (1:1)	0.498 ± 0.010
Hex. Acid:$[N_{4444}]Cl$ (2:1)	2.483 ± 0.017
Hex. Acid:$[N_{2222}]Cl$ (2:1)	0.518 ± 0.007
Pure Hex. Acid	1.944 ± 0.002

Oct. Acid:[N_{4444}]Br (2:1)	1.694 ± 0.016
Oct. Acid:[N_{4444}]Br (1:1)	ND
Oct. Acid:[N_{4444}]Cl (2:1)	2.768 ± 0.023
Oct. Acid:[N_{2222}]Cl (2:1)	ND
Pure Oct. Acid	2.083 ± 0.028
Dec. Acid:[N_{4444}]Br (1:1)	ND
Dec. Acid:[N_{4444}]Br (2:1)	2.085 ± 0.001
Dec. Acid:[N_{4444}]Cl (2:1)	2.842 ± 0.014
Dec. Acid:[N_{2222}]Cl (2:1)	0.851 ± 0.003
Pure Dec. Acid	ND

*ND – Not determined.

Table S3. Weight fraction percentage (extraction yield, wt.%) of cynaropicrin from the leaves of *Cynara cardunculus L.* with decanoic acid:[N_{4444}]Cl (2:1) at different temperatures and other fixed conditions (S/L ratio = 1:10 and t = 120 min).

DES/Temperature	**Cynaropicrin (wt.%)**		
	25 ^{0}C	**35 ^{0}C**	**45 ^{0}C**
Decanoic acid:[N_{4444}]Cl	2.842 ± 0.014	2.473 ± 0.030	2.292 ± 0.022

Table S4. Weight fraction percentage (extraction yield, wt.%) of cynaropicrin from the leaves of *Cynara cardunculus L.* with decanoic acid:[N_{4444}]Cl (2:1) in different extraction time and fixed conditions, S/L ratio = 1:10 and T = 25°C.

DES/Extraction time	Cynaropicrin (wt.%)						
	30 min	**40 min**	**50 min**	**60 min**	**120 min**	**300 min**	**1440 min**
Decanoic acid:[N_{4444}]Cl	1.464 ± 0.005	1.614 ± 0.099	1.812 ± 0.052	3.130 ± 0.044	2.842 ± 0.014	2.295 ± 0.000	2.080 ± 0.042

Table S5. Optimization of weight fraction percentage of cynaropicrin extracted from the leaves of *Cynara cardunculus L.* with decanoic acid:[N_{4444}]Cl (2:1) at solid-liquid ratio and other fixed conditions (T = 25°C and t = 60 min).

DES/Solid-liquid ratio	Cynaropicrin (wt.%)				
	1:10	**1:20**	**1:30**	**1:40**	**1:50**
Decanoic acid:[N_{4444}]Cl	3.130 ± 0.044	3.853 ± 0.026	4.842 ± 0.086	4.942 ± 0.045	5.055 ± 0.117

Table S6. Weight fraction percentage (extraction yield, wt.%) of cynaropicrin from the leaves of *Cynara cardunculus L.* using aqueous solutions of decanoic acid:[N_{4444}]Cl (2:1), and other fixed conditions (T = 25°C, S/L ratio = 1:30 and t = 60 min).

DES/Added water (wt.%)	Cynaropicrin (wt.%)											
	0	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**Pure water**
Decanoic acid:[N_{4444}]Cl	4.842 ± 0.086	4.896 ± 0.012	5.065 ± 0.080	5.134 ± 0.164	5.309 ± 0.021	5.431 ± 0.089	5.622 ± 0.030	5.832 ± 0.030	6.202 ± 0.048	3.188 ± 0.025	1.928 ± 0.056	0.676 ± 0.036

Table S7. Weight fraction percentage (extraction yield, wt.%) of cynaropicrin from the leaves of *Cynara cardunculus L.* with several solvents and decanoic acid:[N_{4444}]Cl (2:1) (70 wt.% of water) at the following fixed conditions: S/L ratio = 1:30, t = 60 min and T = 25°C.

Solvent	Cynaropicrin (wt.%)
Decanoic acid:[N_{4444}]Cl	6.202 ± 0.048
n-hexane	0.037 ± 0.010
Acetone	0.346 ± 0.045
H_2O	0.676 ± 0.017
Dichloromethane	4.529 ± 0.266
Soxhlet	8.652 ± 0.407

Table S8. Weight fraction percentage (extraction yield, wt.%) of cynaropicrin from the leaves of *Cynara cardunculus L.* with the biomass recycle at fixed conditions (S/L ratio= 1:30, t = 60 min, T = 25°C).

Cycle	Cynaropicrin (wt.%)
1st	6.202 ± 0.048
2nd	1.491 ± 0.003
3rd	0.732 ± 0.018
4th	0.351 ± 0.003
5th	0.103 ± 0.009
6th	0.097 ± 0.012

Table S9. Weight fraction percentage (extraction yield, wt.%) of cynaropicrin from the leaves of *Cynara cardunculus L.* with the aqueous solution of DES recycle at fixed conditions (S/L ratio = 1:30, t = 60 min and T = 25°C)

Cycle	Cynaropicrin (wt.%)
1st	6.202 ± 0.048
2nd	6.664 ± 0.009
3rd	6.958 ± 0.109
4th	7.760 ± 0.093

Table S10. Amount of water (mL) added and e percentage of precipitation/recovery of cynaropicrin (0.5 mL of the DES-water solution used).

Amount of water (mL)	Cynaropicrin recovery (%)
5	38.26
10	48.28
15	52.51
25	65.70
50	73.61