Supporting information

Glycerol and its derivative

Glycerol is a byproduct of the biodiesel industry produced by transesterification of triglycerides with ethyl alcohol figure 1 (top). It is possible to convert glycerol into different valuable derivatives by simple methods, as shown in figure 1 (bottom).[1-4]

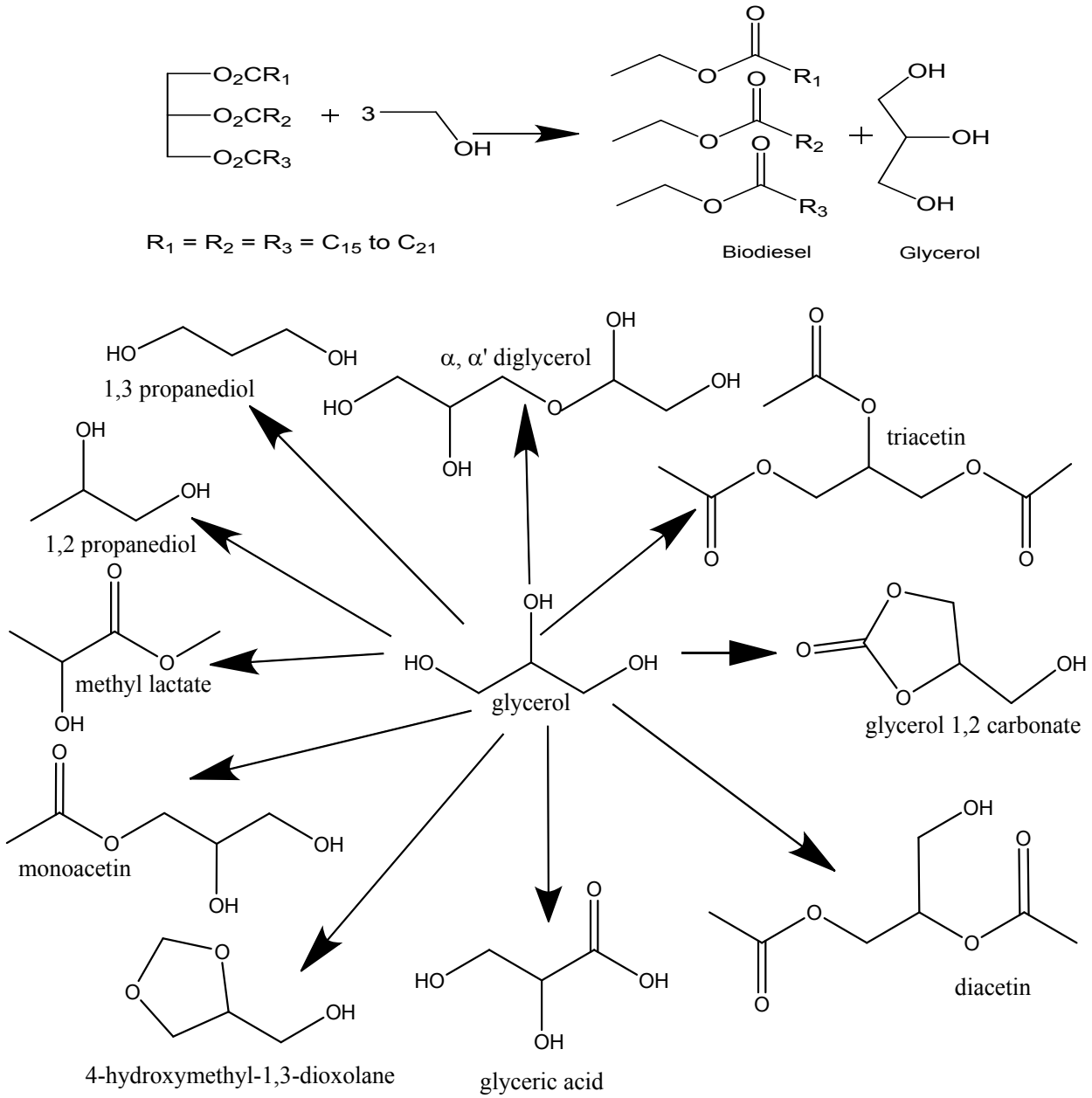


Figure 1. Transesterification of triglycerides with ethanol to produce biodiesel and glycerol and glycerol conversion into its most common derivatives

By using table 1, Hansen solubility parameters (HSP) values were calculated for those polymers and solvents, for which HSP values were not given in literature. [5-10]

Table 1. Solubility parameter component group distribution (Hoftyzer Van Krevelen method).

Contributing group	F_{di} $(MJ/m^3)^{1/2}\ mol^{-1}$	F_{pi} $(MJ/m^3)^{1/2}\ mol^{-1}$	E_{hi} $(MJ/m^3)^{1/2}\ mol^{-1}$	Molar volume V (cm^3/mol)
CH_3-	420	0	0	31.6
CH_2-	270	0	0	16.5
CH-	80	0	0	1.9
C	-70	0	0	-14.8
C=	70	0	0	-2.4
CH(=	200	0	0	13.7
(-O-	100	400	3000	5.1
OH-	210	770	20000	10.4
CO-	280	500	2000	10.7
COO-	390	490	4500	19.6
COOH-	530	420	10000	27.8
Ph- (o, m, p subs.)	1270	110		58.5
NH_2-	280	0	8400	17.9
-NH-	160	210	3100	4.5
N	20	800	5000	-8.5
ring	190	0	0	
-F	220	0	0	18
-S-	440	0	0	8

Table 2. HSP and Hildebrand values of the polymers and green solvents.

Polymers/solvents	HSP values $(MPa^{1/2})$			Hildebrand values $(MPa^{1/2})$
	δ_D	δ_P	δ_H	δ
PI	20.9	11.3	9.7	25.7
CA	18.6	12.7	11.0	25.1
CTA	18.4	11.9	10.1	24.2
PVDF	17.1	12.6	10.6	23.7
PSU	19.7	8.3	8.3	22.9
Chitosan	21.9	32.5	24.6	46.3
PES	19.6	10.8	9.2	24.2
PAN	21.7	14.1	9.1	27.0
PVA	17.0	9.0	18.0	26.3
Diacetin	16.4	8.9	14.2	23.4
α,α′-Diglycerol	16.1	25.8	24.8	39.2
Monoacetin	14.9	17.5	18.9	29.8
Triacetin	16.5	4.5	9.1	19.4
Methyl lactate	15.5	7.2	7.6	18.7
1,2-Propanediol	16.8	9.4	23.3	30.2
1,3-Propanediol	16.8	13.5	23.5	31.9
Glycerol carbonate	17.9	25.5	17.4	35.7
Glycerol	17.4	12.4	29.3	36.3
Glycerol formal	16.5	17.3	16.9	29.3
Glyceric acid	14.9	26.3	23.9	38.6
GVL	15.5	4.7	6.6	17.4

A single parameter to describe solvent quality and ability to dissolve polymer is given by the relative energy difference (RED), which is equal to Ra/R_o. It is used to explain the solubility of polymers in a given solvent by single value.

$$RED = R_a/R_0 \quad (1)$$

While *Ra* is interaction distance between polymer and solvent, R_0 or R is the sphere of the solubility radius of the polymer. If the *RED* value is smaller than 1, this indicates a high affinity between polymer and solvent, polymer should be soluble in the given solvent. When the *RED* value is higher than 1, indicates a low affinity between solvent and the polymer and the polymer would probably not be soluble in given solvent. Details of the Hansen solubility parameters and RED values are given in each table (Table 3-20) . RED values of all solvents/solvent blends have been calculated and given in tables 3-20 for corresponding polymers. Polymer which is soluble in a given solvent or solvent blend is highlighted by green color, while in some cases theoretical solubility were expected but no experimental solubility was found, highlighted by yellow color.

Table 3. Hansen solubility parameters and relative energy difference (RED) for CA.

Polymer/solvent	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
CA	16	7.5	13.5	22.2	8.8	
	Hansen solubility parameters				Ra	RED=Ra/R
	δ_D	δ_P	δ_H	δ		
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
Diacetin	16.4	8.9	14.2	23.4	1.8	0.2
$\alpha\alpha'$ Diglycerol	16.1	25.7	24.8	39.2	21.5	2.4
Monoacetin	14.9	17.5	18.9	29.8	11.6	1.3
Triacetin	16.5	4.5	9.1	19.4	5.4	0.6
Methyl lactate	13.8	15.2	15.1	25.5	3.5	0.4
1,2-Propanediol	16.8	9.4	23.3	30.2	10.1	1.1
1,3-Propanediol	16.8	13.5	23.5	31.9	11.8	1.3
Glycerol carbonate	17.9	25.5	17.4	35.7	18.8	2.1
Glycerol	17.4	12.4	29.3	36.3	16.8	1.9
Glyceric acid	14.9	26.2	23.9	38.6	5.9	0.7
GVL	15.5	4.7	6.6	17.4	10.5	1.2
Glycerol formal	16.5	17.3	16.9	29.3	1.8	0.2

Table 4. Hansen solubility parameters and relative energy difference (RED) for PI.

Polymer/solvent	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
PI (Polyimide)	20.9	11.3	9.7	25.7	13.4	
Solvents	Hansen solubility parameters				Ra	RED= Ra/R
	δ_D	δ_P	δ_H	δ		
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
Diacetin	16.4	8.9	14.2	23.4	10.3	0.8
$\alpha\alpha'$ Diglycerol	16.1	25.8	24.8	39.2	23.0	1.7
Monoacetin	14.9	17.5	19.0	29.8	16.4	1.2
Triacetin	16.5	4.5	9.1	19.4	11.1	0.8
Methyl lactate	15.5	7.2	7.6	18.7	11.7	0.9
1,2-Propanediol	16.8	9.4	23.3	30.2	16.0	1.2
1,3-Propanediol	16.8	13.5	23.5	31.9	16.2	1.2
Glycerol carbonate	17.9	25.5	17.4	35.7	17.2	1.3
Glycerol	17.4	12.4	29.3	36.3	20.8	1.6
Glyceric acid	14.9	26.2	23.9	38.6	23.8	1.8
GVL	15.5	4.7	6.6	17.4	13.1	0.9

Glycerol formal	16.4	17.3	16.9	29.3	13.0	1.0

Table 5. Hansen solubility parameters and relative energy difference (RED) for PSU.

Polymer/solvent	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
PSU	19.7	8.3	8.3	22.9	8	
Solvents	Hansen solubility parameters				Ra	RED=Ra/R
	δ_D	δ_P	δ_H	δ		
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
Diacetin	16.4	8.9	14.2	23.4	8.9	1.1
α,α′-Diglycerol	16.1	25.7	24.8	39.2	25.0	3.1
Monoacetin	14.9	17.50	18.9	29.8	17.0	2.1
Triacetin	16.5	4.5	9.1	19.4	7.5	0.9
Methyl lactate	15.5	7.2	7.6	18.7	8.5	1.1
1,2-Propanediol	16.8	9.4	23.3	30.2	16.1	2.0
1,3-Propanediol	16.8	13.5	23.5	31.9	17.1	2.1
Glycerol carbonate	17.9	25.5	17.4	35.7	19.8	2.5
Glycerol	17.4	12.4	29.3	36.3	21.9	2.7
Glyceric acid	14.9	26.23	23.9	38.6	25.6	3.2
GVL	15.5	4.68	6.56	17.4	9.4	1.1
Glycerol formal	16.5	17.3	16.9	29.3	14.1	1.8

Table 6. Hansen solubility parameters and relative energy difference (RED) for PVDF.

Polymer/solvent	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
PVDF	17.1	12.6	10.6	23.7	5.0	
Solvents	Hansen solubility parameters				Ra	RED =Ra/R
	δ_D	δ_P	δ_H	δ		
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
Diacetin	16.4	8.9	14.2	23.4	5.3	1.1
α,α′-Diglycerol	16.1	25.7	24.8	39.2	19.4	3.9
Monoacetin	14.9	17.5	18.9	29.8	10.6	2.1
Triacetin	16.5	4.5	9.1	19.4	8.3	1.7
Methyl lactate	15.5	7.2	7.6	18.7	7.0	1.4
1,2- Propanediol	16.8	9.4	23.3	30.2	13.1	2.6
1,3-Propanediol	16.8	13.5	23.5	31.9	12.9	2.6
Glycerol carbonate	17.9	25.5	17.4	35.7	14.7	2.9
Glycerol	17.4	12.4	29.3	36.3	18.7	3.7
Glyceric acid	15.0	26.2	23.9	38.6	19.6	3.9
GVL	15.5	4.7	6.6	17.4	9.5	1.9
Glycerol formal	16.5	17.3	16.9	29.3	8.0	1.6

Table 7. Hansen solubility parameters for PES and relative energy difference (RED) for PES.

Polymer/solvent	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
PES	19.6	10.8	9.2	24.2	6.2	
Solvents	Hansen solubility parameters				Ra	RED=Ra/R
	δ_D	δ_P	δ_H	δ		
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
Diacetin	16.4	8.9	14.2	23.4	8.3	1.3
α,α′-Diglycerol	16.1	25.6	24.8	39.2	22.7	3.7

Monoacetin	14.3	17.5	18.9	29.8	15.1	2.4
Triacetin	16.5	4.5	9.1	19.4	8.8	1.4
Methyl lactate	15.5	7.2	7.6	18.7	9.1	1.5
1,2-Propanediol	16.8	9.4	23.3	30.2	15.2	2.5
1,3-Propanediol	16.8	13.5	23.5	31.9	15.6	2.5
Glycerol carbonate	17.9	25.5	17.4	35.7	17.2	2.8
Glycerol	17.4	12.4	29.3	36.3	20.6	3.3
Glyceric acid	15.0	26.2	23.9	38.6	23.3	3.8
GVL	15.5	4.7	6.6	17.4	10.6	1.7
Glycerol formal	16.5	17.3	16.9	29.3	11.9	1.9

Table 8. Hansen solubility parameters and relative energy difference (RED) for PAN.

Polymer/solvent	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
PAN	21.7	14.1	9.1	27.4	10.9	
Solvents	Hansen solubility parameters				Ra	RED=Ra/R
	δ_D	δ_P	δ_H	δ		
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
Diacetin	16.4	8.9	14.2	23.4	12.9	1.2
α,α′-Diglycerol	16.14	25.7	24.8	39.22	22.5	2.1
Monoacetin	14.9	17.5	19.0	29.82	17.1	1.6
Triacetin	16.5	4.5	9.1	19.4	14.2	1.3
Methyl lactate	15.5	7.2	7.6	18.7	14.3	1.3
1,2-Propanediol	16.8	9.4	23.3	30.2	17.9	1.6
1,3-Propanediol	16.8	13.5	23.5	31.9	17.4	1.6
Glycerol carbonate	17.9	25.5	17.4	35.7	16.0	1.5
Glycerol	17.4	12.4	29.3	36.3	22.0	2.0
Glyceric acid	14.9	26.2	23.9	38.6	23.4	2.1
GVL	15.5	4.7	6.6	17.4	15.8	1.5
Glycerol formal	16.5	17.3	16.9	29.3	13.5	1.2

Table 9. Hansen solubility parameters and relative energy difference (RED) for PVA.

Polymer/solvent	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
PVA	17	9	18	26.3	4.0	
Solvents	Hansen solubility parameters				Ra	RED=Ra/R
	δ_D	δ_P	δ_H	δ		
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
Diacetin	16.4	8.9	14.2	23.4	4.0	1.0
Triacetin	16.5	4.5	9.1	19.4	10.0	2.5
Methyl lactate	15.5	7.2	7.6	18.7	11.0	2.7
1,2-Propanediol	16.8	9.4	23.3	30.2	5.3	1.3
1,3-Propanediol	16.8	13.5	23.5	31.9	7.1	1.8
Glycerol carbonate	17.9	25.5	17.4	35.7	16.6	4.2
Glycerol	17.4	12.4	29.3	36.3	11.8	3.0
α,α′-Diglycerol	16.1	25.7	24.8	39.2	18.2	4.5
Monoacetin	14.9	17.5	18.9	29.8	9.5	2.4
Glyceric acid	15.0	26.2	23.9	38.6	18.7	4.7
GVL	15.5	4.7	6.6	17.4	12.6	3.2
Glycerol formal	16.5	17.3	16.9	29.3	8.5	2.1

Table 10. Hildebrand and Hansen solubility parameters for chitosan.

Polymer/solvent	δ_D	δ_P	δ_H	δ	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	
Chitosan	21.9	32.5	24.6	46.3	
Solvents	Hansen solubility parameters				Ra
	δ_D	δ_P	δ_H	δ	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	
Diacetin	16.4	8.9	14.2	23.4	28.1
α,α′-Diglycerol	16.1	25.8	24.8	39.2	13.4
Monoacetin	14.9	17.5	18.9	29.8	21.3
Triacetin	16.5	4.5	9.1	19.4	33.8
Methyl lactate	15.5	7.2	7.6	18.7	33.1
1,2-Propanediol	16.8	9.4	23.3	30.2	25.3
1,3-Propanediol	16.8	13.5	23.5	31.9	21.6
Glycerol carbonate	17.9	25.5	17.4	35.7	12.9
Glycerol	17.4	12.4	29.3	40.4	15.4
Glyceric acid	15.0	26.2	26.9	40.4	15.4
GVL	15.4	4.68	6.7	17.4	35.6
Glycerol formal	16.4	17.3	16.9	29.3	20.2

Table 11. Hildebrand and Hansen solubility parameters for solvent blends and RED for CA.

Polymer/solvent blend	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
CA	16	7.5	13.5	22.2	8.8	
Solvent blends	δ_D	δ_P	δ_H	δ	Ra	RED=Ra/R
α,α′-Diglycerol /methyl lactate	15.9	19.3	18.8	31.3	12.9	1.5
1,2-Propanediol/methyl lactate	16.3	8.6	17.8	25.6	4.5	0.5
1,3-Propanediol/methyl lactate	16.3	11.3	17.9	26.7	5.8	0.7
Glycerol carbonate/Me. lactate	17.1	19.1	14.0	29.2	11.8	1.3
Glycerol/methyl lactate	16.7	10.6	21.7	29.4	8.9	1.0

Table 12. Hildebrand and Hansen solubility parameters for solvent blends and RED for PI.

Polymer/solvent blend	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
PI	20.9	11.3	9.7	25.7	13.4	
Solvent blends	Hansen solubility parameters				Ra	RED=Ra/R
Diacetin/NMP	17	10.1	11.8	23.0	8.2	0.6
α,α′-Diglycerol /NMP	16.8	21.0	18.6	32.7	15.5	1.2
Monoacetin/NMP	16.0	15.7	14.9	26.9	11.9	0.9
Triacetin/NMP	17.0	7.2	8.4	20.3	8.9	0.7
Methyl lactate/NMP	16.4	9.0	7.5	20.2	9.5	0.7
1,2-Propanediol/NMP	17.2	10.4	17.7	26.8	10.9	0.8
1,3-Propanediol/NMP	17.2	13.1	17.8	28.0	11.1	0.8
Glycerol carbonate/NMP	17.9	20.9	13.8	30.8	12.0	0.9
Glycerol/NMP	17.6	12.4	21.6	30.5	13.7	1.0
Glycerol formal/NMP	17.0	15.6	13.5	26.7	9.7	0.7

Table 13. Hildebrand and Hansen solubility parameters for solvent blends and RED for PSU.

Polymer/solvent blends	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
PSU	19.7	8.3	8.3	22.9	8	
Solvent blends	Hansen solubility parameters				Ra	RED=Ra/R
	δd	δp	δh	δ		

Diacetin/NMP	17	10.1	11.8	23.0	6.7	0.8
α,α′-Diglycerol /NMP	16.8	21	18.6	32.7	17.3	2.2
Monoacetin/NMP	16.0	15.7	14.9	26.9	12.4	1.5
Triacetin/NMP	17.0	7.2	8.4	20.3	5.5	0.7
Methyl lactate/NMP	16.4	9.0	7.5	20.2	6.7	0.8
1,2-Propanediol/NMP	17.2	10.4	17.7	26.8	10.9	1.4
1,3-Propanediol/NMP	17.2	13.1	17.8	28.0	11.8	1.5
Glycerol carbonate/NMP	17.9	20.9	13.8	30.8	14.2	1.8
Glycerol/NMP	17.6	12.4	21.6	30.5	14.5	1.8
Glycerol formal/NMP	17.0	15.6	13.5	26.7	10.5	1.3

Table 14. Hildebrand and Hansen solubility parameters for solvent blends and RED for PES.

Polymer/solvent blend	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
PES	19.6	10.8	9.2	24.2	6.2	
Solvent blends	Hansen solubility parameters				Ra	RED=Ra/R
	δd	δp	δh	δ		
Diacetin/DMF	16.8	10.6	13.2	23.9	6.9	1.1
α,α′-Diglycerol /DMF	16.6	21.5	20.1	33.8	16.4	2.6
Monoacetin/DMF	15.8	16.2	16.3	27.9	11.7	1.9
Triacetin/DMF	16.8	7.7	9.9	21.0	6.4	1.0
Methyl lactate/DMF	16.2	9.5	8.9	20.8	6.9	1.1
1,2-Propanediol/DMF	17.0	10.9	19.1	27.8	11.2	1.8
1,3-Propanediol/DMF	17.0	13.6	19.2	29.0	11.6	1.9
Glycerol carbonate/DMF	17.7	21.4	15.3	31.7	12.8	2.1
Glycerol/DMF	17.4	12.9	23.0	31.6	14.6	2.4
Glycerol formal/DMF	16.8	16.1	15.0	27.7	9.6	1.6

Table 15. Hildebrand and Hansen solubility parameters for solvents blends and RED for PAN.

Polymer/solvent blends	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
PAN	21.7	14.1	9.1	27.4	10.9	
Solvent blends	Hansen solubility parameters				Ra	RED=Ra/R
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
Diacetin/DMF	16.8	10.6	13.2	23.9	11.2	1.0
α,α′-Diglycerol /DMF	16.6	21.5	20.1	33.8	16.7	1.5
Monoacetin/DMF	15.8	16.2	16.3	27.9	14.0	1.3
Triacetin/DMF	16.8	7.7	9.9	21.0	11.7	1.1
Methyl lactate/DMF	16.2	9.5	8.9	20.8	11.9	1.1
1,2-Propanediol/DMF	17.0	10.9	19.1	27.8	14.1	1.3
1,3-Propanediol/DMF	17.0	13.6	19.2	29.0	13.8	1.3
Glycerol carbonate/DMF	17.7	21.4	15.3	31.7	12.5	1.1
Glycerol/DMF	17.4	12.9	23.0	31.6	16.4	1.5
Glycerol formal/DMF	16.8	16.1	15.0	27.7	11.6	1.1

Table 16. Hildebrand and Hansen solubility parameters for solvents blends and RED for PVDF.

Polymer/solvent blends	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
PVDF	17.1	12.6	10.6	23.7	5.0	
Solvent blends	Hansen solubility parameters				Ra	RED=Ra/R

Diacetin/NMP	17.0	10.1	11.8	23.0	2.8	0.6
α,α′-Diglycerol /NMP	16.8	21	18.6	32.7	11.6	2.3
Monoacetin/NMP	16.0	15.7	14.9	26.9	5.7	1.1
Triacetin/NMP	17.0	7.2	8.4	20.3	5.8	1.2
Methyl lactate/NMP	16.4	9.0	7.5	20.2	5.0	1.0
1,2- Propanediol/NMP	17.2	10.4	17.7	26.8	7.4	1.5
1,3-Propanediol/NMP	17.2	13.1	17.8	28.0	7.2	1.4
Glycerol carbonate/NMP	17.9	20.9	13.8	30.8	9.0	1.8
Glycerol/NMP	17.6	12.4	21.6	30.5	11.0	2.2
Glycerol formal/NMP	17.0	15.6	13.5	26.7	4.2	0.8

Table17. Hildebrand and Hansen solubility parameters for solvents blends and RED values for PVA.

Polymer/solvent blends	δ_D	δ_P	δ_H	δ	R	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
PVA	17.0	9.0	18.0	26.3	4.0	
	Hansen solubility parameters			δ	Ra	RED=Ra/R
Solvent blend	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$		
Diacetin/ H_2O	16.1	11.4	24.1	31.1	6.8	1.7
α,α′-Diglycerol / H_2O	15.9	22.3	31.0	41.4	18.7	4.7
Monoacetin/ H_2O	15.1	17.0	27.2	35.5	12.8	3.2
Triacetin/ H_2O	16.2	8.5	20.8	27.7	3.3	0.8
Methyl lactate/ H_2O	15.5	10.3	19.8	27.2	3.7	0.9
1,2-Propanediol/ H_2O	16.3	11.7	30.0	36.1	12.4	3.1
1,3-Propanediol/ H_2O	16.3	14.4	30.1	37.1	13.3	3.3
Glycerol carbonate/ H_2O	17.1	22.2	26.2	38.4	15.5	3.9
Glycerol/ H_2O	16.7	13.7	33.9	40.2	16.6	4.1
Glycerol formal/H_2O	16.1	16.9	25.9	34.9	11.3	2.8

Table 18. Hildebrand/Hansen solubility parameters of solvent blends and interaction distance for chitosan.

Polymer/solvent blends	δ_D	δ_P	δ_H	δ	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	
Chitosan	21.9	32.5	24.6	46.3	
Solvent blend	Hansen solubility parameters				Ra
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	
Diacetin/ H_2O	16.1	11.4	24.1	31.1	24.1
α,α′-Diglycerol / H_2O	15.9	22.3	31.0	41.4	17.0
Monoacetin/ H_2O	15.1	17.0	27.2	35.5	20.8
Triacetin/ H_2O	16.2	8.5	20.8	27.7	26.9
Methyl lactate/ H_2O	15.5	10.3	19.8	27.2	26.1
1,2-Propanediol/ H_2O	16.3	11.7	30.0	36.1	24.2
1,3-Propanediol/ H_2O	16.3	14.4	30.1	37.1	22.0
Glycerol carbonate/ H_2O	17.1	22.2	26.2	38.4	14.2
Glycerol/ H_2O	16.7	13.7	33.9	40.2	23.4
Glycerol formal/H_2O	16.1	16.9	25.9	34.9	19.5
GVL/ H_2O	15.5	4.7	6.6	17.4	35.6
Water (H_2O)	15.5	16.0	42.3	47.8	27.4
Glyceric acid/ H_2O	15.1	23.2	29.5	40.4	17.2

Table 19. Hildebrand/Hansen solubility parameters of solvents and interaction distance for CTA.

Polymer/solvent	δ_D	δ_P	δ_H	δ	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	
CTA	18.0	12.0	10.0	23.8	
Solvents	Hansen solubility parameters				Ra

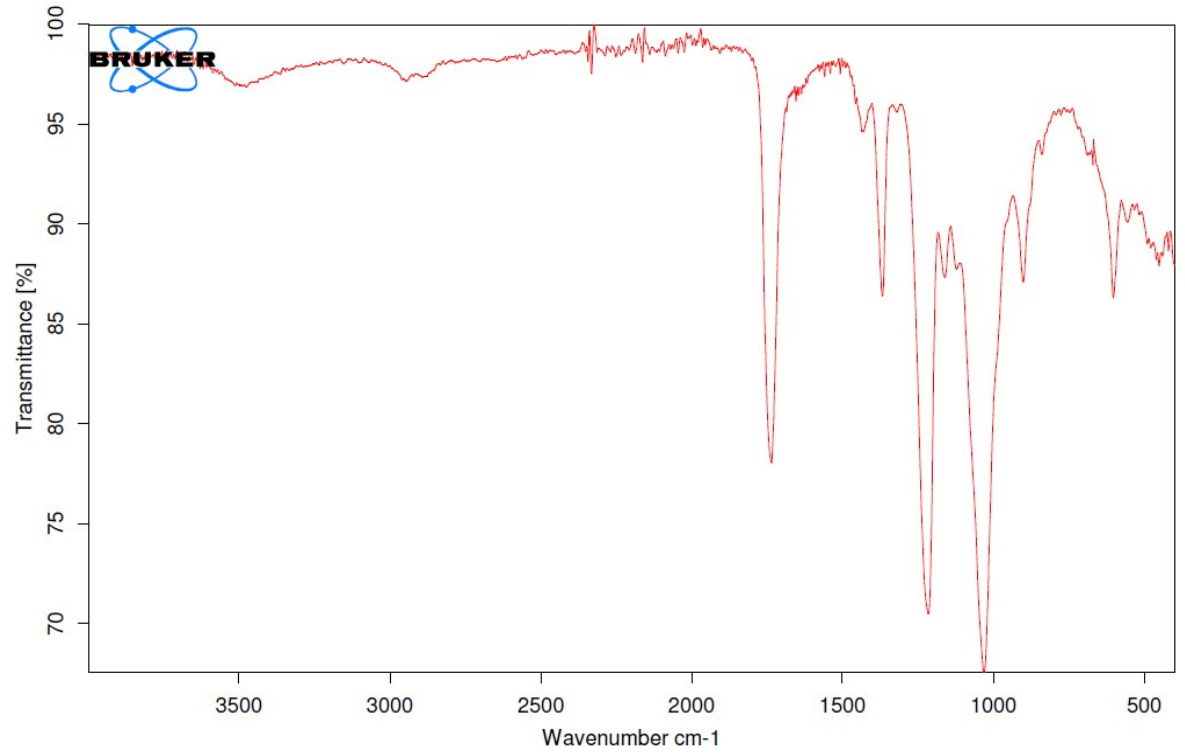
	δd	δp	δh	δ	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	
Diacetin	16.4	8.9	14.2	23.4	6.1
α,α′-Diglycerol	16.1	25.8	24.8	39.2	20.5
Monoacetin	14.9	17.5	19.0	29.8	12.2
Triacetin	16.5	4.5	9.1	19.4	8.1
Methyl lactate	15.5	7.2	7.6	18.7	7.3
1,2-Propanediol	16.8	9.4	23.3	30.2	13.8
1,3-Propanediol	16.8	13.5	23.5	31.9	13.8
Glycerol carbonate	17.9	25.5	17.4	35.7	15.4
Glycerol	17.4	12.4	29.3	36.3	19.3
Glycerol formal	16.5	17.3	16.9	29.3	9.3
Glyceric acid	14.9	26.2	23.9	38.6	20.8
GVL	15.5	4.7	6.6	17.4	9.5

Table 20. Hildebrand/Hansen solubility parameters of solvent blends and interaction distance for CTA.

Polymer/solvent blend	δ_D	δ_P	δ_H	δ	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	
CTA	18.0	12.0	10.0	23.8	
Solvents	Hansen solubility parameters				Ra
	δ_D	δ_P	δ_H	δ	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	
Diacetin/NMP	17.0	10.1	11.8	23.0	3.3
α,α′-Diglycerol /NMP	16.8	21.0	18.6	32.7	12.7
Monoacetin/NMP	16.0	15.7	14.9	26.9	7.3
Triacetin/NMP	17.0	7.2	8.4	20.3	5.4
1,2-Propanediol/NMP	17.2	10.4	17.7	26.8	8.0
1,3-Propanediol/NMP	17.2	13.1	17.8	28.0	8.0
Glycerol carbonate/NMP	17.9	20.9	13.8	30.8	9.7
Glycerol/NMP	17.6	12.4	21.6	30.5	11.6
Glycerol formal/NMP	17.0	15.6	13.5	26.7	5.4
Glyceric acid/NMP	15.9	22.1	18.9	33.1	14.1

Table 21 Solubility parameters difference (Ra) of solvents and non-solvent.

Solvent/non-solvent	δ_D	δ_P	δ_H	δ	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	
Water (as non-solvent)	15.5	16	42.3	47.8	
Solvent	Hansen solubility parameters				Ra
	δd	δp	δh	δ	
	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	$MPa^{1/2}$	
Diacetin	16.4	8.9	14.2	23.4	29.0
α,α′-Diglycerol	16.14	25.76	24.79	39.2	20.1
Monoacetin	14.92	17.50	18.98	29.8	23.4
Triacetin	16.5	4.5	9.1	19.4	35.2
Methyl lactate	15.5	7.2	7.6	18.7	35.8
1,2-Propanediol	16.8	9.4	23.3	30.2	20.3
1,3-Propanediol	16.8	13.5	23.5	31.9	19.1
Glycerol carbonate	17.9	25.5	17.4	35.7	27.1
Glycerol	17.4	12.4	29.3	36.3	14.0
Glycerol formal	16.5	17.3	16.9	29.3	25.5
Glyceric acid	15.0	26.2	23.9	38.6	21.0
GVL	15.5	4.7	6.6	17.4	37.5



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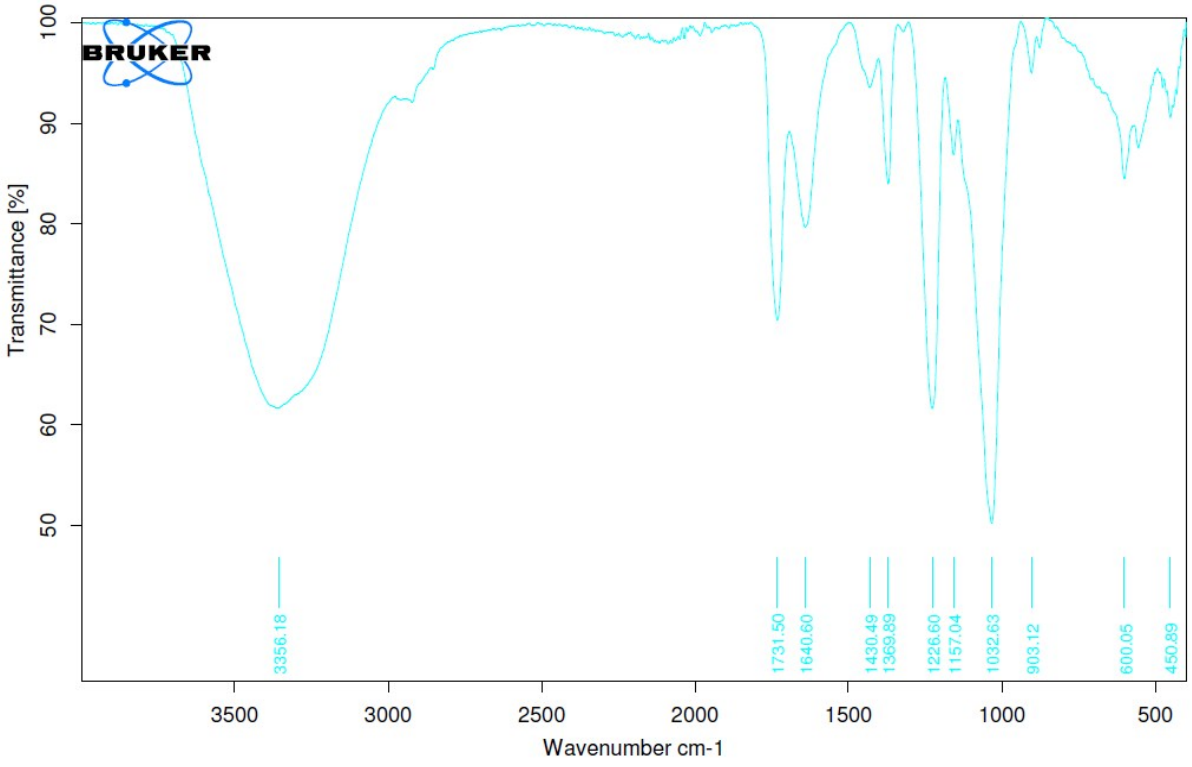

(2)

Figure 2. FTIR spectra of CA (1) and CA membrane (2) prepared by using glycerol formal solvent

According to the United Nations globally harmonized system of classification and labelling chemicals (GHS) codes and phrases were developed for labelling hazards (H) and precautionary statements (P) for dangerous traditional solvents. Classification of traditional solvents with hazards statement and toxicological information, commonly used in membrane preparation, is given in table 22.[10–13]

Table 22. Properties of solvents conventionally used in membrane preparation: boiling point, heat of vaporization, classification according to EU-regulation no. 1272/2008, the corresponding typical membrane preparation method and their cost price as available for small quantities.[10–13]

Traditional Solvents (Boiling point)	*Heat of vaporization (KJ/mol)	Hazard statement and toxicological information	Membrane preparation method	**Price (euros/L)
Dibutyl phthalate (DBP) (340 ^{0}C)	79.2	H360Df- May damage the unborn child. Suspected of damaging fertility. H400-Very toxic to aquatic life. (Assumed human reproductive toxicant).	TIPS	35-60
N-Methyl-2-pyrrolidone (NMP) (202 ^{0}C)	54.5	H315-Cuase skin irritation H319-Cause serious eye irritation H335-May cause respiratory irritation H360D-May damage the unborn child (Damage to fetus possible)	NIPS and TIPS	80-150
N,N-Dimethylacetamide (DMA) (165^{0}C)	50.8	H319-Cause serious eye irritation H312+H332-Harmful in contact with skin Toxic if inhaled H360D-May damage unborn child. • Rapidly absorbed through skin. • May cause congenital malformation to the fetus. • Presumed human reproductive toxicant.	NIPS	35-100
N,N-Dimethylformamide (DMF) (154 ^{0}C)	47.6	H226-Flammable liquid and vapor. H312+H332-Harmful in contact with skin Toxic if inhaled. H319-Cause serious eye irritation. • Rapidly absorbed through skin. • Germ cell mutagenicity. • Mutations in mammalian somatic cells.	NIPS	130-200
Toluene (111 ^{0}C)	38.1	H225-Cause skin irritation H304-May be fatal if swallowed and enters airways. H315-Cause skin irritation H336-May cause drowsiness and dizziness H361d-Suspected to damage unborn child	NIPS	>100

		H373- May cause organ damages prolonged exposure. • Damage to fetus is possible. • Suspected human reproductive toxicant. • Effect on embryo and fetus (fetotoxicity).		
1,4-Dioxane (101 ^{0}C)	34.1	H225-Cause skin irritation H319-Cause serious eye irritation H335-May cause respiratory irritation. H351-Suspected of causing cancer. • May form explosive peroxides • Repeating exposure may cause skin dryness or cracking.	NIPS	45-105
Tetrahydrofuran (THF) (66 ^{0}C)	32	H225-Highly flammable liquid and vapor. H319-Cause serious eye irritation H335-May cause respiratory irritation. H351-Suspect to cause cancer. (Suspected human carcinogens)	NIPS	50-150
Acetone (56 ^{0}C)	30.9	H225-Highly flammable liquid and vapor. H319-Cause serious eye irritation H336- May cause drowsiness and dizziness	NIPS	30-60
Chloroform (61.5 ^{0}C)	29.4	H302+H332-Harmful if swallowed or inhaled. H315-Cause skin irritation. H319-Cause serious eye Irritation. H351-Suspected of causing cancer. H361d-Suspected of damaging the unborn child. H373- May cause organ damages prolonged exposure. (Germ cell mutagenicity)	NIPS	30-69
Diphenyl ether (121 ^{0}C)	15.9	H319-Cause serious eye irritation H411-Toxic to aquatic life with long lasting effects.	TIPS	60-400

*Heat of vaporization values taken from National Center for Biotechnology Information, U.S. National Library of Medicine, 8600 Rockville Pike, Bethesda, MD20894, USA (website: https://www.ncbi.nlm.nih.gov/pccompound)

** Physical properties and prices of the solvents are taken from Sigma-Aldrich and TCI chemicals Belgium catalogue websites. https://www.sigmaaldrich.com/belgium-nederlands.html https://www.tcichemicals.com/en/be/

The use of glycerol derivatives and GVL as bio-based solvents, that were selected in this work do not impose any risk related to health and safety during membrane preparation.

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