Electronic Supplementary Information

Development of anti-photo and anti-thermal high internal phase emulsions stabilized by biomass lignin as nutraceutical delivery system

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It Includes 14 Pages, 3 Tables, 10 Figures.

Table S1. Physicochemical parameters of lignin from different technical resources.

Samples	Mw (Da)	Mn (Da)	PDI	Ph-OH (mmol/g)	-COOH (mmol/g)	$-SO_3^-$ (mmol/g)	Contact angle
EHL	3100	1100	2.82	1.14±0.02	1.93±0.04	0.00	45°±1°
AL	2700	1600	1.69	1.74±0.01	1.95±0.03	0.00	40°±1°
OL	2600	800	3.25	1.16±0.03	1.58±0.02	0.00	52°±2°
SAL	10500	3700	2.84	1.86±0.24	2.18±0.05	2.01±0.04	16°±2°
NaLS	21000	3700	5.68	1.87±0.17	1.52±0.02	1.57±0.02	24°±1°
CaLS	10200	2700	3.78	1.51±0.48	2.08±0.53	1.54±0.03	24°±1°

Table S2 Experimental factors & levels for preparation of lignin-based HIPEs.

Samples	Lignin wt%	APG wt%	Oil vol%
HIPEs-1	1.0	3.5	80.0
HIPEs-2	3.0	3.5	80.0
HIPEs-3	5.0	3.5	80.0
HIPEs-4	8.0	3.5	80.0
HIPEs-5	10.0	3.5	80.0
HIPEs-6	3.0	3.0	80.0
HIPEs-7	3.0	3.3	80.0
HIPEs-8	3.0	3.5	75.0
HIPEs-9	3.0	3.5	78.0
HIPEs-10	3.0	3.5	82.0

***** Lignin including EHL, AL, OL, SAL, NaLS and CaLS.

Table S3. Viscoelastic parameters for HIPEs prepared by different types and concentrations of lignin, APG dosages and oil phase fractions.

EHL wt%	AL wt%	APG wt%	Oil vol%	γ_c %	|η*| Pa.s	Tan(δ)
1.0	0	3.5	80.0	0.07	118.4	0.02
3.0	0	3.5	80.0	0.10	121.9	0.04
5.0	0	3.5	80.0	0.07	95.82	0.02
8.0	0	3.5	80.0	0.05	40.32	0.07
10.0	0	3.5	80.0	0.03	26.58	0.1
0	1.0	3.5	80.0	0.10	138.8	0.1
0	3.0	3.5	80.0	0.13	165.2	0.03
0	5.0	3.5	80.0	0.10	97.2	0.08
0	8.0	3.5	80.0	0.04	18.88	0.15
0	10.0	3.5	80.0	0.02	14.68	0.20
3.0	0	3.5	75.0	0.06	83.87	0.09
0	3.0	3.5	75.0	0.09	88.85	0.09
3.0	0	3.5	78.0	0.07	93.87	0.08
0	3.0	3.5	78.0	0.10	118.85	0.07
3.0	0	3.3	80.0	0.05	27.89	0.21
3.0	0	3.0	80.0	0.04	6.06	0.7
0	3.0	3.3	80.0	0.05	40.79	0.1
0	3.0	3.0	80.0	0.03	26.59	0.27

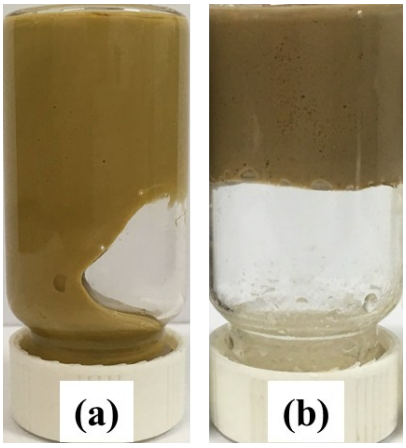

Figure S1. Appearance of HIPEs prepared by different emulsification technologies at 5.0 wt% EHL, 3.5 wt% APG and 80 vol% oil phase: (a) using homogenizer; (b) using ultrasonic cavitation technique.

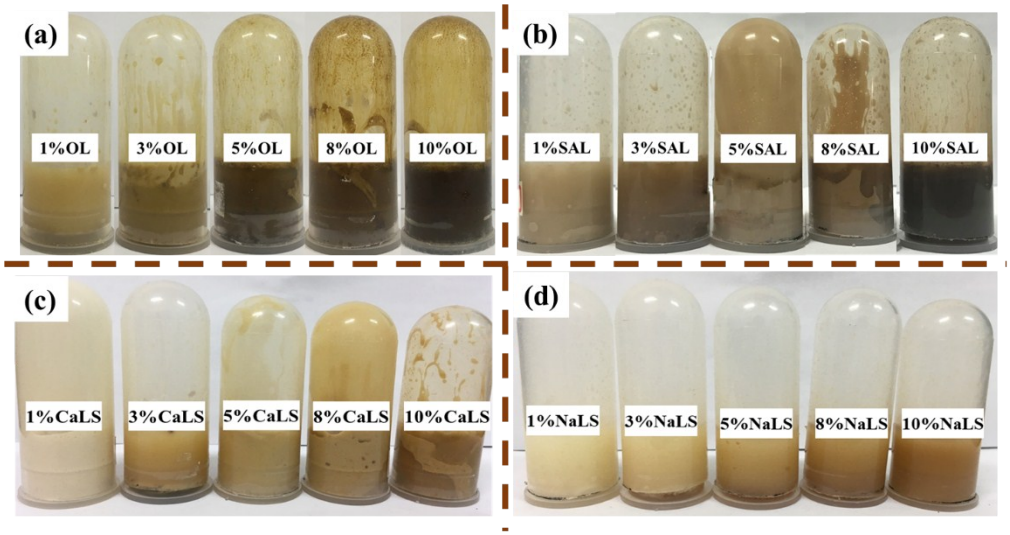

Figure S2. Appearances of the HIPEs prepared using different types and concentrations of lignin at 3.5 wt% APG and 80 vol% oil phase. (a) OL; (b) SAL; (c) CaLS; (d) NaLS.

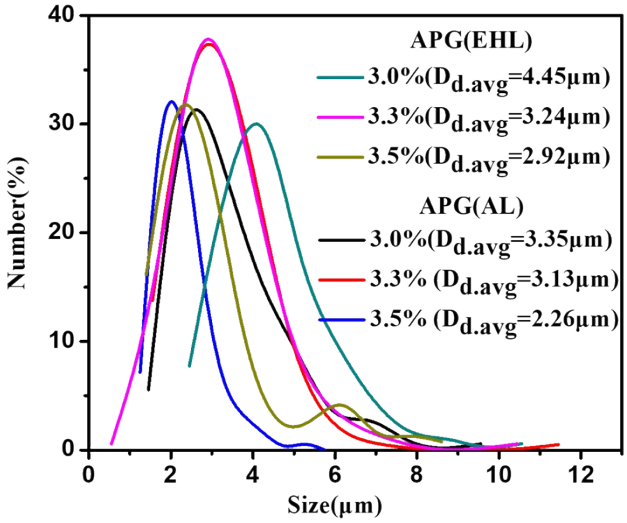

Figure S3. The droplet sizes and size distributions of HIPEs prepared using different APG dosages at 3.0 wt% lignin and 80 vol% oil phase.

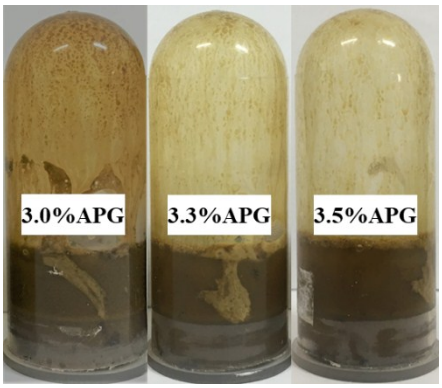

Figure S4. Appearances of HIPEs prepared using different APG dosages at 3.0 wt% OL and 80 vol% oil phases.

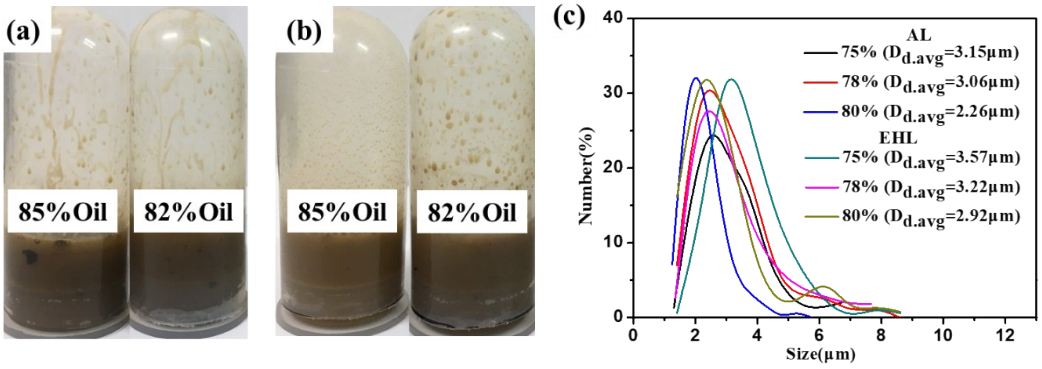

Figure S5. Appearances (a, b) and droplet sizes (c) of the HIPEs prepared by different oil phase fractions at 3.0 wt% lignin and 3.5 wt% APG: (a) AL and (b) EHL.

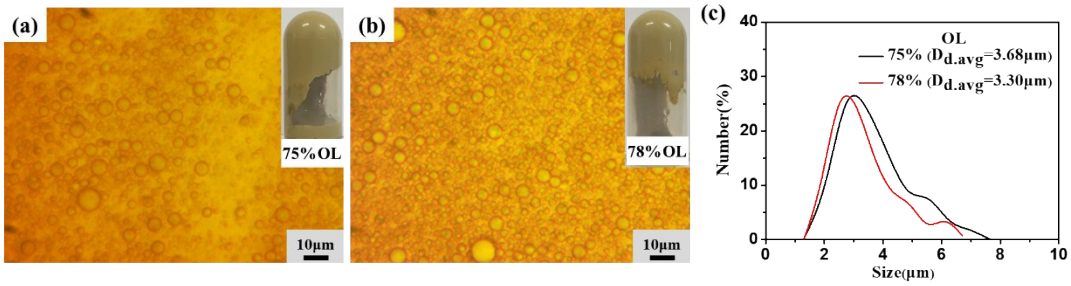

Figure S6. Appearances (a, b) and droplet sizes (c) of HIPEs prepared by different oil phase volume fractions at 3.0 wt% OL and 3.5 wt% APG.

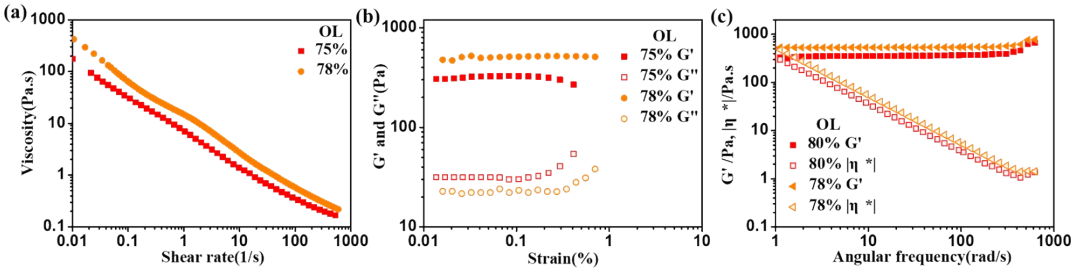

Figure S7. Rheological spectra of HIPEs prepared with different oil phases at 3.0 wt% OL and 3.5 wt% APG. (a) Flow curves of the HIPEs; (b) Amplitude sweep; (c) Frequency sweep.

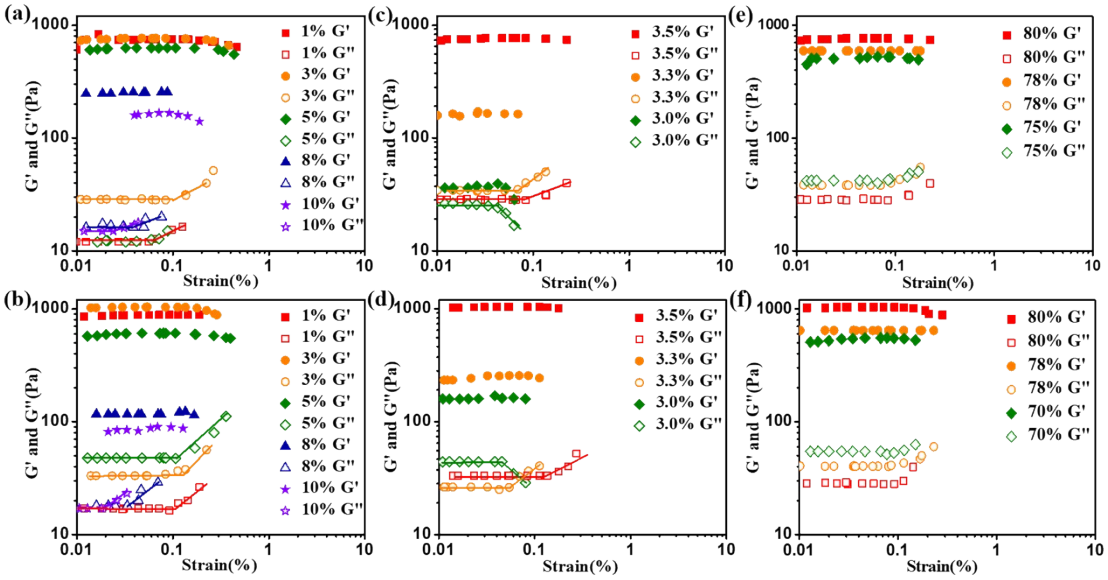

Figure S8. Amplitude sweep results in terms of the variation of storage and loss moduli (G´ and G") with shear strain: (a) different EHL content; (b) different AL content; (c) different APG dosage and 3.0 wt% EHL; (d) different APG dosage and 3.0 wt% AL; (e) different oil phase volume fraction and 3.0 wt% EHL;(f) different oil phase volume fraction and 3.0 wt% AL.

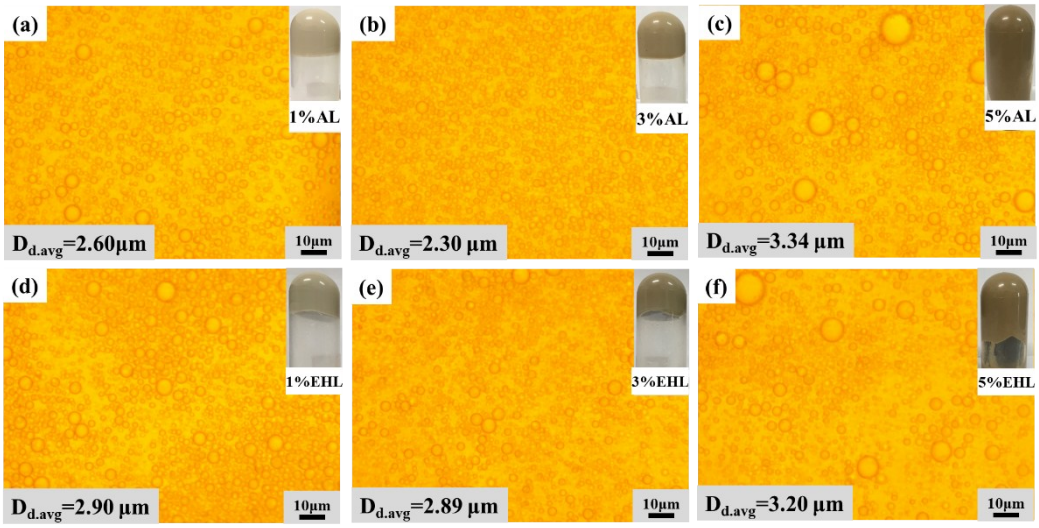

Figure S9. Optical microscope images of HIPEs stabilized by different types and concentrations of lignin at 3.5 wt% APG and 80 vol% oil after stored for 7 days. (a-c) AL and (d-f) EHL with concentration of 1 wt% - 5wt%. The HIPEs were diluted with a same volume of aqueous phase.

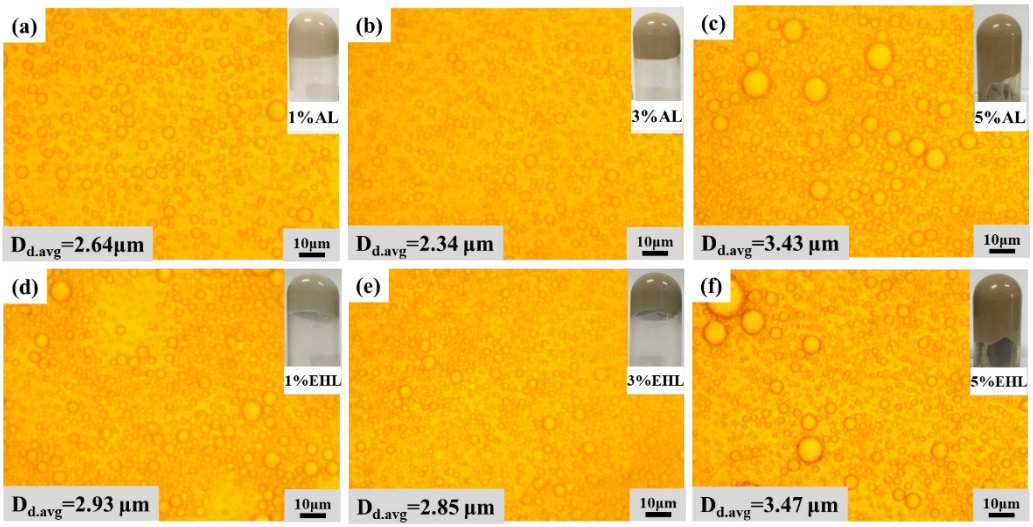

Figure S10. Optical microscope images of the HIPEs stabilized by different types and concentrations of lignin at 3.5 wt% APG and 80 vol% oil after stored for 30 days: (a-c) AL and (d-f) EHL with concentration of 1 wt% - 5wt%. The HIPEs were diluted with a same volume of aqueous phase.