Electronic Supplementary Material (ESI) for Soft Matter.

Supporting document S1

Effect of ultrasound on physical properties and processing of biopolymers-A review

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Table S1

Effect of ultrasound on the extraction and properties of three major biopolymers

Biopolymer	Extraction					Physical properties	Ref.
	Method of extraction	Step(s) involved US	US intensity	Time (min)	Temp (℃)		
Chitin and Chitosan	Chemical+ US in 40% (w/w) NaOH	Deacetylation	52.6 Wcm^{-2}	50	60	• Chitosan molecular weight decreased to (912,000 g/mol) • Degree of polymerization decreased from 6865 to 4889 • Degree of acetylation falls from 80.7% to 4.3% • Dispersity of 1.3 is found	2016 [1]
	Chemical+ US in 40% (w/w) NaOH	Deacetylation	37 kHz	360	80	• Molecular weight decreased from 378 to 361 kDa at 60% NaOH • Molecular weight decreased from 439 to 421 kDa at 50% NaOH	2017 [2]
	US under oil-water emulsion	Emulsification	300-600 W	3 to 5	10	• One step process requires less time and energy • High intensity decreases droplet size	2018 [3]
	Chemical+ dual US in 10% NaOH	Deacetylation	15 kHz and 20 kHz	15	25	• Molecular weight falls from 20000 g/mol to 5000 g/mol for dual frequency transducer at parallel position • Degree of deacetylation (DD) increases from approximately	2019 [4]

						30% to 80% • Viscosity reduced to 12 cP from 85 cP	
	US in 1.0 M NaOH under ice bath	Deproteinization	750W and 20 kHz	41.46	30-40	• Less amount of protein is left after treatment • Reduce extraction time with 34 % chitin after deproteinization • Not suitable for fat absorption purpose	2019 [5]
	US in deionized water	Deproteinization	-	15 25 40	-	• Molecular weight 73.61 kDa • DD = 80.60 % • Particle size = 35.70 µm • Molecular weight 86.82 kDa • DD = 92.86 % • Particle size = 25.51 µm • Molecular weight 55.66 kDa • DD = 55.66 % • Particle size = 20.10 µm	2020 [6]
Starch	US in starch solution + Enzyme		7.20 W/mL	10		• Molecular weight decreased by 80.19 % • Solubility raised by 136.50 %	2017 [7]
	US under water		450 W (25 kHz) with 70 % amplitude	15		• Yield increase from 29.85 % to 32.09 % • Amorphous region damaged but crystalline region remain fixed.	2018 [8]
	US under water		(20 and 45 kHz) (15.29,			• High amylose content starch is obtained	2019 [9]

			20.38, 22.93, 24.46 and 25.38 kW/m^2)				
	US under water		150, 300, 450 and 600 W	20		• Granule size did not change but their homogeneity has increases • Peak and breakdown viscosity increases	2019 [10]
	US in starch suspension	Nano and Microparticle formation	20 kHz	30		• Starch nanoparticle and microparticle fabrication without chemicals and additional purification steps • High amylose content starch source provides smaller nano and microparticle	2019 [11]
Cellulose	Acid hydrolysis and US in cellulose suspension to get NCC	Acid hydrolysis	60 Hz	10 (max)	-	• Molecular weight decreases • Disintegrate NCC aggregates and degrade nanocrystals • Increase optical clarity of fabricated material	2016 [12]

		37 Hz	120	45	• High crystallinity, thermally stable spherical shaped NCC is obtained	2017 [13]
US with Water and Fenton reagent	MCC enzymatic hydrolysis pretreatment	800 W, 21-23 kHz	150	25	• Decrease DP and aspect ratio of MCC	2016 [14]
US in NCC suspension	Modifying properties	20 kHz and 60% amplitude	Up to 10	RT	• Increase transparency and tensile strength of US treated NCC based film	2017 [12]
US in 2M NaOH	Cellulose and lignin extraction	500 W, 20 kHz	Up to 40	90	• Higher thermal stability of cellulose • Less cellulose extraction time	2017 [15]
US with enzymatic hydrolysis		500 W, 20 kHz, 16.2-43.4 Wcm^{-2}	90	50	• Enzymatic hydrolysis is more effective with US compared to conventional method • Size and form of raw material, position of the US radiation source are equally important to improve process efficiency	2017 [16]
US under water with cellulose	Cellulose nanofibers fabrication	25 kHz	-	-	• High thermal stability	2016 [17]
		400-1200 W			• Ionic repulsion between the fabricated fiber makes easy separation of fiber	2017 [18]

		400 W			• High yield of fiber	2018 [19]
US in MCC suspension	To produce fibrillated MCC		120		• Hydrogels from high aspect fiber is obtained	2018 [20]
US applied to cellulose pulp	Improving swelling and dissolution behaviour	320 W, 37 kHz	20	30	• Lowers the crystallinity under a low temperature treatment • Decreases the particle size and dissolution time of cellulose	2018 [21]
US applied to homogenized cellulose pulp	Cellulose micro and nanofiber fabrication	500 W	40		• High aspect ratio small fiber is obtained	2019 [22]
US of cellulose in water	Depolymerizing cellulose to glucose	525 kHz	180	60	• Selective depolymerization of cellulose is recorded without catalyst and extensive heating	2020 [23]
US with NaOH solution	Cellulose nanocrystal fabrication	120 W, 20 kHz	105		• Increased crystallinity, lower particle size and high thermal stability are obtained	2021 [24]

US= Ultrasound, NCC= Nanocrystalline cellulose, MCC= Microcrystalline cellulose, RT= Room temperature

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