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## Natural Deep Eutectic Solvent-Assisted Pectin Extraction from Pomelo Peel Using Sonoreactor: Experimental Optimization Approach

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### Abstract

Background: Natural deep eutectic solvents (NADESs) can be used for extracting a wide range of biomaterials, such as pectin. This study introduces a new generation of natural solvents for pectin extraction which could replace the conventional solvents in the food industry. Methods: In this study, NADESs were used for pectin extraction from pomelo (*Citrus grandis* (L.) Osbeck) peels using a sonoreactor. Definitive screening design (DSD) was used to screen the influence of time, temperature, solid/liquid ratio, and NADES/water ratio on the pectin yield and degree of esterification (DE). Results: The primary screening revealed that the best choices for the extraction were choline chloride-malonic acid (ChCl-Mal) and choline chloride-glucose-water (ChCl:Glc:W). Both co-solvents yielded 94% pectin and 52% DE after optimization at 80 degrees C, with 60 min of sonication, pH < 3.0, and a NADES-to-water ratio of 1:4.5 (v/v). Morphological screening showed a smooth and compact surface of the pectin from ChCl-Mal where glucose-based pectin had a rough surface and lower DE. Conclusions: NADESs proved to be promising co-solvents for pectin extraction with a high degree of esterification (>55%).

### Keywords

**Author Keywords:** pectin; natural deep eutectic solvent; *Citrus grandis*; definitive screening design; pomelo; extraction  
**KeyWords Plus:** PHENOLIC-COMPOUNDS; CHOLINE CHLORIDE; SEPARATION; OIL

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## Cited References: 29

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(from Web of Science Core Collection)

- Natural deep eutectic solvents from choline chloride and betaine - Physicochemical properties** Times Cited: 52  
By: Aroso, Ivo M.; Paiva, Alexandre; Reis, Rui L.; et al.  
JOURNAL OF MOLECULAR LIQUIDS Volume: 241 Pages: 654-661 Published: SEP 2017
- Effect of pectins on the gelling properties of surimi from silver carp** Times Cited: 82  
By: Barrera, AM; Ramirez, JA; Gonzalez-Cabriales, JJ; et al.  
FOOD HYDROCOLLOIDS Volume: 16 Issue: 5 Pages: 441-447 Article Number: PII S0268-005X(01)00121-7 Published: SEP 2002
- Title: [not available] Times Cited: 1  
By: Bogaars, R.A.  
Exploring Commercial Applications of Natural Deep Eutectic Solvents Published: 2015  
30 April 2019  
Publisher: TUDelft University  
URL: <https://repository.tudelft.nl/islandora/object/uuid%3Abe6d9d2b-93d7-4af5-9860-91bd75e0632b>
- Extraction of pectin from apple pomace** Times Cited: 130  
By: Canteri, MHG; Fertoni, HCR; Waszczynski, N; et al.  
BRAZILIAN ARCHIVES OF BIOLOGY AND TECHNOLOGY Volume: 48 Issue: 2 Pages: 259-266 Published: 2005
- Application of natural deep eutectic solvents to the extraction of anthocyanins from Catharanthus roseus with high extractability and stability replacing conventional organic solvents** Times Cited: 67  
By: Dai, Yuntao; Rozema, Evelien; Verpoorte, Robert; et al.  
JOURNAL OF CHROMATOGRAPHY A Volume: 1434 Pages: 50-56 Published: FEB 19 2016
- Extraction of pectin from passion fruit peel using moderate electric field and conventional heating extraction methods** Times Cited: 46  
By: de Oliveira, Cibele Freitas; Giordani, Diego; Gurak, Poliana Deyse; et al.  
INNOVATIVE FOOD SCIENCE & EMERGING TECHNOLOGIES Volume: 29 Special Issue: SI Pages: 201-208 Published: MAY 2015
- 110th Anniversary: Distribution Coefficients of Furfural and 5-Hydroxymethylfurfural in Hydrophobic Deep Eutectic Solvent plus Water Systems: Experiments and Perturbed-Chain Statistical Associating Fluid Theory Predictions** Times Cited: 5  
By: Dietz, Carin H. J. T.; Gallucci, Fausto; Annaland, Martin van Sint; et al.  
INDUSTRIAL & ENGINEERING CHEMISTRY RESEARCH Volume: 58 Issue: 10 Pages: 4240-4247 Published: MAR 13 2019
- Optimized extraction condition and characterization of pectin from orange peel** Times Cited: 3  
By: Elizabeth Devi, W.; Shukla, R. N.; Abraham, Anitha; et al.  
Int. J. Res. Technol. Volume: 2 Pages: 1-9 Published: 2014  
[\[Show additional data\]](#)
- Extraction of phenolic compounds from virgin olive oil by deep eutectic solvents (DESs)** Times Cited: 116  
By: Garcia, Aranzazu; Rodriguez-Juan, Elisa; Rodriguez-Gutierrez, Guillermo; et al.  
FOOD CHEMISTRY Volume: 197 Pages: 554-561 Part: A Published: APR 15 2016
- Performance of Choline-Based Deep Eutectic Solvents in the Extraction of Tocols from Crude Palm Oil** Times Cited: 19  
By: Hadi, Nu'man Abdul; Ng, Mei Han; Choo, Yuen May; et al.  
JOURNAL OF THE AMERICAN OIL CHEMISTS SOCIETY Volume: 92 Issue: 11-12 Pages: 1709-1716 Published: DEC 2015
- Fruit sugar-based deep eutectic solvents and their physical properties** Times Cited: 109  
By: Hayyan, Adeeab; Mjalli, Farouq S.; AlNashef, Inas M.; et al.  
THERMOCHIMICA ACTA Volume: 541 Pages: 70-75 Published: AUG 10 2012
- Natural deep eutectic solvents: cytotoxic profile** Times Cited: 58  
By: Hayyan, Maan; Mbous, Yves Paul; Looi, Chung Yeng; et al.  
SPRINGERPLUS Volume: 5 Article Number: 913 Published: JUN 29 2016

13. **Deep Eutectic Solvents: Fractionation of Wheat Straw** Times Cited: 49  
 By: Jablonsky, Michal; Skulcova, Andrea; Kamenska, Lucia; et al.  
 BIORESOURCES Volume: 10 Issue: 4 Pages: 8039-8047 Published: NOV 2015
14. **Extraction and Characterization of Pectin from Passion Fruit Peels** Times Cited: 36  
 By: Liew, Shan Qin; Chin, Nyuk Ling; Yusof, Yus Aniza  
 2ND INTERNATIONAL CONFERENCE ON AGRICULTURAL AND FOOD ENGINEERING (CAFE 2014) - NEW TRENDS FORWARD Book Series: Agriculture and Agricultural Science  
 Procedia Volume: 2 Pages: 231-236 Published: 2014
15. **Acid and Deep Eutectic Solvent (DES) extraction of pectin from pomelo (Citrus grandis (L.) Osbeck) peels** Times Cited: 18  
 By: Liew, Shan Qin; Ngoh, Gek Cheng; Yusoff, Rozita; et al.  
 BIOCATALYSIS AND AGRICULTURAL BIOTECHNOLOGY Volume: 13 Pages: 1-11 Published: JAN 2018
16. **Pomelo (Citrus maxima) pectin: Effects of extraction parameters and its properties** Times Cited: 70  
 By: Methacanon, Pawadee; Kongsin, Jaruwan; Gamonpilas, Chaiwut  
 FOOD HYDROCOLLOIDS Volume: 35 Pages: 383-391 Published: MAR 2014
17. **Pectin structure and biosynthesis** Times Cited: 863  
 By: Mohnen, Debra  
 CURRENT OPINION IN PLANT BIOLOGY Volume: 11 Issue: 3 Pages: 266-277 Published: JUN 2008
18. **Optimization of pectin extraction from banana peels with citric acid by using response surface methodology** Times Cited: 63  
 By: Oliveira, Tulio Italo S.; Rosa, Morsyleide F.; Cavalcante, Fabio Lima; et al.  
 FOOD CHEMISTRY Volume: 198 Pages: 113-118 Published: MAY 1 2016
19. **Natural Deep Eutectic Solvents - Solvents for the 21st Century** Times Cited: 519  
 By: Paiva, Alexandre; Craveiro, Rita; Aroso, Ivo; et al.  
 ACS SUSTAINABLE CHEMISTRY & ENGINEERING Volume: 2 Issue: 5 Pages: 1063-1071 Published: MAY 2014
20. **Evaluation of toxicity and biodegradability of choline chloride based deep eutectic solvents** Times Cited: 165  
 By: Radosevic, Kristina; Bubalo, Marina Cvjetko; Srcek, Visnje Gaurina; et al.  
 ECOTOXICOLOGY AND ENVIRONMENTAL SAFETY Volume: 112 Pages: 46-53 Published: FEB 2015
21. **Extraction optimization and physicochemical properties of pectin from melon peel** Times Cited: 24  
 By: Raji, Zarifeh; Khodaiyan, Faramarz; Rezaei, Karamatollah; et al.  
 INTERNATIONAL JOURNAL OF BIOLOGICAL MACROMOLECULES Volume: 98 Pages: 709-716 Published: MAY 2017
22. **Deep eutectic solvents (DES) mediated extraction of pectin from Averrhoa bilimbi: Optimization and characterization studies** Times Cited: 3  
 By: Shafie, Muhammad Hakim; Yusof, Rizana; Gan, Chee-Yuen  
 CARBOHYDRATE POLYMERS Volume: 216 Pages: 303-311 Published: JUL 15 2019
23. **Synthesis of BiVO<sub>4</sub>/MWCNT/Ag@AgCl composite with enhanced photocatalytic performance** Times Cited: 11  
 By: Sun, Tingting; Cui, Dongming; Ma, Qian; et al.  
 JOURNAL OF PHYSICS AND CHEMISTRY OF SOLIDS Volume: 111 Pages: 190-198 Published: DEC 2017
24. **Enhanced and Selective Lipid Extraction from the Microalga P. tricornutum by Dimethyl Carbonate and Supercritical CO<sub>2</sub> Using Deep Eutectic Solvents and Microwaves as Pretreatment** Times Cited: 13  
 By: Tommasi, Elena; Cravotto, Giancarlo; Galletti, Paola; et al.  
 ACS SUSTAINABLE CHEMISTRY & ENGINEERING Volume: 5 Issue: 9 Pages: 8316-8322 Published: SEP 2017
25. **Separation Performance of BioRenewable Deep Eutectic Solvents** Times Cited: 34  
 By: Verevkin, Sergey P.; Sazonova, Aleksandra Yu; Frolkova, Alla K.; et al.  
 INDUSTRIAL & ENGINEERING CHEMISTRY RESEARCH Volume: 54 Issue: 13 Pages: 3498-3504 Published: APR 8 2015
26. **Effect of extraction conditions on the yield, purity and surface properties of sugar beet pulp pectin extracts** Times Cited: 129  
 By: Yapo, B. M.; Robert, C.; Etienne, I.; et al.  
 FOOD CHEMISTRY Volume: 100 Issue: 4 Pages: 1356-1364 Published: 2007
27. **New horizons in the extraction of bioactive compounds using deep eutectic solvents: A review** Times Cited: 81  
 By: Zainal-Abidin, Mohamad Hamdi; Hayyan, Maan; Hayyan, Adeeb; et al.  
 ANALYTICA CHIMICA ACTA Volume: 979 Pages: 1-23 Published: AUG 1 2017
28. **Influence of the drying operating conditions on the chemical characteristics of the citric acid extracted pectins from 'pera' sweet orange (Citrus sinensis L. Osbeck) albedo and flavedo** Times Cited: 10  
 By: Zanello, Karine; Taranto, Osvaldir Pereira  
 JOURNAL OF FOOD ENGINEERING Volume: 166 Pages: 111-118 Published: DEC 2015
29. **Efficient separation of phenolic compounds from model oil by the formation of choline derivative-based deep eutectic solvents** Times Cited: 23  
 By: Zhang, Yue; Li, Zhiyong; Wang, Huiyong; et al.

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