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Green extraction technique to separate bioactive compounds from coffee husk waste using natural deep eutectic solvent based on choline chloride-proline

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ABSTRACT: The focus of developing analytical methods in sample preparation is directed at green chemistry. This has led to the recent development of a green solvent that uses natural deep eutectic solvent (NADES) in the extraction process. Therefore, this study presents the application of choline chloride and proline-based NADES in analytical chemistry as a green solvent, resulting in an extraction yield of 2.8%. The extracted compounds were analyzed using liquid chromatography-mass spectrometry (LC-MS), which identified 17 compounds with m/z values. The main compounds with retention time were caffeic acid (6.675 min), chlorogenic acid (6.056 min), 4,5-dicaffeoylquinic acid (9.628 min), (+/—)12(13)-dihydoxyoctadec-9-enoic acid (DiHOME) (17.231 min), D-(-)-quinic acid (6.051 min), and neochlorogenic acid (4.713 min). The use of NADES as a green solvent offers an attractive alternative method for extracting active compounds from the coffee husk, with potential applications in pharmaceuticals.

KEYWORDS: natural deep eutectic solvent, coffee husk, green extraction, choline chloride, LC-MS

INTRODUCTION

In order to adopt an environmentally friendly approach, it is essential to develop analytical methods that incorporate sustainable and profitable strategies for sample preparation. This includes careful consideration of environmental impacts, particularly the reduction of solvents in the extraction process. The first step in evaluating the chemical composition of a plant is to extract its bioactive compounds [1]. However, conventional organic solvents, such as ethanol, methanol, ethyl acetate, and hexane, which are commonly used in extraction processes for their dissolution ability are not ideal for the environment [2]. Due to their toxicity, explosiveness, and low biodegradability, the use of these solvents must be limited, as they do not comply with the principles of green solvents [3]. Fortunately, green technology offers a solution by finding new solvents that can replace conventional organic solvents with high volatility and easy evaporation. In this case, a green solvent has been developed to serve as an environmentally friendly replacement for organic solvents, especially in the extraction of bioactive compounds. Various studies have been conducted to support green chemistry by developing green solvents. One method involves developing ionic liquid solvents, although they have low biodegradability and biocompatibility [4]. Another alternative is the development of green solvents using a eutectic solvent or a natural deep eutectic solvent (NADES), which have broad applications in various products. The extraction based on NADES is a reliable separation method with wide potential applications in the chemical analysis of natural products [5]. A eutectic solvent is a mixture of two or more components in a liquid form with a specific composition obtained by lowering the melting point of the liquid at room temperature. The NADES can be formed by complexing a hydrogen bond acceptor (HBA) with a hydrogen bond donor (HBD) [6]. The most common NADES are based on choline chloride (ChCl) compounds, citric acid, succinic acid, carboxylic acids, urea, and glycerol. NADES has similarities with ionic liquids but is easier to produce, non-toxic, purified naturally, has a high viscosity, and decomposes naturally [7]. Furthermore, NADES with microextraction technique can be used in analytical chemistry for homogeneous liquid extraction. After the extraction process, the analyte will be quantified using the analytical instrument. This technique has been applied to extract pesticide residues in fruits and vegetables, followed by GC-FID determination. NADES-based headspace solid-phase microextraction was followed with GC-FID for the determination of bioactive terpenoids. The analytical instrument can be used to quantify the analyte obtained from the extraction using NADES, such as HPLC for aromatic hydrocarbon [7], GC-MS for volatile compounds [8], and spectrophotometric for methanol [9].

The coffee husk is a byproduct of coffee production [10], that contains active compounds like antioxidants, caffeine, and dietary fiber, making it a potential source for the food and pharmaceutical industries [11]. Several methods have been used to extract the active compounds from the coffee husk, such as extraction using methanol, water [10], water bath, ultrasound, ethanol [12], microwave-assisted extraction [13], and

supercritical fluid extraction [14]. The extraction method used plays a crucial role in determining the efficiency of the sample preparation. Subsequently, extraction using conventional procedures such as maceration, Soxhlet extraction, and reflux are widely used but require a longer time. To extract the active compounds from coffee husk using the principles of green chemistry and a shorter extraction time, a NADES solvent was developed. No previous studies have reported the use of NADES for separating active compounds from the coffee husk. Therefore, this study aimed to utilize NADES as an environmentally friendly solvent to extract active compounds from the coffee husk, and the components were analyzed using liquid chromatography-mass spectrometry (LS-MS).

MATERIALS AND METHODS

Material and chemicals

The sample of the coffee husk (Robusta) used was purchased from Sumedang, Indonesia, and was dried at 100 °C for 24 h, ground until 20 mesh. The sample was stored in a plastic container. The chemicals were choline chloride, proline, formic acid, acetonitrile, and formic acid were pa grade from Merck, Germany, and PTFE membrane (Sigma-Aldrich, USA).

NADES preparation

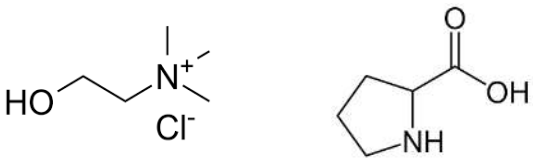
NADES was prepared with a ratio between the hydrogen bond acceptor (HBA) and the hydrogen bond donor (HBD). In this study, HBA was derived from choline chloride and HBD from proline with a mol ratio (1:2). Furthermore, NADES was prepared by heating 90 °C with constant stirring for 120 min until a clear solution was formed [15]. The mixture was cooled at room temperature and used as a solvent.

Extraction of active compounds using NADES

The extraction of active compounds from coffee husk using NADES was carried out by mixing 0.5 g sample with 10 ml NADES, stirred at 150 rpm at room temperature. The mixture was filtered, and the supernatant was analyzed using LC-MS.

Analysis of components using LC-MS

Analysis of the extract from coffee husk was carried out using LC-MS, Vanquish Tandem Q Exactive Plus Orbitrap HRMS ThermoScientific, USA. The extract was filtered with a 0.2 μm PTFE membrane. The condition of the instrument was adjusted using a column accucore™ C18, 100 × 2.1 mm, 1.5 μm (ThermoScientific). The eluent used H_2O + 0.1% formic acid (A) and acetonitrile + 0.1% formic acid (B). The flow rate was 0.2 ml/min. Gradient elution techniques were 0–1 min (5% B), 1–25 min (5–95% B), 25–28 min (95% B), and 28–30 min (5% B). The column temperature was 30 °C, and the injection volume was 2.0 μl. The mass was in the range of 100–1500 m/z, the ionization mode is negative, and the database tolerance was 5 ppm.



Choline chloride Proline

Fig. 1 Structure of HBA and HBD.

RESULTS AND DISCUSSION

Isolation and identification of lactic acid bacteria (LAB)

The green extraction using NADES based on choline chloride and proline in mol ratio 1:2 with the addition of water 20% extracted the active compounds from a coffee husk. The extraction was 2.8%, and the structure of HBA and HBD are shown in Fig. 1. The analysis component from extract using LC-MS is shown in Fig. 2.

Fig. 2 shows that the peak of the chromatogram identifies the active compounds in coffee husk extract, and 17 compounds were detected. The main compounds were shown at the retention time of 6.65 min, which refers to caffeic acid. The other compounds detected were chlorogenic acid (6.02 min) and 4,5-dicafferolquinone acid (9.68 min). The first step in the chemical analysis of the plant is sample preparation, as the chemical composition needs to be extracted for further separation and characterization. Subsequently, the metabolite may differ in their quantities, polarities, and stabilities [3]. Several factors influence the extraction process, including the ratio of solvent to material, particle size, temperature, and pressure [1]. The extraction influences the physical properties of NADES, such as polarity and viscosity. Extraction optimization is strongly influenced by viscosity, polarity, and temperature. NADES can also dissolve bioactive and biomolecular compounds and is good to use as an alternative solvent in the extraction process because it is a safe solvent with liquid properties at room temperature, adjustable viscosity, and sustainability. Furthermore, NADES can dissolve polar and nonpolar compounds. The component identified in the extract is shown in Table 1.

Table 1 shows that 17 compounds m/z and molecular structures were detected by LC-MS. The main components are caffeic acid, chlorogenic acid, 4,5-dicaffeoylquinic acid, (+/−)12(13)-DiHOME, D-(-)-quinic acid, and neochlorogenic acid. The NADES application can be developed from the extraction effectiveness, which depends on the solubility proper-

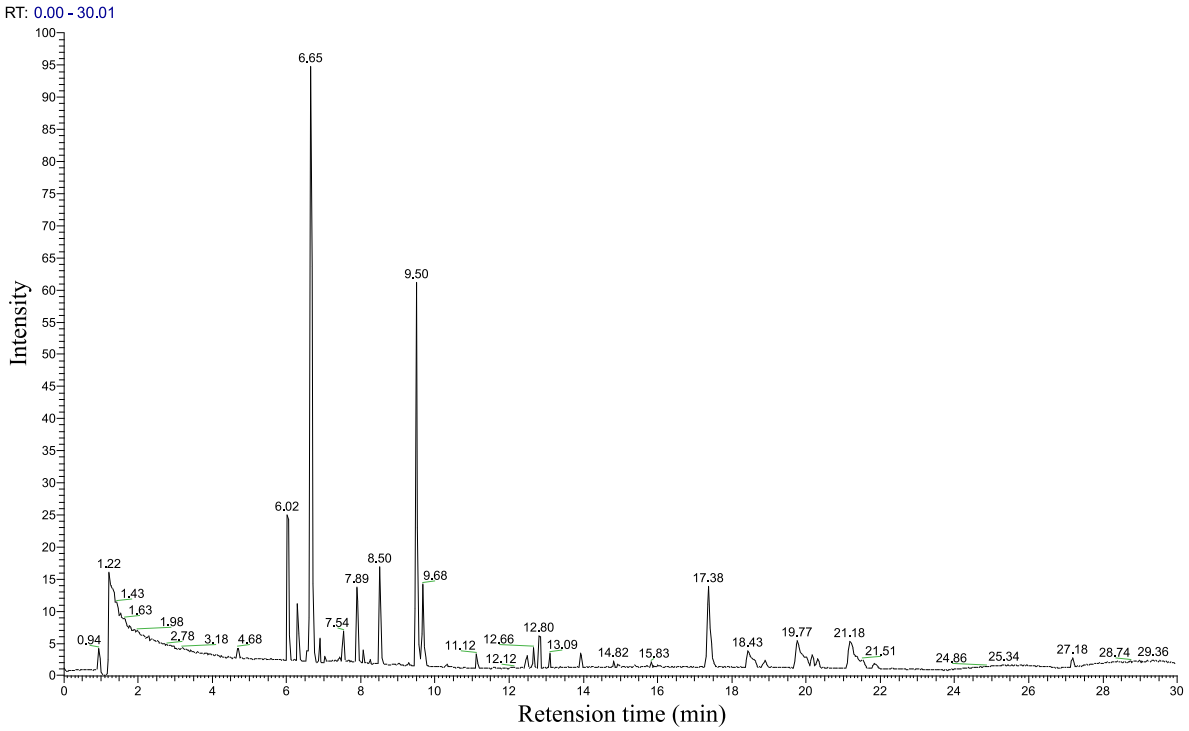


Fig. 2 LC-MS Chromatogram of extract from coffee husk using NADES.

Table 1 The active compounds in coffee husk extract using NADES.

No	Compound	Formula	Molecular weight	Retention time (min)	Group
1	Caffeine	$C_9H_8O_4$	180.04	6.675	Alkaloid
2	Chlorogenic acid	$C_{16}H_{18}O_9$	354.09	6.056	Polyphenolic
3	4,5-Dicaffeoylquinic acid	$C_{25}H_{24}O_{12}$	516.13	9.628	Phenolic
4	(+/−)12(13)-DiHOME (formal dihydroxylation)	$C_{18}H_{34}O_4$	314.25	17.231	Organic acid
5	(15Z)-9,12,13-Trihydroxy-15-octadecenoic acid	$C_{18}H_{34}O_5$	330.24	13.110	Organic acid
6	D-(-)-Quinic acid	$C_7H_{12}O_6$	192.06	6.051	Phenolic
7	Neochlorogenic acid	$C_{16}H_{18}O_9$	354.09	4.713	Phenolic
8	5-carboxyvanillic acid	$C_9H_8O_6$	212.03	6.568	Organic acid
9	3,4-dihydroxyphenylpyruvic acid	$C_9H_8O_5$	196.04	7.050	Organic acid
10	4-(2-{4-[(2E)-3-(4-Chlorophenyl)-2-propen-1-yl]-1-piperazinyl}ethyl)benzoic acid	$C_{22}H_{25}ClN_2O_2$	384.16	13.954	Organic acid
11	4-Hydroxybenzoic acid	$C_7H_6O_3$	138.03	5.427	Organic acid
12	Picrasin G	$C_9H_8O_4$	392.18	9.305	Terpenoid
13	Ninhydrin	$C_9H_6O_4$	178.02	6.248	Amine
14	10,16-Dihydroxyhexadecanoic acid	$C_{16}H_{32}O_4$	288.23	13.613	Organic acid
15	N-Acetyl-L-glutamic acid	$C_7H_{11}NO_5$	189.06	1.529	Organic acid
16	6-Hydroxy-5-methyl-4,11-dioxoundecanoic acid	$C_{12}H_{20}O_5$	244.13	10.528	Organic acid
17	Gentisic acid	$C_7H_6O_4$	154.03	3.860	Organic acid

ties. Analytical separation methods have advanced in various fields with the NADES application. Meanwhile, NADES was developed as a solvent in extraction techniques for natural compounds. The development of the separation technique can be used as an intelligent solvent with certain modifications to obtain an optimal separation process. NADES can donate or accept protons and electrons, forming hydrogen bonds and increasing solubility. In addition, it can extract phenolic compounds using lactic acid, glucose, choline chloride, fructose, and glucose, commonly found in living cells. Therefore, NADES has the potential to extract bioactive compounds that can be applied in the food industry. NADES has been applied to extract

phenol compounds [16], flavonoids, alkaloids, and saponins [17]. Phenolic separation with NADES and extraction uses microwaves from olive leaves [2] and flavonoids from *Lycium barbarum* L [18]. The green separation processes using this aqueous solvent can extract many bioactive compounds, and the development of a new green solvent is one of the critical issues to make chemical processes more environmentally friendly [18]. The application of NADES for the extraction of natural products is still limited to the efficiency of the extraction. Bioactive compounds have shown several benefits, such as antioxidant, antimicrobial, anti-inflammatory, antifungal, and anti-allergic [1]. Mass spectrometry from the main compounds is explained below.

Fig. 3 shows the mass spectrum of caffeic acid, which includes the molecular weight of the compounds. Caffeic acid uses a molecular weight (m/z) of 180.0423. Caffeine (1,3,7-tri methylxanthine) is a psychoactive drug commonly found naturally in coffee, tea, and chocolate [19]. It is an alkaloid derived from plants that can increase sympathetic stimulation sensitivity to the adenosine system [20]. The consumption of caffeine will increase energy availability, reduce fatigue, improve physical performance and increase brain concentration [21]. Bioactive and antioxidant activity has been reported in the coffee husk of Arabian and Robusta beans using conventional and microwave-assisted extraction. The experiment showed that the caffeine was extracted at 100 °C for 5 min [13].

Chlorogenic acid was detected at a retention time of 6.06 with a molecular weight (m/z) of 354.0951. Additionally, chlorogenic acid (CGA) is a biologically important dietary polyphenol with important and therapeutic functions, such as antioxidant, antibacterial, cardioprotective, anti-inflammatory, and antipyretic activities. CGA can play a role in the regulation of lipid and glucose metabolism, it can help in the treatment of many disorders such as heart disease, obesity, and diabetes [22]. CGA is a group of polyphenolic compounds that are esters between trans-cinnamic acid (caffeic, ferulic, and coumaric acid) and quinic acid. There are 3 subclasses of CGA, namely caffeoylquinic (CQA), ferulol quinic (FQA), and dicaffeoylquinic (diCQA) acid. The main CGA in coffee is 5-O-caffeoylquinic, and its isomers are 3- and 4-CGA [21].

The 4,5-dicaffeoylquinic acid (4,5 DCQA) was detected at a retention time of 9.63 with a molecular weight (m/z) of 516.1268. This DCQA is a plant-derived compound that can be isolated and has pharmacological properties such as antioxidant, antibacterial, and antihistamine and has anti-HIV activity indicated by the amount of quinic acid triester. Inhibition of HIV-1 catalyzes the integration of acetate and showed a strong antioxidant activity IC_{50} of 4.26 μg/ml [24]. It has properties against DU-145 prostate cancer cells with a 50% inhibitor concentration of 5 M [25].

The (+/−)12(13)-DiHOME was detected at a retention time of 17.23 min with a molecular weight (m/z) of 315,2457. The compound 12,13-dihydroxy-9Z-octadecenoic acid (+/−12(13)-DiHOME) can act as a stimulator of brown adipose tissue activity and lower triglyceride levels to treat metabolic disorders [26]. Improved circulation (+/−12(13)-DiHOME) in humans can affect lipid metabolism and fatty acid absorption of skeletal muscle [27]. In addition, it can also contribute to metabolite oxidized linoleic acid in inflammatory pain [28]. (+/−)12(13)-DiHOME can promote an asthma-like immunophenotype in the lung [29].

D-(-) quinic acid was detected at a retention time of 6.05 with a molecular weight (m/z) of 192.0634. Quinic acid is cyclitol, a cyclic polyol, a crystalline acid from coffee beans that can be synthesized by hydrolysis of chlorogenic acid. D-(-) quinic acid has antioxidant and anti-inflammatory properties [30]. The active compounds are obtained from natural matrices by extraction processes using organic solvents such as hexane, methanol, acetone, chloroform, and petroleum ether. The use of organic solvents shows toxicity and flammability. Therefore, they are very harmful to the environment and health [31–33].

Neochlorogenic acid was detected at a retention time of 4.71 min with a molecular weight (m/z) of 354.0951. Neochlorogenic acid (3-O-caffeoylquinic acid), an isomer of chlorogenic acid (5-O-caffeoylquinic acid), was formed by ester bonds between caffeic acid and D-(-) quinic acid. This acid is found in some food as prunes, coffee beans, cherries, and rosemary leaves [34]. These compounds have antioxidant, antifungal, anti-inflammatory, and anticancer activities. Various analysis methods were identified based on the determination of phenolic compounds. The main extraction techniques reported are liquid-liquid, solid-phase, and maceration. Recently, NADES has been developed to replace this solvent. The extraction of active compounds in coffee husk using NADES was influenced by the extraction time, ratio of sample to volume, and temperature [35]. NADES was developed to extract active compounds from natural samples.

CONCLUSION

In this study, the green solvent was used as NADES based on choline chloride-proline with a molar ratio (1:2) and was able to separate the active compounds from the coffee husk. The compounds reported are alkaloid, polyphenolic, phenolic acid, organic acid, and amine. The interaction of hydrogen bonds and phenolic compounds is responsible for their extraction ability. The extraction capability using NADES can separate metabolites from materials that have the potential

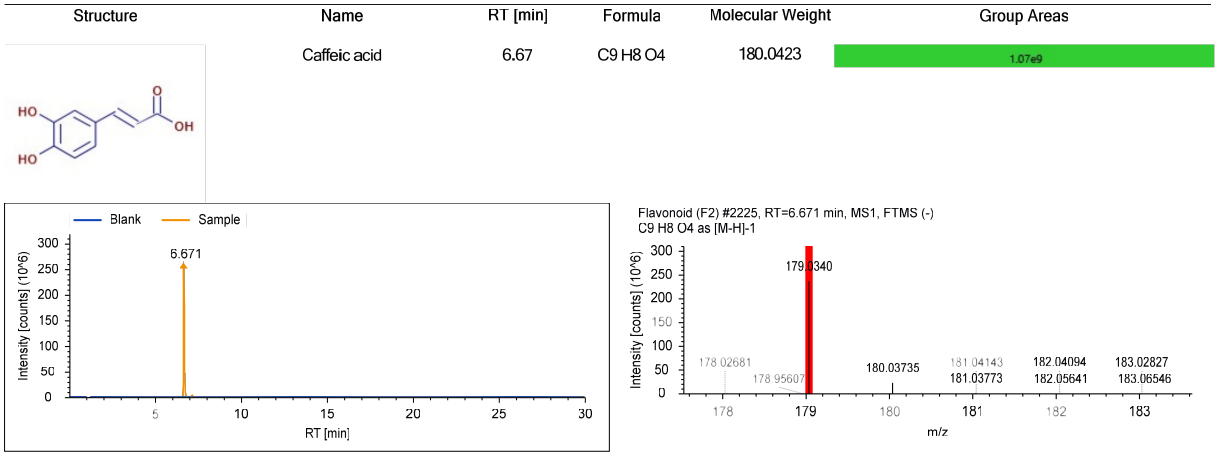


Fig. 3 Mass spectrometry from caffeic acid.

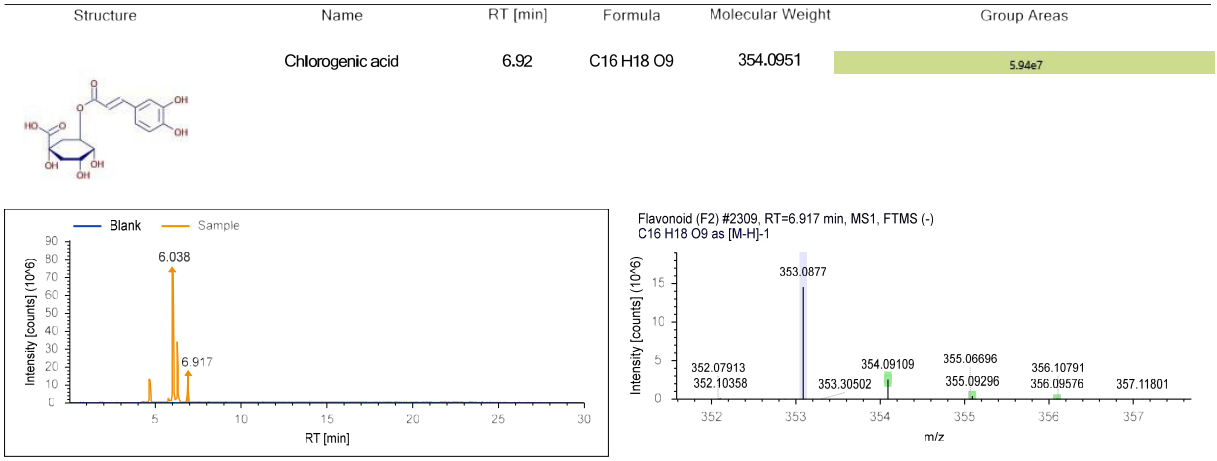


Fig. 4 Mass spectrometry from chlorogenic acid.

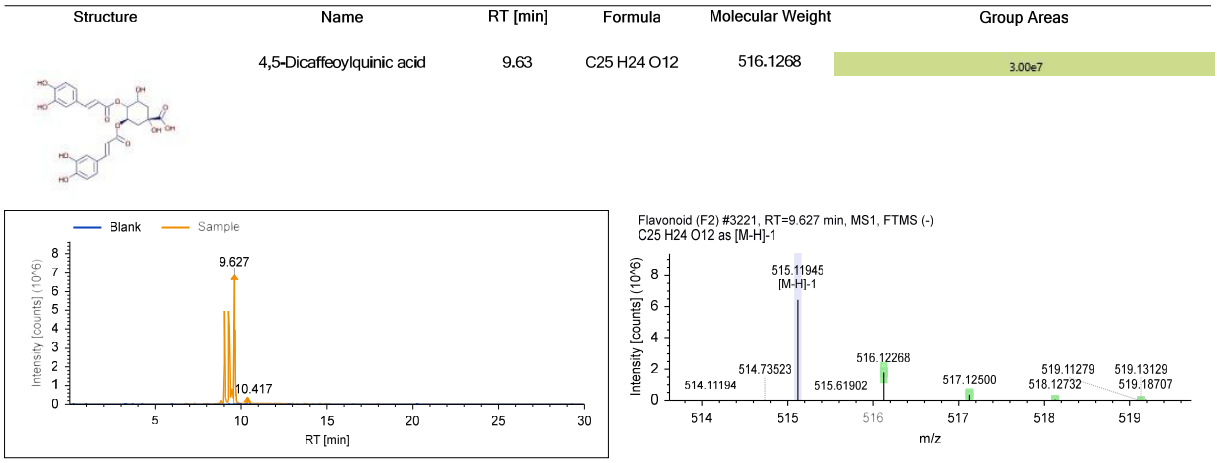


Fig. 5 Mass spectrometry from 4,5-dicaffeoylquinic acid.

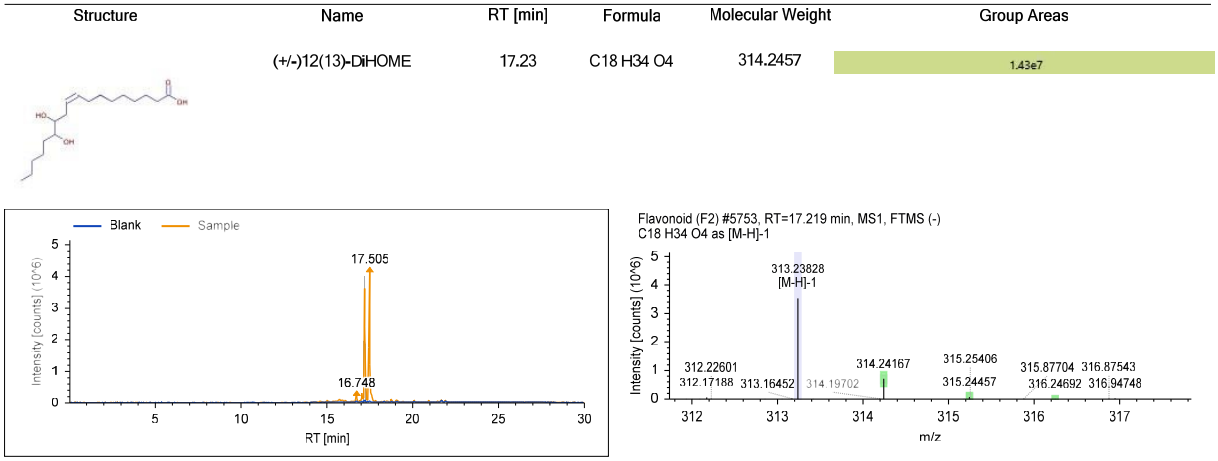


Fig. 6 Mass spectrometry from (+/−)12(13)-DiHOME.

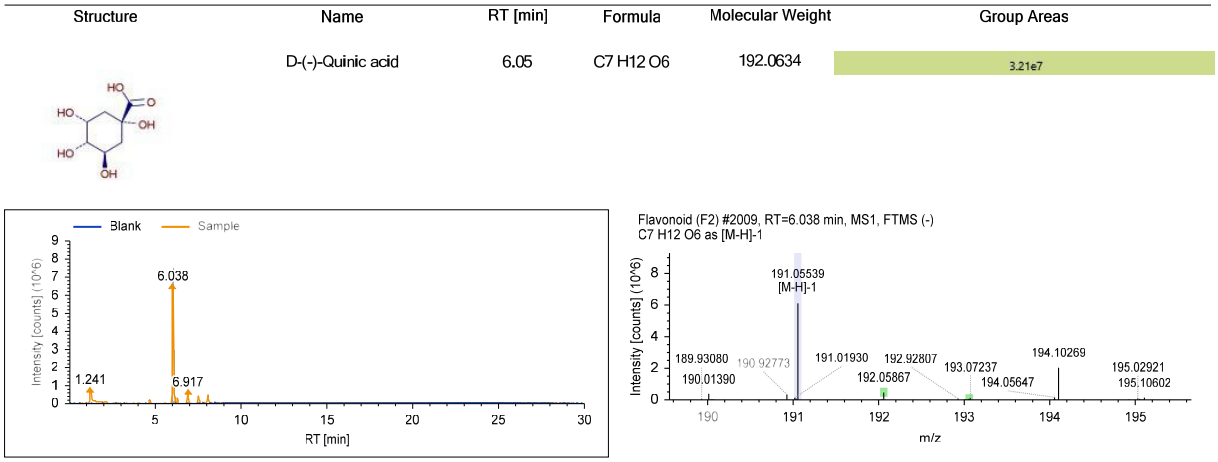


Fig. 7 Mass spectrometry from D-(-) quinic acid.

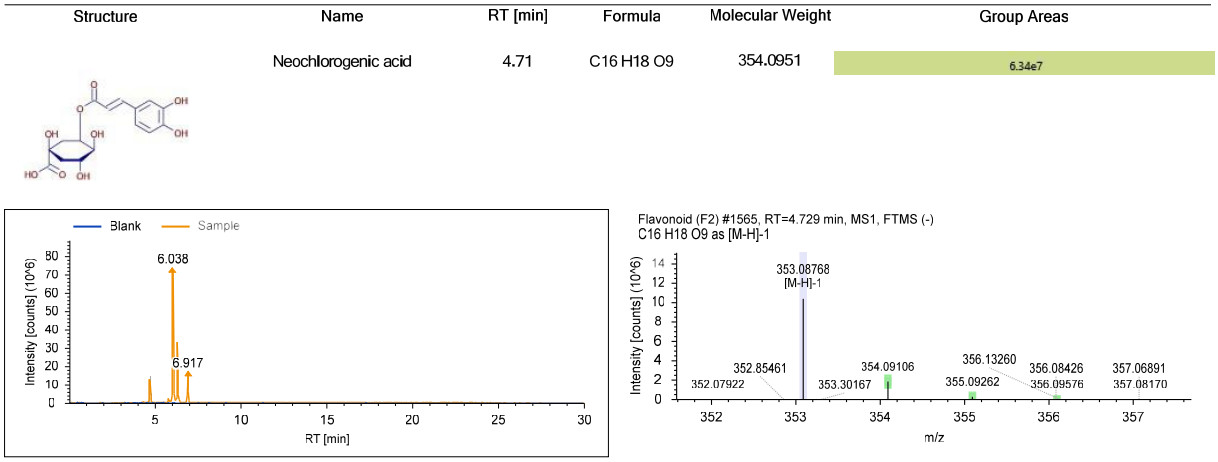


Fig. 8 Mass spectrometry from neochlorogenic acid.

as active substances in pharmaceuticals. NADES is formed from safe components and can be applied to the extraction of natural and environmentally friendly materials, which can be developed for the pharmaceutical industry.

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REFERENCES

1. Bentley J, Olsen EK, Moore JP, Farrant JM (2020) The phenolic profile extracted from the desiccation-tolerant medicinal shrub *Myrothamnus flabellifolia* using natural deep eutectic solvents varies according to the solvation conditions. *Phytochemistry* **173**, 112323.
2. Alanon ME, Ivanovic M, Gómez-Caravaca AM, Arraez-Roman D, Carretero AS (2018) Choline chloride derivative-bases deep eutectic liquids as a novel green alternative solvents for extraction of phenolic compounds from olive leaf, *Arab J Chem* **13**, 1685–1701.
3. Bajkacz S, Adamek J (2018) Development of a method based on natural deep eutectic solvents for extraction of flavonoids from food samples. *Food Anal Met* **11**, 1330–1344.
4. Paiva A, Craveiro R, Aroso I, Martins M, Reis RL, Duarte ARC (2014) Natural deep eutectic solvent-solvent for the 21st century. *Sustain Chem Engin* **2**, 1063–1071.
5. Yue Y, Huang Q, Fu Y, Chang J (2020) A quick selection of natural deep eutectic solvent for the extraction of chlorogenic acid from herba *artemisiae scopariae*. *RSD Adv* **10**, 23403–23409.
6. Yin XS, Zhong ZF, Blan G, Cheng X, Li D (2020) Ultrarapid enhanced and eco-friendly extraction for main flavonoids from the seeds *Oroxylum indicum* by deep eutectic solvents combination with tissue extraction. *Food Chem* **319**, 126555.
7. Farajzadeh MA, Mogaddam MRA, Feriduni B (2016) Simultaneous synthesis of deep eutectic solvent and its application in liquid-liquid microextraction of polycyclic aromatic hydrocarbons from aqueous samples. *RSC Adv* **6**, 47990–47996.
8. Nie J, Yu G, Song Z, Wang X, Li Z, She Y, Lee M (2017) Microwave-assisted deep eutectic solvent extraction coupled with headspace solid-phase microextraction followed by GC-MS for analysis of volatile compounds from tobacco. *Anal Methods* **9**, 856–863.
9. Khezeli T, Daneshfar A (2017) Synthesis and application of magnetic deep eutectic solvents: Novel solvents for ultrasound assisted liquid-lquid microextraction of thiophene. *Ultra Sonochem* **38**, 590–597.
10. Castaldo L, Graziani G, Gaspari A, Izzo L, Luz C, Manes J, Rubino M, Meca G, et al (2018) Study of the chemical components, bioactive and antifungal properties of the coffee husk. *J Food Res* **7**, 43–54.
11. Murthy PS, Naidu MM (2012) Sustainable management of coffee industry by-product and value addition-A review. *Res Conserv Recyc* **66**, 45–58.
12. Silva MO, Honfoga JNB, de Medeiros LL, Madruga MS, Bezerra TKA (2021) Obtaining bioactive compounds from the coffee husk (*Coffea arabica* L) using different extraction methods, *Molecules* **26**, 46.
13. Thaiphanit S, Wedprasert W, Srabva A (2020) Conventional and microwave-assisted extraction for bioactive compounds from dried coffee cherry peel by-products and antioxidant activity of the aqueous extract. *ScienceAsia* **46S**, 12–18.
14. Andrade KS, Goncalves RT, Maraschin M, Ribeiro-do-Valle RM, Martinez J, Ferreira SRS (2012) Supercritical fluid extraction from spent coffee ground and coffee husk: antioxidant and effect of operational variables on extract composition. *Talanta* **88**, 544–522.
15. Dai Y, Row KH (2019) Application of natural deep eutectic solvent in the extraction of quercetin from vegetables. *Molecules* **24**, 2300.
16. Wei Z, Qi Q, Li T, Luo M, Wang W, Zu Y, Fu Y (2015) Application of natural deep eutectic solvents for extraction and determinantion of phenolic in *Cajanus cajan* leaves by ultra performance liquid chromatography. *Separ Pur Technol* **149**, 237–244.
17. Duan L, Dou LL, Guo L, Li P, Liu EH (2016) Comprehensive evaluation of deep eutectic solvents in extraction of bioactive natural products. *ACS Sustain Chem Engin* **4**, 2405–2411.
18. Ali MC, Chen J, Zhang H, Li Z, Zhao L, Qiu H (2019) Effective extraction of flavonoids from *Lyceum barbarum* L. fruits by deep eutectic solvents based ultra sound-assisted extraction. *Talanta* **203**, 16–22.
19. Temple JL, Bernard C, Lipshultz SE, Czachor JD, Westphal JA, Mestre MA (2017) The safety of ingested caffeine: A comprehensive review. *Front Phsyc* **8**, 80.
20. Dam RV, Hu FB, Willett WC (2020) Coffee, caffeine and health. *The New Eng J Med* **383**, 369–378.
21. Glade MJ (2010) Caffeine-not just a stimulant. *Nutrition* **26**, 932–938.
22. Naveed M, Hejazi V, Abbas M, Kamboh AA, Khan GJ, Shumzaid M, Ahmad F, Babazadef DX (2018) Chlorogenic acid (CGA): A pharmacological review and call for further research. *Fang Biomed Pharm* **97**, 67–74.
23. Miketova KH, Schram J, Whitney EH, Keans BM, Timmermann (1999) Mass spectrometry of 3,5- and 4,5 -dicaffeoylquinic acids and selected derivates. *J Mass Spect* **34**, 1240–1252.
24. Hong S, Joo T, Jhoo JW (2015) Antioxidant and anti-inflammatory activities of 3,5-dicaffeoylquinic and isolated from *Ligularia fischeri* leaves. *Food Sci Biotecnol* **24**, 257–263.
25. Lodise O, Patil K, Karshenboym I, Prambo S, Chukwueke C, Pai SB (2019) Inhibition of prostate cancer cells through cell cycle arrest by 4,5-dicaffeoylquinic acid through cell cycle arrest. *Prost Cancer* **2019**, 4520645.
26. Lynes MD, Leiria LO, Lundh M, Bartelt A, Shamsi F, Huang TL, Takahashi H, Hirshman MF, et al (2017) The cold-induced lipokine 12,13-diHOME promotes fatty acid transport into brown adipose tissue. *Nat Med* **2**, 631–637.
27. Stanford KI, Lynes MD, Takashi H, Baer LA, Arts PJ, May FJ, Lehnig AC, Middlebeek RJW, et al (2018) 12,13-diHOME: An exercise-induced lipokine that increase skeletal muscle fatty acid uptake. *Cell Metabolism* **27**, 1111–1120.
28. Zimmer B, Angioni C, Osthues T, Toewe A, Thomas D, Pierre SC, Geisslinger G, Scholich K, et al (2018) The oxidized linoleic acid metabolite 12,13-DiHOME mediates thermal hyperalgesia during inflammatory pain. *Biochim Biophy Acta* **1863**, 669–678.
29. Steward CJ (2019) Homing in on 12,13-diHOME in

asthma. *Nat Microb* **4**, 1774–1775.
30. Tuyun AF, Uslu H (2012) Extraction of D-(-)-Quinic acid using an amine extract in different diluents. *J Chem Engin Data* **57**, 190–194.
31. Benvenutti L, Zielinski AAF, Ferreira SRS (2019) Which is the best food emerging solvent: IL, DES or NADES. *Trends Food Sci Tech* **90**, 133–146.
32. Alhakmani F, Kumar S, Khan SA (2013) Estimation of total phenolic content, *in vitro* antioxidant and anti-inflammatory activities of flowers of *Moringa oleifera*. *Asian Pac J Trop Biomed* **3**, 623–627.
33. Wong-Paz JE, Esquivel JCC, Herrera RR, Inungaray MLC, Lopez LI, Moorillon GVN, Anguilar CN (2015) Total phenolic content, *in vitro* antioxidant activity and chemical composition of plant extracts from semiarid Mexican region. *Asian Pacific J Trop Med* **8**, 104–111.
34. Orcajada SN, Matencio A, Herrero CV, Carmona FG, Nicolar JML (2021) Study of fluorescence and interaction between cyclodextrins and neochlorogenic acid in comparison with chlorogenic acid. *Sci Rep* **11**, 3275.
35. Maimulyanti A, Nurhidayati I, Mellisani B, Putri FAR, Puspita F, Prihadi AR (2023) Development of natural deep eutectic solvent (NADES) based on choline chloride as a green solvent to extract phenolic compounds from coffee husk waste. *Arab J Chem* **16**, 104634.