GIDA
THE JOURNAL OF FOOD
E-ISSN 1309-6273, ISSN 1300-3070

Research / Araştırma
GIDA (2026) 51 (2) 318-326
doi:10.15237/gida. GD25133

APPLICATION OF DEEP EUTECTIC SOLVENTS FOR EXTRACTION OF BIOACTIVE COMPOUNDS FROM *MYRTUS COMMUNIS* L. LEAVES: ASSESSING TOTAL PHENOLICS, ANTIOXIDANT ACTIVITY, AND PROCESS SUSTAINABILITY

Ezgi KALKAN[1*], Medeni MASKAN[2]

[1]Hasan Kalyoncu University Faculty of Health Sciences, Department of Nutrition and Dietetics, Gaziantep, Türkiye
[2]Gaziantep University Faculty of Engineering, Department of Food Engineering, Gaziantep, Türkiye

Received / Geliş: 17.10.2025; *Accepted* / Kabul:27.01.2026; *Published online* /Online baskı: 31.03.2026

ABSTRACT

In this study, a green extraction method for extracting bioactive chemicals from *Myrtus communis* L. leaves was explored. Seven selected Choline chloride (ChCl)-based deep eutectic solvents (ChCl: Ethylene glycol, ChCl: Diethylene glycol, ChCl: Triethylene glycol, ChCl: Oxalic acid, ChCl: Lactic acid, ChCl: Glycerol, ChCl: Urea) were utilized as extraction medium and compared with traditional solvents, specifically methanol, ethanol, and ethyl acetate. The extracts were assessed for total phenolicc content (TPC) and radical scavenging activity (RSA). In terms of TPC, methanol produced the highest value, closely followed by ChCl:Triethylene glycol. In terms of RSA, ChCl:Oxalic acid had the highest antioxidant activity, followed by ChCl:Ethylene glycol. Additionally, the proposed green approach was evaluated with AGREEprep metrics. The results of the study validated that it was in line with the fundamentals of green chemistry and achieving a score of 0.79 for the present approach in contrast to 0.37 for the conventional approach. Overall, this study revealed a green and promising method for extracting considerable amounts of antioxidative phenolic compounds from *Myrtus communis* L. leaves.

Keywords: *Myrtus communis* L, deep eutectic solvent, phenolics extraction, antioxidant capacity, sustainability

MYRTUS COMMUNIS L. YAPRAKLARINDAN BİYOAKTİF BİLEŞİKLERİN EKSTRAKSİYONUNDA DERİN ÖTEKTİK ÇÖZÜCÜLERİN KULLANIMI: TOPLAM FENOLİK İÇERİK, ANTİOKSİDAN AKTİVİTE VE PROSES SÜRDÜRÜLEBİLİRLİĞİNİN DEĞERLENDİRİLMESİ

ÖZ

Bu çalışmada, *Myrtus communis* L. yapraklarından biyoaktif bileşiklerin ekstraksiyonu için yeşil bir ekstraksiyon yöntemi araştırılmıştır. Ekstraksiyon ortamı olarak, seçilen yedi adet kolin klorür (ChCl) bazlı derin ötektik çözücü (ChCl: Etilen glikol, ChCl: Dietilen glikol, ChCl: Trietilen glikol, ChCl: Oksalik asit, ChCl: Laktik asit, ChCl: Gliserol, ChCl: Üre) kullanılmış ve bunlar geleneksel çözücüler olan metanol, etanol ve etil asetat ile karşılaştırılmıştır. Elde edilen ekstraktlar toplam fenolik madde içeriği (TPC) ve radikal süpürme aktivitesi (RSA) açısından değerlendirilmiştir. TPC bakımından en yüksek değer metanolle elde edilmiş, bunu çok yakın bir biçimde ChCl:Trietilen glikol takip etmiştir. RSA açısından ise en yüksek antioksidan aktivite ChCl:Oksalik asit ile elde edilmiş, bunu ChCl:Etilen glikol izlemiştir. Ayrıca önerilen yeşil yaklaşım AGREEprep metrikleri ile değerlendirilmiştir. Çalışmanın sonuçları, bu yöntemin yeşil kimyanın temel ilkeleriyle uyumlu olduğunu ve sunulan yöntemin AGREEprep skorunun 0.79, geleneksel yaklaşım için ise 0.37 olduğunu göstermiştir. Sonuç olarak, bu çalışma *Myrtus communis* L. yapraklarından önemli miktarda antioksidanca yüksek fenolik bileşiklerin ekstraksiyonu için yeşil ve umut vadeden bir yöntem ortaya koymuştur.

Anahtar kelimeler: *Myrtus communis* L., derin ötektik çözücü, fenolik ekstraksiyonu, antioksidan kapasite, sürdürülebilirlik

Yazışmalardan sorumlu yazar / Corresponding author: Ezgi KALKAN
ORCID No: 0000-0002-4215-2155 **E-posta:** kalkannezgi@gmail.com

INTRODUCTION

Myrtus communis L. is a prominent medicinal plant belonging to the *Myrtaceae* family, renowned for its utilizations in the food and pharmaceutical areas (Yaghoobi et al., 2022). This aromatic plant is naturally found in coastal zones of the Mediterranean region and also found in South America (Al-Snafi et al., 2024). The plant's fruit, leaves, seeds, and essential oils possesses valuable natural sources that have significant positive effects on health The astringent nature of its leaves support their nutritional value in the wound's healing and gastrointestinal problems (Alipour et al., 2014). Earlier researches have recognized *M. Communis* L. as a substantial source of phenolics, flavonoids, tannins, essential oils, which support its extensive range of biological activities (Berendika et al., 2022; Snoussi et al., 2021; Yarahmadi et al., 2024).

The extraction of phenolic compounds has traditionally taken place with organic solvents like methanol and ethanol (Ling & Hadinoto, 2022). Nevertheless, these conventional solvents pose environmental drawbacks owing to their toxicity, non-biodegradability, potential corrosive properties and waste disposal. In addition, their flammability, volatility, and toxicity may pose hazards to human health (Koraqi et al., 2024). As an alternative, deep eutectic solvents (DESs) have emerged as a group of eco-friendly solvents that are distinguished by properties such as non-volatility, non-flammability, a broad polarity range, high biodegradability, simple preparation, and tunable characteristics. The physicochemical properties of DESs are formed by the molecular interactions among their constituents and the molar ratios of these constituents (Gómez-Urios et al., 2023). These benefits underscore the superiority of DESs compared to traditional solvents across various applications (Kalkan & Maskan, 2025; Kalkan et al., 2024). Numerous recent research have exhibited that DESs surpass petroleum-based solvents in the separation of bioactive substances, including perilla leaves (Chen et al., 2022), neem leaves (Kaur et al., 2024), and *Moringa oleifera* leaves (Wei et al., 2023).

Consequently, the limitations of conventional organic solvents have been significantly overcome through the invention of DESs, an innovative non-toxic solvent. To date, only two studies have reported the extraction of phenolic compounds from *Myrtus communis* L. leaves employing conventional solvents (Snoussi et al., 2021; Yaghoobi et al., 2022). This gap highlights the urgent necessity of investigating more sustainable and environmentally friendly alternatives for the bioactive compound recovery from *Myrtus communis* L. leaves, a food by-products. To address this, the current study is the first to employ seven different ChCl-based DESs for phenolics extraction and compare their efficiency to traditional solvents in terms of total phenolics content (TPC) and antioxidant activity using the radical scavenging activity (RSA) method. Furthermore, another novelty of this study lies in demonstrating, for the first time, the advantages of DESs through a greenness assessment of the extraction process using the AGREEprep green metric tool (Pena-Pereira et al., 2020). These tools are 1) sample preparation, 2) risky substances, 3) reusability, 4) waste, 5) quantity of sample, 6) 7) automated process, 8) Energy usage, 9) post-sample preparation, and 10) security.

MATERIALS AND METHODS

Materials and Chemicals

The plant of *Myrtus communis* L. were gathered in September 2025 from Osmaniye Province, Türkiye. The plant material was dried at ambient temperature in the shade for four days. Following the drying process, the leaves were separated from the stems and fruits, and subsequently preserved in airtight polyethylene bags at 4°C under refrigerated conditions until being used. Prior to extraction, the leaves were crushed into a thin powder using a blender (Blender 8011ES, Model HGB2WTS3, 400 W).

The chemical analysis were conducted by using 1,1-Diphenyl-2-picrylhydrazyl, gallic acid, Folin-Ciocalteu's reagent, sodium carbonate (Na_2CO_3), methanol (≥99.5%), hexane (≥99.5%), ethyl acetate (≥99.5%), ethanol (≥99.5%) and methanol (≥99.5%). These were obtained from TEKKİM (Türkiye) and from Merck (Darmstadt, Germany). The chemicals adopted as hydrogen bond acceptors (HBAs) and hydrogen bond donors (HBDs) in the formulation of DESs came from by TEKKİM (Türkiye) and Sigma-Aldrich (St. Louis, MO, USA). Choline chloride (≥98%), oxalic acid (≥99.9%), ethylene glycol (≥99.5%), diethylene glycol (≥99.5%), triethylene glycol (≥99.5%), lactic acid (80-85%), urea, and glycerol (≥99.5%) were among the substances that were included. Every ingredient used for the analysis and extraction processes were of analytical grade.

Preparation of Deep Eutectic Solvents

At varied molar ratios, ethylene glycol, diethylene glycol, triethylene glycol, urea, lactic acid, oxalic acid, and glycerol were used to create seven distinct choline chloride (ChCl)-based DES combinations as shown in Table 1. The molar ratios applied for the preparation of each DES were selected based on previously reported formulations in the literature (Le et al., 2024; Wojeicchowski et al., 2021), where these ratios were demonstrated to form stable and homogeneous eutectic mixtures, and are widely validated in DES-based studies as the most suitable for bioactive compounds extractions. Also, ethanol, methanol and ethyl acetate were employed as conventional solvents for comparison as control solvents. The components of the hydrogen bond donor (HBD) and acceptor (HBA) were combined to create the DESs at 400 rpm and 80°C using a hot plate stirrer (Hot & StirrerTepe, MS300HS) for approximately 1 hour until a homogenous and transparent liquid phase was produced (Kalkan & Maskan, 2025). The resultant DES mixtures, augmented with 20% (v/v) water, were later utilized as green extraction medium for the recovery of bioactive compounds from the dried leaves of *Myrtus communis* L.

Table 1. Screening of DESs and conventional solvents for extraction of bioactive compounds from *Myrtus communis L.* leaves

	Chemicals	HBA	HBD	Molar Ratio
1	ChCl: EG	Choline chloride	Ethylene glycol	1:2
2	ChCl: DiEG	Choline chloride	Diethylene glycol	1:2
3	ChCl: TriEG	Choline chloride	Triethylene glycol	1:3
4	ChCl: OX	Choline chloride	Oxalic acid	1:1
5	ChCl: LA	Choline chloride	Lactic acid	1:1
6	ChCl: Gly	Choline chloride	Glycerol	1:1
7	ChCl: Urea	Choline chloride	Urea	1:2
8	Ethanol			-
9	Methanol			-
10	Ethyl acetate			-

Extraction Procedure

For DESs-based solvent extraction, the dried and ground plant leavaes were mixed with the solvents in a 1:30 solid to solvent ratio (g/mL) in 50 mL erlenmeyer flasks. For all extraction runs, 0.5 g of dried leavaes was mixed with 15 mL of solvent. The flask was placed in hotplate magnetic stirrer (Model US152; Staffordshire, UK) and solvent extraction technique was employed at room temperature (28°C) for 1 hour at 400 rpm. The water was arranged only for DESs-based solvents as 20% of total volume. According to Zannou & Koca (2022), DESs' superior extractability may be attributed to the inclusion of 20% water to control the viscosity of resultant solvent mixture.

On the other hand, for methanol, ethanol and ethyl acetate, the experiment was conducted at room temperature (28°C) for 1 hour at 400 rpm and in a 1:30 solid to solvent ratio (g/mL) using solvent extraction method. All experiments and analyses were carried out in duplicate, and data were provided as means±standard error of the mean (SEM). The statistical grouping of the bars was established in line to the overlapping of SEMs. Separate letters were allocated to bars with non-overlapping ranges and the identical lowercase letter to bars with overlapping SEMs.

Determination of Moisture Content

Before extraction, the moisture content of ground plant leaves was tested using an infrared moisture analyzer (Mettler

Toledo MJ33, Greifensee, Switzerland) as per Li et al. (2018). The percentage of moisture of the leaves was detected as 5.25%±0.04.

Determination of Total Phenolics Content (TPC)

TPC of plant leaves was measured utilizing the Folin-Ciocalteu method as outlined by Yaghoobi et al. (2022), with minor modifications. In summary, 0.1 mL of extract was pippetted into a test tube and combined with 1 mL of tenfold diluted Folin-Ciocalteu reagent. Following a 5-min, 1 mL of 7.5% sodium carbonate solution was incorporated, and the total volume was adjusted to 10 mL using distilled water. The combination was subsequently incubated in darkness for 30 min, and the absorbance was recorded at 765 nm utilizing a Novaspec II spectrophotometer (Pharmacia Biotech, Cambridge, England). The calibration curve was constructed using gallic acid solutions in the range 0.05 to 1 mg/mL. The mathematical equation of calibration curve was expressed as y=0.111x - 0.0561 (R^2=0.9904). The TPC was reported as milligrams of gallic acid equivalents per gram of dry weight of leaves (mg GAE/g DW).

Determination of Radical Scavenging Activity (RSA) By DPPH

The antioxidant potential of the extracts were evaluated utilizing the 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) scavenging test (Kaur et al., 2024). A DPPH solution was freshly prepared by dissolution of 2.84 mg of DPPH in 100 mL of methanol (Acontrol). Subsequently, 200 µL of the adjusted extract (1:70 v/v) was blended with 6 mL of the DPPH solution. Through the use of a Novaspec II spectrophotometer (Pharmacia Biotech, Cambridge, England), the absorbance was detected at 517 nm following 30 minutes of standing at room temperature. The control absorbance (Acontrol) referred to all reagents without extract, while the extract absorbance (Aextract) included the reagents. The extracts' inhibitory percentage was determined via Eqn (1).

$$Inhibition\ (\%) = \frac{A_{control} - A_{extract}}{A_{control}} \quad (1)$$

Greenness Evaulation

The AGREEprep software was utilized to assess the differences between the proposed green solvent utilizing ChCl-TriEG to the conventional methanol, in accordance with the methods outlined by Pena-Pereira et al. (2020). ChCl:TriEG was selected for greenness assessment because it produced the maximum TPC of the investigated ChCl-based DESs and had extraction performance comparable to methanol. According to Bystrzanowska & Tobiszewski (2021), greennes status of different DESs were evaulated and TriEG was found nontoxic to all examined organisms. In accordance with the green chemistry principles, this program rates each stage of chemical processes in ten criteria on a scale of 0 to 1, with 1 representing the greennest approach. The scale evaluates the extraction process from multiple aspects, including sample size, minimization of solvent waste, use of renewable reagents, toxicity, and safety.

RESULTS AND DISCUSSION

Results of Total Phenolics Content

In the current investigation, phenolic compounds from *Myrtus communis L.* leaves were isolated using ChCl-based DESs and conventional solvents (methanol, ethanol, and ethyl acetate). Choosing the right solvent is an important step in the extraction process since it has a major effect on how well the target chemicals are recovered. The literature does not contain enough scientific studies that compare the TPC of *Myrtus communis L.* extracts as affected by DESs. The physicochemical qualities of solvents are crucial for the extraction efficiency of the target component. The ChCl-based DESs bioactive compound extraction has been a hot topic of research in the world (Wang et al., 2023; Wu et al., 2020).

In the current research, the significant differences in TPC among extraction solvents were observed. Fig 1 depicts the TPC of *Myrtus communis L.* extracts with various DESs (20% water content in DESs, v/v) and commonly used solvents. Different lowercase letters above the bars indicate statistically significant differences among TPC extracted by different solvents. Lowercase letters represent grouping according to mean±standard deviation range overlapping. Results vary between 102.05±0.51 and 395.60±0.50 mg GAE/g dry solids in leaves. This demonstrated that solvents exhibited a wide range of extraction capabilities. The highest phenolics content was extracted using methanol (395.60±0.50), followed by ChCl: TriEG at 374.83±1.70 mg GAE/g dry solids in leaves.

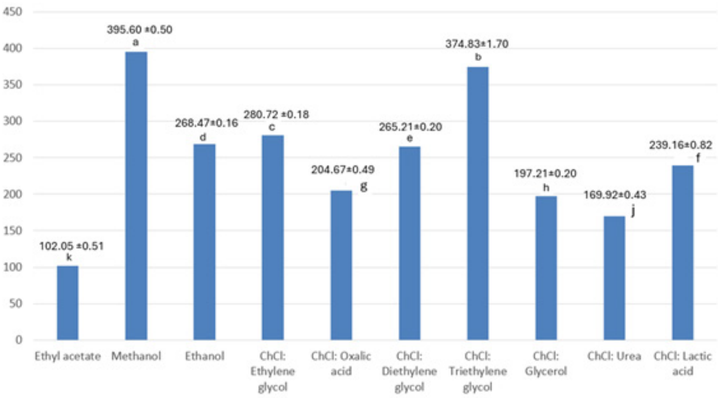

Figure 1. TPC of Myrtus leaves extract obtained with different solvents (DESs, methanol, ethanol, ethyl acetate). Statistically significant changes are denoted by various lowercase letters

Results of Radical Scavenging Antioxidant Activity

The antioxidant activity of *Myrtus communis L.* leaf extracts was assessed using the DPPH assay, wherein a reduction in absorbance signifies free-radical scavenging (Wu et al., 2020). The violet-to-yellow color shift reflects antioxidant potency, with a brighter yellow suggesting greater RSA. Figure 2 demostrated the RSA of *Myrtus communis L.* Leaves extracts obtained by ten different solvents. Distinct lowercase letters above the bars indicate pairwise differences among solvents. Lowercase letters indicate grouping by overlapping mean±standard deviation ranges. Bars with at least one common letter are indistinguishable within the reported variation. Nonetheless, no substantial variations were noted for the bars (ethyl acetate, ChCl: Glycerol, ChCl: Triethylene glycol) and displayed the letters of gh, hi, ghi. According to Figure 2, The RSA values varied from 17.06±0.06 to 41.08±0.07 % with the greatest activity seen for ChCl:Oxalic acid (41.08±0.07%), followed by ChCl:EG (28.36±0.18%), and the minimum for ethanol (17.06±0.06%). Extracts prepared using DESs had RSA values ranging from 22.08±0.08 to 41.08±0.07% whereas conventional solvents produced 17.06±0.06 to 23.29±0.10 %. It was noteworthy that the solvent yielding the highest RSA (ChCl:Oxalic acid) did not align with the solvent producing the highest TPC (methanol). It was explained that RSA is not simply reflective of TPC and may be influenced by the composition and structure of the extracted compounds, including non-phenolic structures (Farkas et al., 2004).

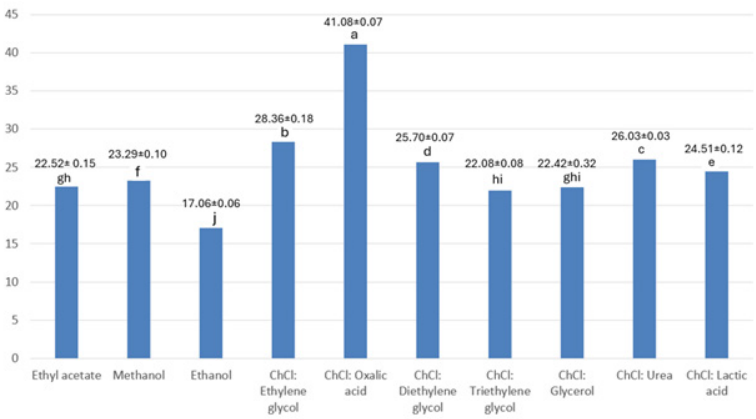

Figure 2. RSA of *Myrtus communis L.* leaves extract obtained with different solvents (DESs, methanol, ethanol, ethyl acetate). Statistically significant changes are denoted by various lowercase letters

Comparison of Present Findings with Literature

The findings obtained from this study was compared with the literature to evaluate the effectiveness of ChCl-based DESs in terms of TPC and RSA of *Myrtus communis L.* leaves. In terms of TPC, the values obtained in this study were notably higher than those reported in earlier researchers (Dahmoune et al., 2015; Yaghoobi et al., 2022). Dahmoune et al. (2015) used a microwave-assisted extraction technique to phenolics recovery from Myrtus leaves by ethanol-water mixture. The present investigation produced substantially more phenolics using ChCl:TriEG (374.82±1.70 mg GAE/g dry solids) than the microwave-assisted extraction technology (162.49±16.95 mg GAE /g dry weight). In an another recent study, the maximum amount of TPC (269.36±3.83 mg GAE/g dry weight) was produced from *Myrtus communis* L. leaves employing ultrasound-assisted aqueous system (Yaghoobi et al., 2022). The current investigation yielded a substantially greater amount of TPC than both previous studies. Similar to present findings, the highest TPC from onion *(Allium cepa* L.) peels had been extracted using 70% (v/v) aqueous methanol (69.21 mg GAE g-1 dw) and closely followed by the onion peel extract by ChCl:Urea (64.23 mg GAE g-1 dw) (Pal & Jadeja, 2019). Kaur et al. (2024) discovered that the maximum (38.2±1.2 mg GAE/g DW), TPC in neem leaves was obtained by using ChCl-EG, attributed to the robust chemical interactions between polyphenols and DESs. According to the concept of 'like dissolves like', the desired molecules move to the solvent via the law of similarity and intermiscibility, which is frequently methanol (Shi et al., 2022). Recent investigations have demonstrated that DESs possess significant potential for the extraction of phenolics from agro-food waste (da Silva et al., 2021; de Almeida Pontes et al., 2021).

In contrast to the current investigation, acetone, methanol, and ethyl acetate extracts of *Myrtus communis* L. berries, as well as methanolic extracts of *Myrtus communis* L. leaves, showed greater antioxidant activity than 90% (Tumen et al., 2012). The antioxidant activity of the methanolic extract found in this investigation (23.29%) was significantly lower than these values. Also, the current study found that when ChCl:OX was utilized instead of tradational solvent extracts (ethanol, methanol, and ethyl acetate), antioxidant activity was approximately twice as great. In another study, the RSA of onion peel extracts obtained with methanol and ChCl-based DESs was also examined by Pal & Jadeja (2019) and found that the methanolic extract (82.40%) exhibited greater antioxidant activity than ChCl:Urea (76.31%) and ChCl:Sucrose (79.81%). In another study, tradational solvents of ethanol, water and ethyl acetate was used to extract myrtle berries. It was found that ethanolic extract had the highest antioxidant activity (41.4 mmol/L TEAC) and followed by the aqueous extract (17.7 mmol/L TEAC) (Tuberoso et al., 2010). On the other hand, Jurić et al. (2021) used six distinct ChCl-based natural DESs to assess the antioxidant activity of peppermint (Mentha piperita) and contrasted them with 70% ethanol. All of the NADES extracts had more antioxidant activity than the 70% ethanol extract. The solvent with the highest antioxidant activity was ChCl:malic acid at a 1:1 molar ratio (IC_{50}=0.67 mg/mL), while 70% ethanol had an IC_{50} value of 0.91±0.04 mg/mL. Intermolecular interactions, specifically hydrogen bonding with phenolic chemicals, may be the cause of NADES extracts' higher antioxidant activity as compared to ethanol. In accordance with this, Zannou & Koca, (2022), reported the highest antioxidant activity of blackberry extract utilizing ChCl:citric acid while Gómez-Urios et al. (2023) determined that ChCl:Gly and ChCl: Malic acid with 25% water were more successful than ethanol for the aim of removing bioactive substances from orange peel. Results from this investigation were in line with earlier studies indicating that DES-based solvents have potential to generate extracts rich in antioxidants when compared to conventional solvents.

Screening of Greenness Metric Evaluation

The AGREEprep metric was employed to assess the performance of the conventional solvent method utilizing methanol with the green alternative involving ChCl: TriEG. The scores for AGREEprep were evaluated by taking into account ten criteria, including sample preparation, risky substances, reusability, waste, quantity of sample, automated process, energy consumption, post-sample preparation, and safety. In the assessment of greenness, the current methodology achieved an overall AGREE-prep score of 0.79, signfying successful environmental performance as illustrated in Figure 3.

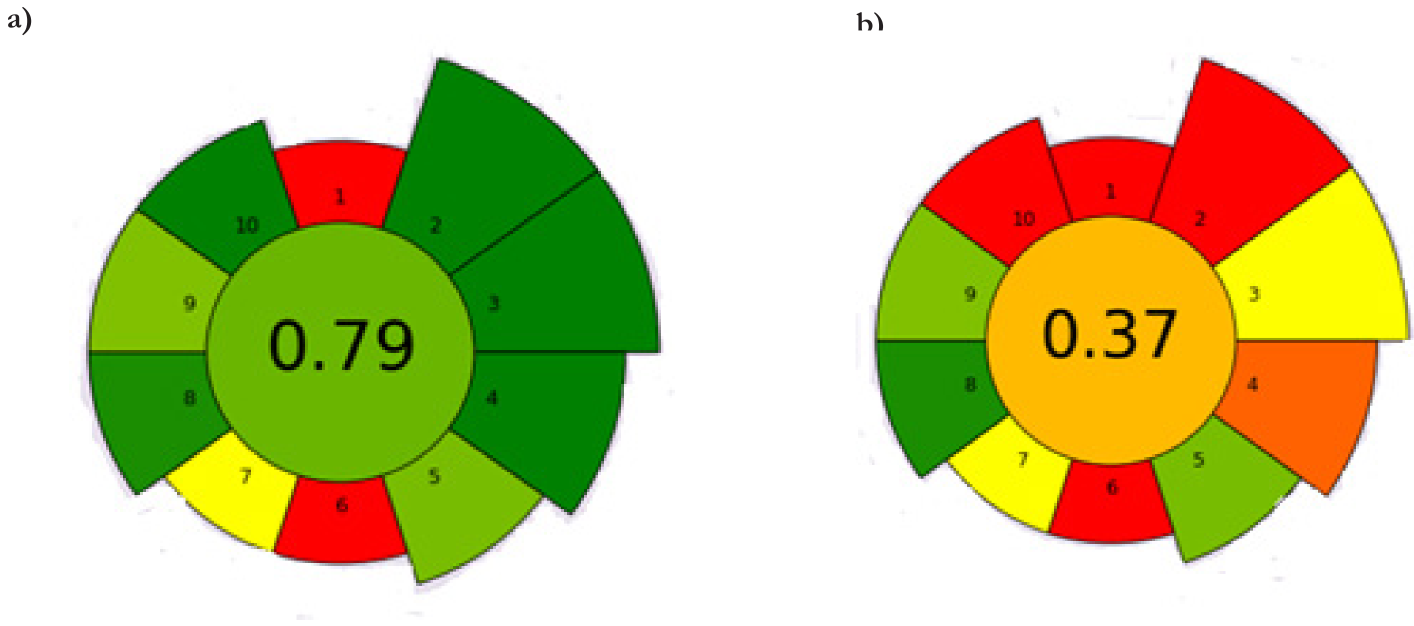

Figure 3. Schematic representation of greenness assessment based on the AGREEprep software for the a) DES based solvent b) conventional solvent

The current method provides an environmentally conscious alternative compared to the traditional method, with scores of 0.79 against 0.37. The technique shown exceptional performance in criteria 2, 3, and 4, which assess risky substances, sustainability, and waste generation, respectively. Furthermore, for criterion 10, which pertains to guaranteeing process safety, the current strategy achieved the best score (1). This advantage stems from ChCl:TriEG's biodegradable, nonflammable, and nonvolatile characteristics when compared to methanol. On the other hand, the both technique received the lowest ratings (0) for criteria 1 and criteria 6. Criteria 1's lowest score was ascribed to the method's lack of in situ sample preparation. This is also the reason for Criteria 7's lower score of 0.5, which is because only one sample may be used in the solvent extraction process with the use of a hotplate magnetic stirrer (Model US152; Staffordshire, UK). Similarly, three metrics-AGREE, AGREEprep, and ChlorTOX-were used to evaluate the suggested approach in order to isolate phenolic components from lettuce samples (Mammana et al., 2024). They obtained 0.72 with use of natural DES. In a comparable recent study, the proposed method's environmental approach was evaluated using the AGREE-prep instrument and received a 0.5 score with DESs (Pour et al., 2025).

CONCLUSION

This work successfully recovered extracts from *Myrtus communis* L. leaves, wealthy in bioactive compounds, employing distinct ChCl-based DESs. Conventional solvents such as methanol, ethanol, and ethyl acetate were utilized for comparison. The extracts were asssessed through analyses of total TPC and RSA. Methanol yielded the highest TPC at 395.60±0.50 mg GAE/g dry weight followed by ChCl:TriEG, which exhibited a TPC of 374.83±1.70 mg GAE/g dry weight whereas the greatest antioxidant activity was recorded with ChCl:OX (41.08±0.07 %). It is noteworthy that the use of DESs yielded significantly higher TPC values compared to similar studies conducted with conventional solvents as well as ultrasound- and microwave-assisted extraction systems (Dahmoune et al., 2015; Yaghoobi et al., 2022). The sustainability of the extraction processes was evaluated using the AGREEprep greenness evaluation. The DES-based methodology exhibited a superior score of 0.79 in contrast to the methanol-based conventional methodology, which scored 0.37, highlighting the sustainability benefits of DESs. This research presents green, affordable, and environmentally benign approaches for extracting high-value bioactive chemicals from *Myrtus communis* L. leaves, thereby proposing a viable technique for the valorization of food by-products within a green chemistry framework.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

AUTHOR CONTRIBUTIONS

Medeni Maskan: Conceptualization, Supervision, Validation and Writing- review & editing. Ezgi Kalkan: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing- review & editing, Software, Validation, Visualization and Roles/Writing- original draft, Writing- review & editing.

REFERENCES

Al-Snafi, A. E., Teibo, J. O., Shaheen, H. M., Akinfe, O. A., Teibo, T. K. A., Emieseimokumo, N., &, Alexiou, A. (2024). The therapeutic value of *Myrtus communis* L.: an updated review. *Naunyn-Schmiedeberg's Archives of Pharmacology*, *397*(7), 4579–4600.

Alipour, G., Dashti, S., Hosseinzadeh, H. (2014). Review of pharmacological effects of *Myrtus communis* L. and its active constituents. *Phytotherapy Research*, *28*(8), 1125–1136.

Berendika, M., Domjanić Drozdek, S., Odeh, D., Oršolić, N., Dragičević, P., Sokolović, M., & Jurčević, I. L. (2022). Beneficial effects of laurel (Laurus nobilis L.) and myrtle (*Myrtus communis* L.) extract on rat health. *Molecules*, *27*(2), 581.

Chen, Z., Wu, K., Zhu, W., Wang, Y., Su, C., & Yi, F. (2022). Chemical compositions and bioactivities of essential oil from perilla leaf (Perillae Folium) obtained by ultrasonic-assisted hydro-distillation with natural deep eutectic solvents. *Food Chemistry*, *375*, 131834.

da Silva, D. T., Smaniotto, F. A., Costa, I. F., Baranzelli, J., Muller, A., Somacal, S., & Barcia, M. T. (2021). Natural deep eutectic solvent (NADES): A strategy to improve the bioavailability of blueberry phenolic compounds in a ready-to-use extract. *Food Chemistry*, *364*, 130370.

Dahmoune, F., Nayak, B., Moussi, K., Remini, H., Madani, K. (2015). Optimization of microwave-assisted extraction of polyphenols from *Myrtus communis* L. leaves. *Food Chemistry*, *166*, 585–595.

de Almeida Pontes, P. V., Shiwaku, I. A., Maximo, G. J., Batista, E. A. C. (2021). Choline chloride-based deep eutectic solvents as potential solvent for extraction of phenolic compounds from olive leaves: Extraction optimization and solvent characterization. *Food Chemistry*, *352*, 129346.

Farkas, O., Jakus, J., Héberger, K. (2004). Quantitative structure–antioxidant activity relationships of flavonoid compounds. *Molecules*, *9*(12), 1079–1088.

Gómez-Urios, C., Vinas-Ospino, A., Puchades-Colera, P., Blesa, J., López-Malo, D., Frígola, A., & Esteve, M. J. (2023). Choline chloride-based natural deep eutectic solvents for the extraction and stability of phenolic compounds, ascorbic acid, and antioxidant capacity from Citrus sinensis peel. *LWT*, *177*, 114595.

Jurić, T., Uka, D., Holló, B. B., Jović, B., Kordić, B., Popović, B. M. (2021). Comprehensive physicochemical evaluation of choline chloride-based natural deep eutectic solvents. *Journal of Molecular Liquids*, *343*, 116968.

Kalkan, E., Maskan, M. (2025). A Green Approach: Optimization of Ultrasound and Homogenization-Assisted Ethyl Acetate Extraction of Cottonseed Oil Using Natural Deep Eutectic Solvent as a Novel Co-solvent. *Food and Bioprocess Technology*. https://doi.org/10.1007/s11947-025-03801-0

Kalkan, M. F., Artan, M., Yilmaz, N. F., & Yavuz, A. (2024). Mn-Ni-based coating on flexible graphite fiber with high length capacitance for flexible supercapacitor applications. *Journal of Energy Storage*, *84*, 110778.

Kaur, K., Schmitt-Kopplin, P., Malik, A. K. (2024). Green and efficient extraction of phenolic compounds from Neem leaves using deep eutectic solvents based ultrasonic-assisted extraction. *Food Chemistry*, *451*, 139500.

Koraqi, H., Aydar, A. Y., Khalid, W., Ercisli, S., Rustagi, S., Ramniwas, S., & Pandiselvam, R. (2024). Ultrasound-assisted extraction with natural deep eutectic solvent for phenolic compounds recovery from Rosa damascene Mill.: Experimental design optimization using central composite design. *Microchemical Journal*, *196*, 109585.

Le, N. T., Chau, N. H. T., Nguyen, P. Q. D., Tran, L. T. T., Phung, H. T., Nguyen, H. T. (2024). Green extraction of berberine from Coscinium fenestratum (Gaertn.) Colebr. using ultrasound-assisted aqueous solutions of organic acids, polyalcohols, and deep eutectic solvents. *Separation and Purification Technology*, *330*, 125541.

Li, Q.-F., Huang, L.-C., Chu, R., Li, J., Jiang, M.-Y., Zhang, C.-Q., & Liu, Q.-Q. (2018). Down-regulation of SSSII-2 gene expression results in novel low-amylose rice with soft, transparent grains. *Journal of Agricultural and Food Chemistry*, *66*(37), 9750–9760.

Ling, J. K. U., Hadinoto, K. (2022). Deep eutectic solvent as green solvent in extraction of biological macromolecules: A review. *International Journal of Molecular Sciences*, *23*(6), 3381.

Mammana, S. B., Canizo, B. V, Elia-Dazat, R., Gomez, F. J. V, Silva, M. F. (2024). Solid Eutectic Systems and Natural Deep Eutectic Solvents in Matrix Solid-Phase Dispersion for the extraction of phenolic compounds from lettuce samples. *Journal of Food Composition and Analysis*, *135*, 106661.

Pal, C. B. T., Jadeja, G. C. (2019). Deep eutectic solvent-based extraction of polyphenolic antioxidants from onion (*Allium cepa* L.) peel. *Journal of the Science of Food and Agriculture*, *99*(4), 1969–1979.

Pena-Pereira, F., Wojnowski, W., Tobiszewski, M. (2020). AGREE—Analytical GREEnness metric approach and software. *Analytical Chemistry*, *92*(14), 10076–10082.

Pour, P. H., Daryanavard, S. M., Memar, M., Naccarato, A. (2025). Development of ultrasound-assisted dispersive liquid–liquid microextraction based on solidification of floating organic droplets and deep eutectic solvents for multi-class pesticide analysis in agricultural waters. *Microchemical Journal*, *212*, 113404.

Shi, L., Zhao, W., Yang, Z., Subbiah, V., Suleria, H. A. R. (2022). Extraction and characterization of phenolic compounds and their potential antioxidant activities. *Environmental Science and Pollution Research*, *29*(54), 81112–81129.

Snoussi, A., Essaidi, I., Ben Haj Koubaier, H., Zrelli, H., Alsafari, I., Živoslav, T., & Ćirković Veličković, T. (2021). Drying methodology effect on the phenolic content, antioxidant activity of *Myrtus communis* L. leaves ethanol extracts and soybean oil oxidative stability. *BMC Chemistry*, *15*(1), 31.

Tumen, I., Senol, F. S., Orhan, I. E. (2012). Inhibitory potential of the leaves and berries of *Myrtus communis* L.(myrtle) against enzymes linked to neurodegenerative diseases and their antioxidant actions. *International Journal of Food Sciences and Nutrition*, *63*(4), 387–392.

Wang, P., Tian, B., Ge, Z., Feng, J., Wang, J., Yang, K., & Cai, M. (2023). Ultrasound and deep eutectic solvent as green extraction technology for recovery of phenolic compounds from Dendrobium officinale leaves. *Process Biochemistry*, *128*, 1–11.

Wei, P., Zhang, Y., Wang, Y.-Y., Dong, J.-F., Liao, B.-N., & Su, H.-H. (2023). Efficient extraction, excellent activity, and microencapsulation of flavonoids from Moringa oleifera leaves extracted by deep eutectic solvent. *Biomass Conversion and Biorefinery*, *13*(16), 15095–15109.

Wojeicchowski, J. P., Marques, C., Igarashi-Mafra, L., Coutinho, J. A. P., Mafra, M. R. (2021). Extraction of phenolic compounds from rosemary using choline chloride–based deep eutectic solvents. *Separation and Purification Technology*, *258*, 117975.

Wu, L., Li, L., Chen, S., Wang, L., Lin, X. (2020). Deep eutectic solvent-based ultrasonic-assisted extraction of phenolic compounds from Moringa oleifera L. leaves: Optimization, comparison and antioxidant activity. *Separation and Purification Technology*, *247*, 117014.

Yaghoobi, M., Sanikhani, M., Samimi, Z., Kheiry, A. (2022). Selection of a suitable solvent for bioactive compounds extraction of myrtle (*Myrtus communis* L.) leaves using ultrasonic waves. *Journal of Food Processing and Preservation*, *46*(3), e16357.

Yarahmadi, R., Mumivand, H., Ehtesham Nia, A., Raji, M. R., Argento, S. (2024). Natural Diversity in Total Phenol, Flavonoids, Antioxidant Properties, and Essential Oil Composition of Iranian Populations of *Myrtus communis* L. *Plants*, *13*(24), 3458.

Zannou, O., Koca, I. (2022). Greener extraction of anthocyanins and antioxidant activity from blackberry (Rubus spp) using natural deep eutectic solvents. *Lwt*, *158*, 113184.

Cite this article as:
*Kalkan E, Maskan M. (2026) Application of deep eutectic solvents for extraction of bioactive compounds from Myrtus communis l. leaves: assessing total phenolics, antioxidant activity, and process sustainability.*GIDA (2026) 51 (2) 318-326 doi: 10.15237/ gida.GD25133

Nasıl Atıf Yapılır?:
Kalkan E, Maskan M. (2026) *Myrtus communis* L. yapraklarından biyoaktif bileşiklerin ekstraksiyonunda derin ötektik çözücülerin kullanımı: toplam fenolik içerik, antioksidan aktivite ve proses sürdürülebilirliğinin değerlendirilmesi. GIDA (2026) 51 (2) 318-326 doi: 10.15237/ gida.GD25133