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Traditional and Modern Methods for Extraction of Bioactive Compounds from *Amaranthus retroflexus L.* and *Chenopodium album L.*

Mihaela Lacatus[1], Iasminca Birta (Cugerean)[1], Patricia-Cristina Tarkanyi[1], Mariana-Atena Poiana[1,2], Despina-Maria Bordean[1,2]*

[1]*Doctoral School “Engineering of Vegetable and Animal Resources”, University of Life Sciences "King Mihai I" from Timisoara, Calea Aradului 119, Timisoara, Romania;*
[2]*Faculty of Food Engineering, University of Life Sciences “King Mihai I” from Timisoara, 300645, Timisoara, Romania;*
** Corresponding author: despina.bordean@gmail.com; despinabordean@usvt.ro.*

Abstract: *The extraction of bioactive compounds from Amaranthus retroflexus L. and Chenopodium album L. offers opportunities for their valorization as sources of functional ingredients. This review examines traditional and modern extraction techniques, focusing on the influence of solvents, temperature, extraction time, and plant characteristics. Literature findings indicate that maceration and Soxhlet extraction remain useful conventional approaches, while ultrasound-assisted extraction offers potential advantages in processing time and solvent consumption. Successive solvent extraction has been investigated for recovering phenolic compounds and flavonoids from Chenopodium album, whereas hydroalcoholic ultrasound-assisted extraction has been applied to Amaranthus retroflexus for phytochemical and antioxidant analyses. Overall, selecting appropriate extraction conditions is essential for improving the recovery of bioactive compounds and supporting future food and nutraceutical applications.*

• Introduction

The extraction of bioactive compounds from plant materials plays an important role in phytochemical research and the development of functional ingredients. Extraction efficiency depends on several factors, including solvent polarity, temperature, processing time, and plant characteristics. Both conventional and modern techniques are used to recover compounds of interest, each presenting specific advantages and limitations. *Amaranthus retroflexus* and *Chenopodium album*, commonly regarded as weeds, represent promising sources of bioactive compounds with potential food and nutraceutical applications. This review compares traditional and modern extraction techniques, highlighting the factors influencing their efficiency and their applicability to the phytochemical characterization and valorization of these underutilized plant species.

• Material and method

This review examined scientific publications on traditional and modern techniques for extracting bioactive compounds, with particular emphasis on *Amaranthus retroflexus* and *Chenopodium album*. The analysis focused on extraction methods, solvent selection, processing conditions, and targeted bioactive compounds. Relevant findings were summarized in a comparative table and schematic figures.

Table 1. *Extraction methods used to obtain bioactive compounds from Chenopodium album and Amaranthus retroflexus.*

Extraction technique	Category	Plant species	Plant material	Extraction solvent / medium	Identified bioactive compounds	Reference
Soxhlet extraction	Conventional	*Chenopodium album*	Aerial parts	Ethyl acetate, acetone, methanol; followed by maceration with 50% methanol	Quercetin, total flavonoids, tannins, saponins	Arora & Itankar, 2018
Soxhlet extraction	Conventional	*Chenopodium album*	Aerial parts	Acetone, ethyl acetate, methanol	Quercetin, flavonoids	Arora & Itankar, 2018
Cold maceration	Conventional	*Chenopodium album*	Leaves and fruits	Methanol	Protocatechuic acid, chlorogenic acid and other free phenolic acids	Laghari et al., 2011
Maceration	Conventional	*Chenopodium album* subsp. *album* var. *microphyllum*	Aerial parts and roots	n-Hexane, acetone, methanol	Protocatechuic acid, rutin, hesperidin, apigetrin, quercetin, astragalin, apigenin, luteolin	Köseoğlu Yılmaz et al., 2019
Maceration	Conventional	*Chenopodium album*	Plant extract	Ethyl acetate	Rutin, chlorogenic acid	Amodeo et al., 2019
Microwave-assisted extraction (MAE)	Modern / Emerging	*Chenopodium album*	Aerial parts	Petroleum ether, ethyl acetate, methanol, hydroalcoholic solvent, and water	Total phenolics, total flavonoids, total saponins, total alkaloids	Effect of conventional method and microwave assisted extraction on phytoconstituents of *C. album*, 2021
Pressurized solvent extraction (PSE)	Modern / Emerging	*Amaranthus retroflexus*	Roots, stems, leaves and flowers	Methanol 99.8%; 5.1 bar; 2 h	Rutin, *p*-coumaric acid, (+)-trans-taxifolin, hyperoside, luteolin-7-rutinoside, quercitrin, salicylic acid, quercetin	Selvi et al., 2025
Hydroalcoholic extraction	Conventional	*Amaranthus retroflexus*	Leaves / seeds	Methanol 70%	Protocatechuic acid, *p*-coumaric acid, ferulic acid, rutin	Sărăcin et al., 2023
Solvent extraction	Conventional	*Amaranthus retroflexus*	Leaves	Methanol	Gallic acid, vanillic acid, rosmarinic acid, oleuropein, rutin, quercetin, ascorbic acid, baicalin	Aytar et al., 2025
Methanolic extraction	Conventional	*Amaranthus retroflexus*	Roots, stems, leaves and flowers	Methanol	Rutin, hyperoside, luteolin-7-rutinoside, quercitrin, quercetin, *p*-coumaric acid, (+)-trans-taxifolin, salicylic acid	Selvi et al., 2025
Solvent extraction	Conventional	*Amaranthus retroflexus*	Leaves	Organic solvent; UHPLC-UV-MS analysis	Rutin, protocatechuic acid, chlorogenic acid, caffeic acid, *p*-coumaric acid, ferulic acid, quercetin	Sărăcin et al., 2023

• Results and discussions

The reviewed literature highlights the importance of extraction techniques and solvent selection in recovering bioactive compounds from *Amaranthus retroflexus*. and *Chenopodium album*. The main extraction approaches and their applicability to different groups of phytochemicals are illustrated in Figure 1.

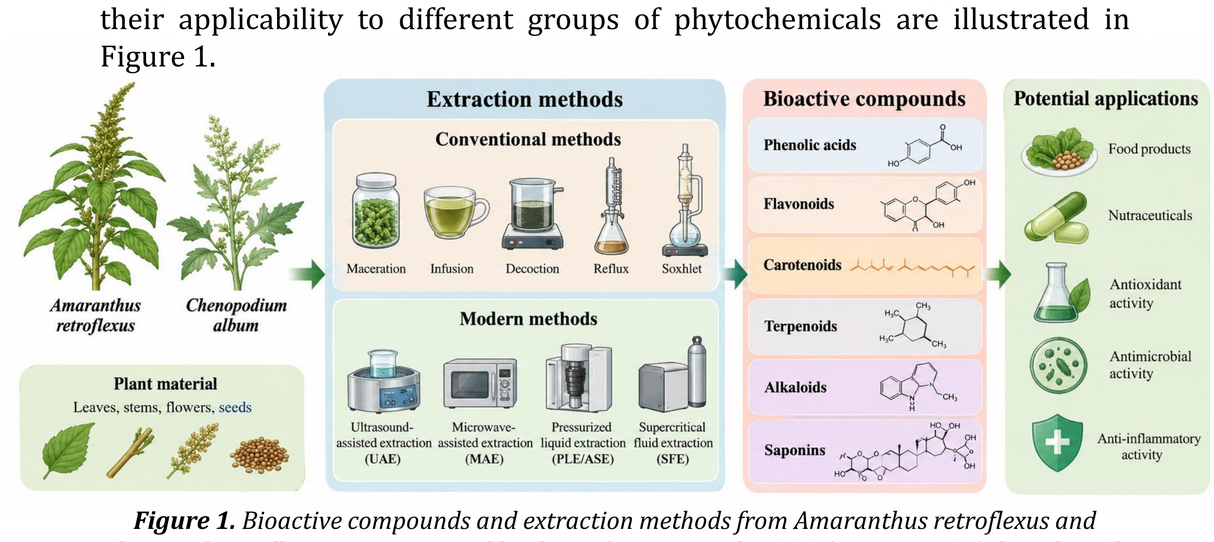


Figure 1. *Bioactive compounds and extraction methods from Amaranthus retroflexus and Chenopodium album. Image created by the authors using ChatGPT (OpenAI, 2026), based on El-Saadony et al. (2025).*

Conventional and Modern Extraction Techniques

Conventional methods, particularly maceration and Soxhlet extraction, remain widely used due to their simplicity and effectiveness. However, they may require longer processing times and higher solvent consumption. Modern techniques, including ultrasound-assisted extraction (UAE), microwave-assisted extraction (MAE), pressurized liquid extraction (PLE), and supercritical fluid extraction (SFE), offer alternatives that may improve extraction efficiency and reduce processing time. Studies on *C. album* have reported the recovery of phenolic acids and flavonoids through maceration and successive solvent extraction. For *A. retroflexus,* hydroalcoholic ultrasound-assisted extraction has been applied to investigate phenolic compounds and antioxidant activity. The extraction methods and identified compounds reported for both species are summarized in Table 1.

Influence of Extraction Conditions

Solvent polarity, temperature, extraction time, and plant characteristics significantly influence the composition and recovery of bioactive compounds. Hydroalcoholic mixtures are commonly used for phenolic compounds and flavonoids, while less polar solvents are more suitable for lipophilic compounds. Supercritical fluid extraction, particularly using CO_2, represents an alternative for recovering carotenoids, terpenoids, and other lipophilic constituents, as illustrated in Figure 2.

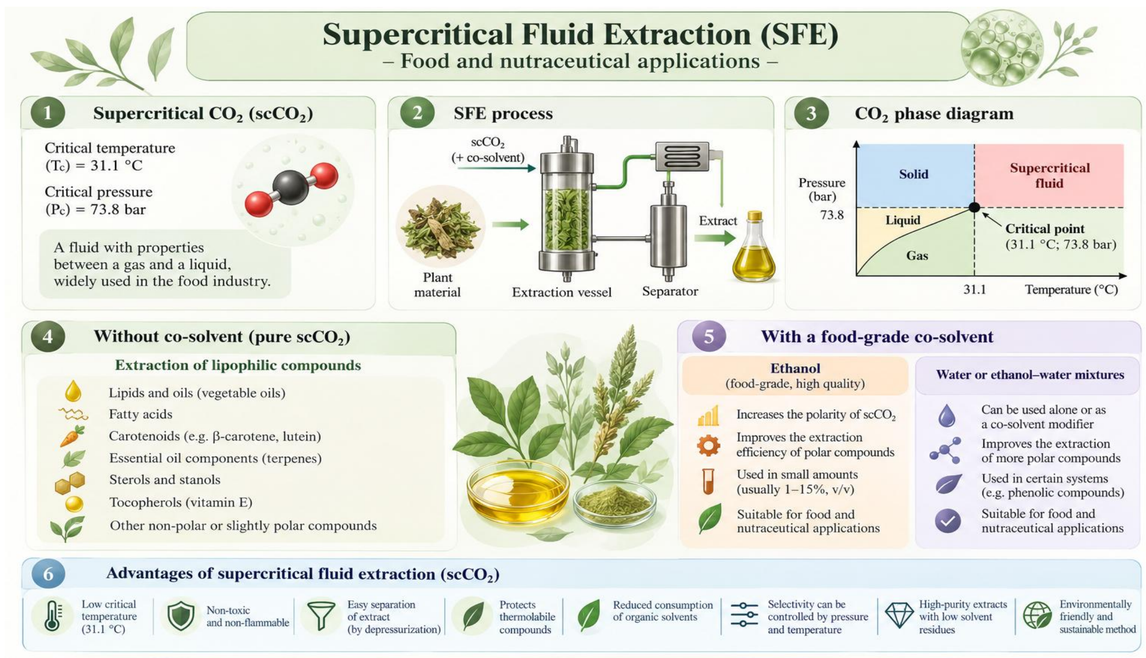


Figure 2. *Supercritical Fluid Extraction (SFE). Image created by the authors using ChatGPT (OpenAI, 2026).*

Extraction of Different Bioactive Compounds

Extraction requirements vary according to the chemical properties of the targeted compounds. Phenolic acids, flavonoids, tannins, and saponins are generally recovered using polar or hydroalcoholic solvents, whereas carotenoids and certain terpenoids require less polar extraction conditions. Alkaloid extraction may also involve pH adjustments to improve selectivity.

• Conclusions

Overall, the findings indicate that no single extraction technique is optimal for all bioactive compounds. Appropriate combinations of extraction methods, solvents, and processing conditions are essential for obtaining extracts suitable for further phytochemical investigation and potential functional applications.

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