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Journal of Agroalimentary Processes and Technologies 2026, 32 (2), pp.275-281

Journal of Agroalimentary Processes and Technologies

Bioactive Compounds in Edible Parts of *Chenopodium Album L.*: Implications for Human Nutrition

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Received 4 May 2026; Revised 1 June 2026, Published 15 June 2026

Abstract

The increasing interest in plant-based diets has brought new attention to underutilized wild edible species, including Chenopodium album L. The aim of this study was to evaluate the variability of bioactive compounds, with a focus on total polyphenol content (TPC) and total antioxidant activity (TAC), and to assess their potential contribution to human nutrition based on existing literature data.

The findings indicate a clear variation of bioactive compounds depending on the analyzed part. Leaves consistently showed the highest levels of total polyphenol content and antioxidant activity, stems generally exhibited lower values, while seeds presented moderate levels. Reported total polyphenol content in leaves ranged widely but was consistently higher than in other tissues, and antioxidant activity followed a similar trend.

In conclusion, Chenopodium album represents a valuable source of natural antioxidants. These findings support the integration of such species into modern diets, especially in the context of functional foods and sustainable nutrition.

Keywords: *antioxidants, polyphenols, dietary intake, edible plants*

1. Introduction

The global interest in plant-based diets has intensified the search for new alternative food sources that are both nutritionally rich and sustainable [1,2]. In light of this, consumers have turned their attention to plant-based foods that may provide bioactive compounds, particularly polyphenolic compounds and antioxidants [3]. These compounds are increasing interest because to their role in human health and one of big importance is the role of reducing the risk of certain chronic diseases that are associated with oxidative stress [4]. All of these changes in modern diets are occurring because eating patterns are evolving rapidly and there is a clear need for diversification into plant-based foods [5].

An important yet underutilized source of food is

Citation: M. Lăcătuș, P. Tarkanyi, M.A. Poiană, R. Popescu, L. Rădulescu, D.M. Bordean, Bioactive Compounds in Edible Parts of Chenopodium Album L.: Implications for Human Nutrition, *Journal of Agroalimentary Processes and Technologies* 2026, 32 (2), 275-281
DOI:10.59463/JAPT2026.2.16

represented by the wild edible plants. These species adapt very well to different environmental conditions and are traditionally consumed in many regions of the world providing essential nutrients and bioactive compounds [6]. The reintegration of these plants from the spontaneous flora into modern diets aligns with current trends in sustainable nutrition and the development of new functional products [7-9].

Among these species, *Chenopodium album L*., commonly called lamb's quarters, is an annual plant widespread in Europe, Asia, and North America [10]. Although it is often considered a weed, this plant has a large history of using its leaves, stems, and seeds in traditional diets. Even though the consumed plant parts have reported significant amounts of nutrients and bioactive compounds, the full potential remains insufficiently characterized and underutilized [10].

Bioactive compounds, especially polyphenolic and antioxidants compounds, play an important role in the human body [11,12]. The total polyphenol content (TPC) reduces oxidative stress involved in the aging process and chronic diseases, and on the other hand, the total antioxidant capacity (TAC) neutralizes free radicals produced in metabolism and intervenes in the deterioration of proteins, membrane lipids, etc. [13,14].

Studies conducted on extracts from *Chenopodium album* L. leaves have demonstrated considerable antioxidant potential and an increased content of polyphenols compared to other parts of the plant [3,15,16]. Additionally, antioxidant activity and polyphenol content can vary quite significantly depending on which part of the plant is analyzed [17]. Despite the increasing number of studies investigating the nutritional properties of *Chenopodium album*, most research has focused predominantly on specific plant parts, especially the leaves [3,15,16].

Studies on comparative analyses between several edible parts of the plant, such as stems and seeds, remain quite limited. Also, variations in the content of bioactive compounds influenced by environmental conditions, plant maturity and processing methods are not regularly summarized in the existing literature. The fact that this integrated analysis is missing limits a comprehensive knowledge of the overall nutritional value of the plant.

Consequently, the aim of this study was to evaluate the different bioactive compounds, with particular emphasis on the total polyphenol content and total antioxidant activity in the edible parts of *Chenopodium album*. In addition, this study aims to evaluate the potential contribution of these plant parts to human nutrition, based on a comprehensive analysis of data reported in the scientific literature.

2. Materials and method

This study was conducted through a structured synthesis of data obtained from peer-reviewed scientific literature with the focus on the polyphenol and antioxidant content of *Chenopodium album* edible parts. All the studies reporting quantitative data were identified and extracted.

Due to the fact that the table values are obtained using different analytical methods and expressed in different measurement units, they cannot be directly compared and we used Integrated Bioactive Index (IBI), an indicator that combines antioxidant capacity and polyphenol content [18].

All experimental values were normalized to a common scale ranging from 0 to 1 to allow comparative assessment of bioactive potential in different parts of the plant. This transformation was applied separately to the antioxidant activity parameters and polyphenol content data, where 0 corresponds to the lowest observed value and 1 to the highest value in the data set. The resulting IBI values range between 0 and 1, reflecting the overall bioactive potential, with lower values indicating reduced activity and higher values indicating an increased contribution of antioxidants and phenolic compounds.

The heatmap was generated with the assistance of ChatGPT (version GPT-5.3, developed by OpenAI, San Francisco, CA, USA) [19]. Graphical representation was performed using GraphPad Prism (version 10; GraphPad Software, San Diego, CA, USA).All the data are presented in table and the statistical interpretation in two representative graphs.

3. Results and Discussion

Extracted data were compiled into a comparative dataset presented in Table 1. The Integrated Bioactive Index (IBI) allows the simultaneous assessment of antioxidant capacity and total polyphenolic content by integrating diverse analytical measurements into a unified metric, thereby overcoming unit-related limitations and enabling an efficient comparative screening of plant organs to identify those with the highest potential for functional food and nutraceutical applications [18].

Table 1. Antioxidant Capacity (CAT) and Total Polyphenol Content (TPC) in different edible parts of *Chenopodium album*

CAT			TPC		
Plant parts	**Value**	**Method**	**Plant parts**	**Value**	**Method**
STEM	156.00	mmol Fe(II) equivalent/100 g, DW, FRAP [20]	STEM	87.00	mg gallic acid (GAE)/100 g, DM, Folin-Ciocalteu [20]
STEM	53.00	mg TE/100, DW, DPPH [20]			
LEAVES	263.96	µmol Fe(II)/g, acetone extract, DW, FRAP [21]	LEAVES	13.10	mg tannin acid/g, acetone extract, DW, Folin-Ciocalteu [21]
LEAVES	57.47	µmol Fe(II)/g, methanol extract, DW, FRAP [21]	LEAVES	8.60	mg tannin acid/g, methanol extract, DW, Folin-Ciocalteu [21]
LEAVES	23.67	µmol Fe(II)/g, aqueous extract, DW, FRAP [21]	LEAVES	7.50	mg tannin acid/g, aqueous extract, DW Folin-Ciocalteu [21]
LEAVES	72.25	mg/L, methanol extract, FW, DPPH [16]	LEAVES	2523.00	mg/100g GA Eq., methanol extract, FW, Folin-Ciocalteu [16]
LEAVES	83.83	mg/L, methanol extract, FW, DPPH [16]	LEAVES	3066.00	mg/100g GA Eq., methanol extract, FW, Folin-Ciocalteu, [16]
LEAVES	84.89	mg/L, methanol extract, FW, DPPH [16]	LEAVES	3160.00	mg/100g GA Eq., methanol extract, FW, Folin-Ciocalteu, [16]
LEAVES	86.42	g/ml, methanol extract, FW, DPPH, [22]	LEAVES	2.70	µg GAE/mg, ether extract, DW, Folin-Ciocalteu [23]
LEAVES	34.00	IC50, mg/ml, ether extract, DW, ABTS, [23]	LEAVES	18.90	µg GAE/mg, dichloromethane extract, DW, Folin-Ciocalteu [23]
LEAVES	11.00	IC50, mg/ml, methanol extract, DW, ABTS [23]	LEAVES	57.00	µg GAE/mg, ethyl acetate extract, DW, Folin-Ciocalteu [23]
LEAVES	2.90	IC50, mg/ml, aqueous extract, DW, ABTS [23]	LEAVES	12.24	µg GAE/mg, methanol extract, DW, Folin-Ciocalteu [23]
LEAVES	26.33	µg BHTE/mg, eter extract, DW, FRAP [23]	LEAVES	19.96	µg GAE/mg, aqueous extract, DW, Folin-Ciocalteu [23]
LEAVES	70.16	µg BHTE/mg, ethyl acetate extract, DW, FRAP [23]	LEAVES	65.41	GAE, µg/mL, methanol extract, DW [24]
LEAVES	146,66	µg BHTE/mg, etil extract, DW FRAP [23]	LEAVES	15.65	GAE, µg/mL, aqueous extract, DW [24]
LEAVES	54.16	µg BHTE/mg, methanol extract, DW, FRAP [23]	LEAVES	30.55	GAE, µg/mL, acetonitrile extract, DW [24]
LEAVES	23.16	µg BHTE/mg, aqueous extract, DW, FRAP [23]	LEAVES	287.00	mg gallic acid (GAE)/100 g DM, Folin-Ciocalteu [20]
LEAVES	74.70	SC50, µg/mL, methanol extract, DW, ABTS [24]	LEAVES	134.12	mgGAE/gPE, methanol extract, DW, Folin-Ciocalteu [14]
LEAVES	103.60	SC50, µg/Ml, aqueous extract, DW, ABTS [24]	LEAVES	118.76	mgGAE/gPE, ethyl acetate extract, DW, Folin-Ciocalteu [14]
LEAVES	76.30	SC50, µg/mL, acetonitrile extract, DW, ABTS [24]	LEAVES	87,06	mgGAE/gPE, chloroform extract, DW, Folin-Ciocalteu [14]
LEAVES	191.10	SC50, µg/mL, methanol extract, DW, DPPH [24]	LEAVES	43.55	mgGAE/gPE, hexane extract, DW, Folin-Ciocalteu [14]
LEAVES	664.40	SC50, µg/mL aqueous extract, DW, DPPH [24]	LEAVES	55.42	mgGAE/gPE, aqueous extract, DW, Folin-Ciocalteu [14]
LEAVES	499.30	SC50, µg/mL, acetonitrile extract, DW, DPPH [24]			
LEAVES	113.54	µM, TEAC, methanol extract, DW, FRAP [24]			
LEAVES	23.75	µM, TEAC, aqueous extract, DW, FRAP [24]			
LEAVES	68.33	µM, TEAC, acetonitrile extract, DW, FRAP [24]			
LEAVES	310.00	mmol Fe(II), equivalent/100			

		g DM, FRAP [20]			
LEAVES	65.00	mg TE/100 g, DW, DPPH [20]			
FLOWERS WITH SEEDS	372.00	mmol Fe(II) equivalent/100 g DM, FRAP [20]	FLOWERS WITH SEEDS	320.00	mg gallic acid (GAE)/100 g, DW, Folin-Ciocalteu [20]
FLOWERS WITH SEEDS	85.00	mg TE/100 g, DW, DPPH [20]			
SEEDS	68.34	mg/L, methanol extract, FW, DPPH [16]	SEEDS	1078.00	mg/100g GA Eq., methanol extract, FW, Folin-Ciocalteu [16]
SEEDS	80.55	mg/L, methanol extract, FW, DPPH [16]	SEEDS	1385.00	mg/100g GA Eq., methanol extract, FW [16]
SEEDS	81.90	mg/L, methanol extract, FW, DPPH [16]	SEEDS	1649.00	mg/100g GA Eq., methanol extract, FW, Folin-Ciocalteu [16]
WHOLE PLANT	20.60	mg AAE/g, aqueous extract, DW, FRAP [15]	WHOLE PLANT	19.80	mg TAE/g, aqueous extract, DW, Folin-Ciocalteu [15]
WHOLE PLANT	37.50	mg AAE/g, ethanol extract, DW, FRAP [15]	WHOLE PLANT	23.80	TAE/g, ethanolic extract, DW, Folin-Ciocalteu [15]
WHOLE PLANT	18.50	mg AAE/g, methanol extract, DW, FRAP [15]	WHOLE PLANT	14.90	mg TAE/g, methanol extract, DW, Folin-Ciocalteu [15]
WHOLE PLANT	17.10	mg AAE/g, acetone extract, DW, FRAP [15]	WHOLE PLANT	17.50	mg TAE/g, acetone extract, DW, Folin-Ciocalteu [15]
WHOLE PLANT	79.60	% aqueous extract, DW, DPPH [15]			
WHOLE PLANT	96.70	% ethanol extract, DW, DPPH [15]			
WHOLE PLANT	91.50	% methanol extract, DW, DPPH [15]			
WHOLE PLANT	74.30	% acetone extract, DW, DPPH [15]			
WHOLE PLANT	86.27	IC50 µg mL, aqueous extract, ABTS [25]			
WHOLE PLANT	75.49	IC50 µg mL, ethanol extract, DW, ABTS [15]			
WHOLE PLANT	55.42	IC50, µg mL, methanol extract, DW, ABTS [25]			
WHOLE PLANT	59.62	IC50, µg mL, aqueous extract, DW, ABTS [25]			
WHOLE PLANT	63.28	IC50, µg mL, ethanol extract, DW, ABTS [25]			
WHOLE PLANT	36.91	IC50, µg mL, methanol extract, DW, ABTS [25]			

Figure 1 compares the values between the FRAP (Ferric Reducing Antioxidant Power) and TPC (Total polyphenols content) methods, depending on the extract (aqueous, ethanol, methanol and acetone) for the whole plant. It can be clearly seen that the type of solvent significantly influences the extract, both for phenolic compounds and antioxidant activity. From the ethanol extracts, the highest value for FRAP is 37.5 mg/g DW, and for TPC it is 23.8 mg/g DW, resulting in ethanol being the most efficient in extracting both large amounts of polyphenols and compounds with high antioxidant activity. The values of the aqueous extracts are relatively high, between 20 and 21 mg/g DW, water being a good solvent but less efficient than ethanol. For methanol extracts, the efficiency is average, the value for FRAP is moderate 18.5 mg/g DW, and lower for TPC 14.9 mg/g DW. Methanol extracts less polyphenols which is also reflected in the antioxidant activity. In acetone, the FRAP values are the lowest 17.1 mg/g DW, but slightly higher in TPC with 17.5 mg/g DW. These values suggest that not all extracted polyphenols have the same antioxidant activity.

The heatmap (Figure 2) illustrates the normalized antioxidant capacity (CAT score), total phenolic content (TPC score), and the resulting Integrated Bioactive Index (IBI) for stem, leaves, flowers with

seeds, seeds, and whole plant samples. All values were normalized on a 0-1 scale to allow evaluation between heterogeneous analytical methods (FRAP, DPPH, ABTS, TEAC, Folin-Ciocalteu).

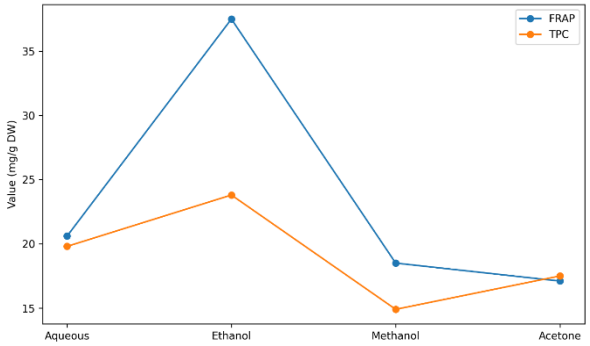

Figure 1. Solvent Extract Comparison Legend: FRAP-Antioxidant capacity; TPC-Total polyphenol content

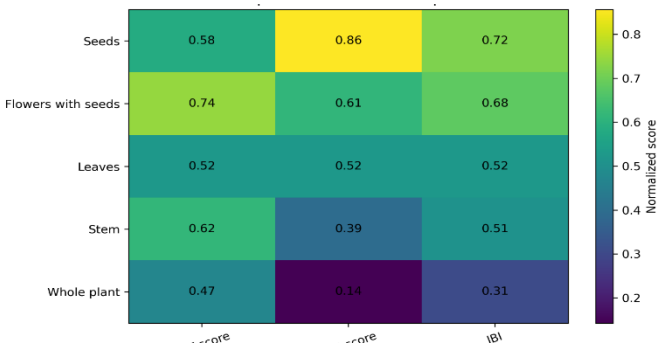

Figure 2. Heatmap of modelled bioactive potential and Integrated Bioactive Index (IBI) across different plant parts. Created with the assistance of ChatGPT (OpenAI, 2026) [19].

Seeds show the Highest IBI (0.719), which means that seeds show very high phenolic content and high antioxidant activity, presenting the highest functional potential, proving that the seeds are the best candidate recommended for: functional foods, nutraceuticals, antioxidant-rich ingredients and /or phytochemical valorization.

The flowers with seed have a high IBI value (0.679), both for CAT and TPC, representing a high bioactive profile, with the highest antioxidant activity, which makes them extremely relevant from a functional point of view. Moderate values, almost equal, can be observed in the leaves (IBI=0.523), which indicates a stable and balanced profile. With approximately the same moderate values, the stem (IBI=0.505) suggests the contribution of other non-phenolic compounds to the antioxidant activity. The lowest value for CAT and TPC is reflected in the whole plant with IBI=0.306, resulting in a lower bioactive potential.

4. Conclusion

The present work, by providing a comparative perspective, supports the valorization of this species as a functional food and underlines its importance in the context of sustainable nutrition.

From a nutritional point of view, bioactive compounds, especially polyphenols, play an important role in reducing oxidative stress, preventing metabolic diseases and supporting general human health. In addition, the use of underutilized species such as *Chenopodium album* aligns with sustainability principles because these plants grow spontaneously, require minimal agricultural resources, diversify the human diet, contribute to the valorization of local resources and reduce pressure on conventional crops.

The results of this study highlight the need for further studies on the individual edible parts of the *Chenopodium album* plant, with an emphasis on the less studied parts (stem and root), as the current literature focuses mainly on the leaves.

Acknowledgments This study was funded by the University of Life Sciences "King Mihai I" from Timisoara" and the results will be included in the PhD Thesis of Mihaela Lăcătuș under the supervision of Prof Habil.Dr.Eng. Despina-Maria Bordean Project PhD Thesis, Doctoral Grant, Doctoral School Engineering of Vegetable and Animal Resources USVT, 202 4 202 8 Analysis of Bioactive Compounds from Plants and Their Application in the Development of Dietary Supplements". The authors would like to thank to the Doctoral School "Engineering of Vegetable and Animal Resources", University of Life Sciences "King Mihai I" from Timişoara Calea Aradului 119 300645 Timişoara Romania), for the academic support and resources provided throughout the development of this research.

Conflicts of interest / Competing interests: No conflict of interest.

Ethics approval: No ethic situation.

Availability of data and material: The data have been reviewed depending on the literature.

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