From Winery Waste to Bioactive Resources: Circular Economy Valorisation of Grape Pomace from Transylvanian Vineyards (Romania)

V.S.Chedea[1], R.M.Pop[2], I. S. Giurca[1], M. Comșa[1], L.-R. Enache[3], D.M. Popescu[1]
[1]Research Department, Research Station for Viticulture and Enology Blaj (SCDVV Blaj), Blaj, 515400, Romania
[2]Pharmacology, Toxicology and Clinical Pharmacology, Department of Morphofunctional Sciences, "Iuliu Haţieganu" University of Medicine and Pharmacy, Cluj-Napoca, 400012, Romania
[3]Research and Development Institute for Viticulture and Enology Valea-Călugărească (ICDVV Valea Călugărească), Valea Călugărească ,107620, Romania
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Presenting author email: chedeaveronica@yahoo.com, veronica.chedea@scdvvblaj.ro

Introduction. The wine industry generates substantial quantities of by-products, among which grape pomace (GP), consisting mainly of skins, seeds, and stems remaining after juice extraction, represents one of the most abundant residues Vosloban *et al* (2020). Traditionally considered waste, grape pomace has attracted increasing attention in recent years due to its high content of bioactive compounds, particularly polyphenols, fatty acids, and dietary fibers Chedea[1] *et al* (2025). These compounds exhibit important biological properties, including antioxidant Chedea *et al* (2012), anti-inflammatory Pop *et al* (2025), and cardioprotective activities Bocsan *et al* (2022), which makes grape pomace a promising raw material for the development of functional foods, nutraceuticals, and cosmetic products Karastergiou *et al* (2024). In the context of sustainable development, the valorisation of winery by-products has become a key component of the **circular economy**, aiming to reduce environmental impact while generating added value from agricultural residues. By transforming grape pomace into a source of valuable bioactive compounds, the wine industry can shift from a linear production model to a more sustainable system based on resource recovery and reuse.
The composition of grape pomace polyphenols varies depending on grape cultivar, geographical origin, climatic conditions, and processing techniques Chedea[1] *et al* (2025), Chedea[2] *et al* (2025). In this context, the present study investigates the **chemical composition, phenolic profile, antioxidant activity, and fatty acid content of grape pomace obtained from grape cultivars cultivated in Transylvanian vineyards (Romania)**, highlighting their potential as valuable resources within a circular economy framework Chedea[1] *et al* (2025).

Materials and Methods. GPs samples were collected from multiple grape cultivars grown in the Târnave vineyard region in Transylvania, Romania. The samples originated from both white- Blasius (BL), Rhine Riesling (RR), Roze Blaj (RB), Astra (AS), Traminer roz (TR), Johaniter (JO), Neuburger (NE), Rubin (RU), Sauvignon Blanc (SB), Fetească Regală (FR), Radames (RA), Brumăriu (BR), Selena (SE), and Muscat Ottonel (MO)- and red grape cultivars- Regent (RE), Syrah (SH), and Amurg (AM) Chedea[1] *et al* (2025). From these, Blasius (BL), Roze Blaj (RB), Astra (AS), Rubin (RU), Radames (RA), Brumăriu (BR), Selena (SE), and Amurg (AM) were created and homologated at SCDVV Blaj Chedea[1] *et al* (2025). After collection, the pomace samples were dried, ground, and subjected to extraction procedures to isolate phenolic compounds and lipids. Ethanolic extraction (mixture of water:ethanol, 30:70, v/v) was applied to obtain polyphenol-rich extracts. The total polyphenol content (TPC) was determined using spectrophotometric methods and expressed as gallic acid equivalents. Several antioxidant assays were employed to evaluate the radical-scavenging and reducing capacity of the extracts, including DPPH, ABTS, FRAP, CUPRAC, reducing power and transition metal ion (Ferrous Fe2+ and Cupric Cu2+) chelation tests. To identify and quantify individual phenolic compounds, high-performance liquid chromatography coupled with diode-array detection and electrospray ionization mass spectrometry (HPLC-DAD-ESI-MS) was used.The fatty acid composition of GPs lipids was determined using gas chromatography with flame ionization detection (GC-FID). Nutritional indices such as the atherogenicity index, thrombogenicity index, and the ratio between hypo- and hypercholesterolemic fatty acids were also calculated to assess the potential nutritional value of the lipid fraction. Additionally, Fourier transform infrared spectroscopy (FTIR) was employed to evaluate structural and compositional differences among the pomace samples Chedea[1] *et al* (2025).

Results and Discussion. The chemical characterization of grape pomace extracts revealed a rich composition of bioactive compounds, confirming that this winery by-product represents a valuable source of natural antioxidants. Thus, flavan-3-ols (catechin, epicatechin, epicatechin gallate, procyanidin B1, B2, B3) are major compounds in all GP extracts. In lower amounts, flavonols (such as quercetin, kaempferol, and myricetin glycosides were) are also found, and in red GPs were identified anthocyanins too Chedea[1] *et al* (2025). NE, RA, RE, and BR cultivars were the richest in catechin derivative, epicatechin, catechin, and epicatechingallate, while cultivars like MO, RR, BL, RB, and AS had lower concentrations of these flavanols Chedea[1] *et al* (2025).The NE cultivar showed the highest total flavanol content and demonstrated the strongest antioxidant activity across all applied assays, $DPPH^{\cdot}$, $ABTS^{\cdot+}$, FRAP, CUPRAC, and reducing power Chedea[1] *et al* (2025). The FR cultivar also displayed substantial antioxidant capacity Chedea[1] *et al* (2025). In contrast, cultivars such as SE and MO presented the lowest levels of phenolic compounds and correspondingly weaker antioxidant activity Chedea[1] *et al*

(2025). The fatty acid analysis indicated that the RB and AS cultivars had the most favorable nutritional profiles Chedea[1] *et al* (2025). These cultivars were characterized by higher ratios of unsaturated to saturated fatty acids (UFA/SFA) and hypocholesterolemic to hypercholesterolemic fatty acids (H/H), as well as lower values of the atherogenicity (AI) and thrombogenicity (TI) indices Chedea[1] *et al* (2025). Such lipid profiles are generally associated with potential cardiovascular health benefits Chedea[1] *et al* (2025). Additionally, RB and NE extracts exhibited strong metal-chelating activity toward Cu^{2+} and Fe^{2+} ions, which may further enhance their antioxidant effectiveness by reducing metal-catalyzed oxidative processes Chedea[1] *et al* (2025) (Figure 1).

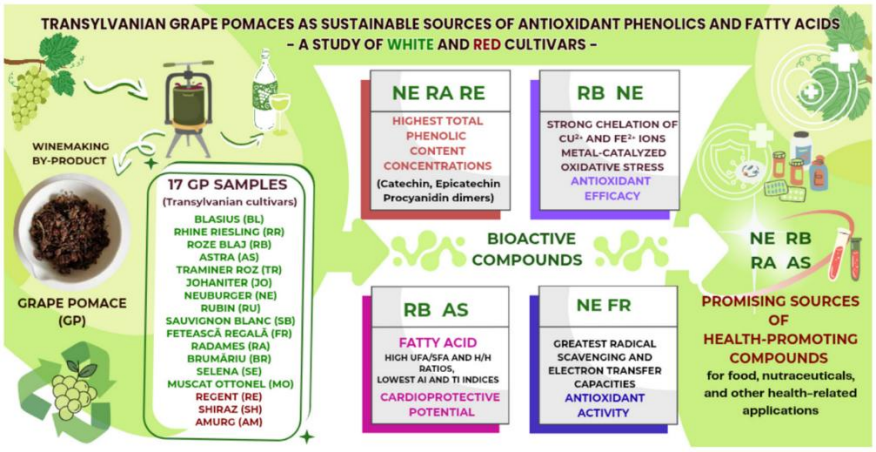

Figure 1. Circular Economy valorisation of grape pomace from Transylvanian vineyards through the sustainable separation, identification and use of their bioactive compounds with health actions Chedea[1] *et al* (2025).

Conclusions. The results demonstrate that GP, especially from NE, RB, RA, and AS cultivars, is a source of bioactive compounds with antioxidant and cardioprotective potential Chedea[1] *et al* (2025). Importantly, RB, RA, and AS are homologated at SCDVV Blaj, emphasizing their regional relevance and potential for local valorisation. Chedea[1] *et al* (2025). Overall, the study supports the sustainable exploitation of winemaking by-products as sources of high-value bioactive compounds Chedea[1] *et al* (2025). Therefore, these findings contribute to an increasing body of evidence supporting the sustainable valorization of winemaking by-products that can be utilized in food, nutraceuticals, and other applications to achieve improved human health Chedea[1] *et al* (2025). Thus, the GP valorisation contributes to sustainable waste management and supports the development of local circular economy strategies in the wine industry. By recovering valuable bioactive compounds from winery residues, it is possible to reduce environmental impact while creating new opportunities for the development of high-value products.

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References

1. Vosloban, C. M.; Tomoiaga, L. L.; Iliescu, M. L.; Pusca, G.; Chedea. V. S. Grape pomace yields from Transylvanian cultivated grapes. ISB-INMA TEH' 2020, Agricultural and mechanical engineering, Bucharest, Romania, 30 October 2020. Jubilee edition 2020, 114.
2. Chedea[1], V.S.; Tomoiagă, L.L; Ropota, M.; Marc, G.; Ranga, F.; Muntean, M.D.; Sîrbu, A.D.; Giurca, I.S.; Comșa, M.; Bocsan, I.C.; Buzoianu, A.D. Transylvanian Grape Pomaces as Sustainable Sources of Antioxidant Phenolics and Fatty Acids—A Study of White and Red Cultivars. Antioxidants. 2025, 14(10), 1152.
3. Chedea, V.S.; Choueiri, L.; Jisaka, M.; Kefalas, P. o-Quinone involvement in the prooxidant tendency of a mixture of quercetin and caffeic acid. Food chemistry 2012, 135(3), 1999.
4. Pop, R.M.; Boarescu, P.M.; Bocsan, C.I.; Gherman, M.L.; Chedea, V.S.; Jianu, E.M.; Roșian, Ș.H.; Boarescu, I.; Ranga, F.; Tomoiagă, L.L.; Sîrbu, A.D. Anti-inflammatory and antioxidant effects of white grape pomace polyphenols on isoproterenol-induced myocardial infarction. International Journal of Molecular Sciences. 2025, 26(5), 2035.
5. Bocsan, I.C.; Măgureanu, D.C.; Pop, R.M.; Levai, A.M.; Macovei, Ș.O.; Pătrașca, I.M.; Chedea, V.S.; Buzoianu, A.D. Antioxidant and anti-inflammatory actions of polyphenols from red and white grape pomace in ischemic heart diseases. Biomedicines. 2020, 10(10), 2337.
6. Karastergiou, A.; Gancel, A.L.; Jourdes, M.; Teissedre, P.L. Valorization of Grape Pomace: A Review of Phenolic Composition, Bioactivity, and Therapeutic Potential. Antioxidants. 2024, 13, 1131.
7. Chedea[2], V.S.; Tomoiagă, L.L.; Ropota, M.; Marc, G.; Ranga, F.; Comșa, M.; Muntean, M.D.; Sîrbu, A.D.; Giurca, I.S.; Răcoare, H.S.; Bocsan, C.I. Phenolic profile, fatty acid composition, and antioxidant activity of Italian riesling grape pomace from two Transylvanian microclimates. Plants 2025, 14(12), 1809.