INNOVATIVE EXTRACTION METHODS FOR BIOACTIVE COMPOUNDS FROM GRAPE POMACE

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Abstract

The main byproduct of winemaking is grape pomace, formed after pressing in white wine and fermentation in red wine. Grape pomace is rich in phenolic chemicals, which have pharmacological, technical, antioxidant, and antibacterial properties. This review seeks ecologically friendly grape pomace bioactive phenolic component extraction strategies. This review discusses green chemistry-based grape pomace extractive technologies like supercritical fluid extraction (SFE), microwave-assisted extraction (MAE), microwave hydro diffusion and gravity (MHG), ultrasound-assisted extraction (UAE), pulsed electric field (PEF), ohmic heating (OH), natural deep eutectic solvents (NADES), and enzyme-assisted extraction. The food sector benefits from these ecologically friendly, economically feasible, and creative technologies. These methods reduce extraction time, unit operations, energy consumption, environmental impacts, economic costs, solvent usage, and waste generation to ensure safe and high-quality functional foods extracts. Subsequently, research could be concentrated on optimizing conditions to reduce limitations and enhance yield while extracting new bioactive compounds.

Keywords: Grape pomace, waste, green extraction, enzyme assisted, phenolic compounds.

1. Introduction

Grapes are extensively farmed fruit crops globally, mostly utilized for direct consumption, wine, juice, raisins, and several other items. Grape pomace, the principal by-product of winemaking, is around 30% of the total material weight and mostly comprises skins, seeds, stalks, and pulp. The product is abundant in carbohydrates, organic acids, vitamins, minerals, and polyphenols, which may provide health advantages associated with pharmacological, technical, antioxidant, and antibacterial qualities. Grape pomace (GP) has historically been utilized for the production of different distillates, fertilizers, or animal feed [1]. The extensive production of wine exacerbates the challenge of disposing of grape pomace, and the processes of handling or incineration generate heat, significantly adding to global warming. Given the prevailing global focus on environmental conservation and the multitude of environmental regulations across nations, the recycling and repurposing of grape pomace are essential. Recent research indicates that grape pomace is a significant source of value-added bioactive compounds [2]. Researchers have developed extraction methods for these bioactive molecules, thereby enhancing waste recovery processes in accordance with green chemistry principles. Green Chemistry seeks to employ novel methods that minimize environmental impact. Consequently, expedited and more automated extraction techniques have been employed, such as supercritical fluid extraction (SFE), microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE), pulsed electric field (PEF), natural deep eutectic solvents (NADES), enzyme-assisted extraction, and microbial fermentation [3]. These novel procedures provide advantages over traditional techniques, since they necessitate reduced extraction durations and utilize less solvent. Consequently, green extraction, via the design of procedures that minimize energy consumption, enables the utilization of alternative, renewable solvents while ensuring the safety and quality of goods [2]. Thus, this review study aims to address the methods of green extraction phenolic compounds from grape pomace.

2. Innovative Green Extraction Methods of Phenolic Compounds from Grape Pomace

Green extraction relies on methods that minimize energy usage, facilitate the uses of alternative solvents, and provide safe and high-quality extraction. Green extraction methods should be 100% natural, nontoxic, biodegradable, suitable for installations and optimize yield of bioactive compounds [1]. Therefore, a concise overview of the green extraction process is stated below.

2.1 Supercritical Fluid Extraction (SFE)

SCF SFE exploits solvents' special characteristics at supercritical conditions. Supercritical fluids have strong solvating properties because their density is like liquids and their viscosity and diffusion coefficients are like gases when temperature and pressure exceed the critical point. SFE may be performed at comparatively lower temperatures, hence preserving thermally unstable molecules and maintaining the quality of the extracted substances. Supercritical carbon dioxide (SC-CO2) is the predominant supercritical fluid utilized in the food industry [2].

2.2 Microwave-Assisted Extraction (MAE)

Generally, microwaves are utilized in food processing and are classified as non-ionizing radiation, operating within a frequency range of 300 MHz to 300 GHz. MAE is a widely utilized technique within green extraction approach and significantly reduce the extraction time, decreased solvent usage, and enhanced extraction rate. Additionally, MAE technology increasing the extraction efficiency of grape-derived phenolics by up to 48% and overall anthocyanin yields up to 85% [3].

2.3 Microwave Hydro diffusion and Gravity (MHG)

The MHG approach is a solvent-free extraction process that integrates microwave heating with atmospheric pressure at gravitational forces. The MHG system has been structured for commercial and laboratory applications for extracting pigments, aroma, and antioxidants compounds from plant sources, and containing at least 60% initial moisture [1].

2.4 Ultrasound-Assisted Extraction (UAE)

The UAE is an innovative extraction technique, holds considerable potential for application in the food sector. Ultrasound waves, functioning at frequencies beyond the human auditory ranges 20 Hz to 20 kHz, can propagate and communicate as mechanical vibrations throughout a spectrum of about 20 kHz to 100 MHz in various mediums. The UAE breaks the cellular structures of plant materials, hence facilitating the release of bioactive compounds. The benefits of UAE encompass enhanced solvent penetration into porous materials in low time, increased product yield, and reducing the solvent and energy [2].

2.5 Pulsed Electric Field (PEF)

The PEF is regarded as an innovative non-thermal, ecological, and cost-effective method for inactivating microbes and enzymes, extracting bioactive compounds like anthocyanins, polyphenols, and pigments from plant sources and by-products, and enhancing mass transfer in food items. It is moreover utilized on plant materials as a preliminary treatment. The PEF therapy facilitates the enhancement of cell membrane permeabilization by electroporation. PEF can reduce the deterioration of heat-sensitive substances by employing a modest electric field from 500 to 1000 V/cm for 10^{-4} to 10^{-2} seconds [3].

2.6 Ohmic Heating (OH)

OH, is the thermal phenomenon wherein heat is produced internally due to the flow of alternating electrical current through a medium of food matrix, which acts as an electrical resistor. The ingredients of food integrate into the electrical circuit via alternating current flows, producing heat due to the inherent features of the electrical resistance of the matrix. Factors include electrical conductivity, field strength, particle size, concentration, ionic concentration, and electrodes using a power supply of 50 or 60 Hz [2].

2.7 Natural deep eutectic solvents (NADES)

NADES is a unique solvent extraction technique employs deep eutectic solvents (DES). DES is a chemical containing two or three components that establish intra-molecular hydrogen bonds, functioning as hydrogen bond acceptors (HBAs) like tetraalkyl ammonium, quaternary ammonium, or phosphine salts, and hydrogen bond donors (HBDs) such as sugars, alcohols, amino acids, and organic acids, often containing up to 50% (v/v) water. Metabolites generated by cellular metabolism and biodegradable compounds can interact to create deep eutectic solvents (DES), referred to as natural deep eutectic solvents (NADES), which have characteristics similar to DES [1].

2.8 Enzyme assisted extraction (EAE) method

The EAE is an environmentally friendly extraction process in contrast to conventional solvent extraction and does not utilize hazardous organic solvents. The utilization of enzymes enhances the extraction of polyphenols to optimize the release of bioactive compounds from the substrate. The extraction process entails the disruption of cell walls, therefore releasing components into the extraction fluid. Cell disintegration is facilitated by many enzymes, including tannases, pectinases, hemicellulases, and cellulases [4].

3. Main Phenolic Compounds in Grape Pomace

Phenolic compounds comprise a group of secondary plant metabolites with great structural diversity, having an aromatic ring, with one or more hydroxyl substituents associated with the ring structure and vary from a single phenol to highly polymerized compounds. Grape pomace includes polymeric polyphenols (proanthocyanidins) called tannins, whereas red grape peels contain monomeric flavonoids called anthocyanins [5]. Grapes include phenolic acids (hydroxybenzoic and hydroxycinnamic acids), flavonoids (catechins, flavonols, and anthocyanins), proanthocyanidins and contains 70% of phenolic compounds wine production. These compounds exhibit antioxidant, antiallergic, anti-inflammatory, antimicrobial, antithrombotic, anticarcinogenic, and cardioprotective properties. However, red grape pomace yields more phenolic chemicals than white and 73 bioactive compounds found in grape pomace, including 13 phenolic acids, 22 flavonols, 3 flavanols and proanthocyanidins, 3 stilbenes, and 16 anthocyanins in red grape pomace and 11 phenolic acids, 19 flavonols, and 14 flavanols and proanthocyanidins in white grape pomace. However, table 1 shows the phenolic compound from grape pomace [6].

Table 1. Phenolic compounds from grape pomace [7]

Type of phenolic compounds	Phenolic compounds from grape pomace
Cafeic acid	Sinapic acid, Ferulic acid
Hydroxycinnamic acids	p-coumaric acid, Caftaric acid, Gallic acid Fertaric acid, Coutaric acid
Hydroxybenzoic acid	Catechin Syringic acid, Protocatechuic acid
Flavanols	Quercetin, Quercetin 3-O-galactoside, Quercetin 3-O-rhamnoside, Epicatechin, Epicatechin gallate, Kaempferol 3-O-glucoside, Isorhamnentin 3-O-glucoside, Rutin
Stilbenes	trans-Polydatin
Procyanidins	Procyanidins B1, ProcyanidinsB2, delphinidin 3-O-glucoside, delphinidin 3-O-acetylglucoside, Cyanidin, Cyanidin 3-O-p-coumaroylglucoside delpinidin, Cyanidin 3-O-glucoside
Anthocyanins	Peonidin, Peonidin 3-O-acetylglucoside, Petunidin, Petunidin 3-O-acetylglucoside, Petunidin 3-O-glucoside

Conclusion

Innovative green extraction methods including SFE, MAE, MHG, UAE, PEF, OH/POH and enzyme assisted methods recover bioactive from plant matrices like grape pomace and reduce extraction time, energy, and solvent consumption. SFE and NADES are new solvent extraction procedures with minimal toxicity, environmental benefits, and simplicity. UAE and PEF disrupt cells strongly, accelerating mass transfer and restoring lipids quickly. MAE and MHG transport mass and heat to destroy cells and release primary and secondary metabolites. The biorefinery idea is demonstrated by MHG's solvent-free matrix recovery. Therefore, enzyme assisted extraction is more ecofriendly methods with more yield of phenolic compounds. Future research may be focus on optimization condition for extraction with microencapsulation.

References

1. Wang C., You Y., Huang W., & Zhan J. (2024). The high-value and sustainable utilization of grape pomace: A review. *Food Chemistry: X*, 101845. https://doi.org/10.1016/j.fochx.2024.101845
2. Moro K. I. B., Bender A. B. B., da Silva L. P., & Penna N. G. (2021). Green extraction methods and microencapsulation technologies of phenolic compounds from grape pomace: A review. *Food and Bioprocess Technology*, *14*, 1407-1431. https://doi.org/10.1007/s11947-021-02665-4
3. Wani T. A., Majid D., Dar B. N., Makroo H. A., & Allai F. M. (2023). Utilization of novel techniques in extraction of polyphenols from grape pomace and their therapeutic potential: A review. *Journal of Food Measurement and Characterization*, *17*(5), 5412-5425. https://doi.org/10.1007/s11694-023-02040-1
4. Batista D., Chiocchetti G D M E., & Macedo J. A. (2023). Effect of enzymatic biotransformation on the hypotensive potential of red grape pomace extract. *Foods*, *12*(22), 4109. https://doi.org/10.3390/foods12224109
5. Averilla JN., Oh J., Kim HJ., Kim JS., Kim JS (2019). Potential health benefits of phenolic compounds in grape processing by-products. Food science and biotechnology. 2019 Dec; 28(6): 1607-15. doi: 10.1007/s10068-019-00628-2
6. Zhao X., Zhang S. S., Zhang X. K., He F., & Duan, C. Q. (2020). An effective method for the semi-preparative isolation of high-purity anthocyanin monomers from grape pomace. *Food chemistry*, *310*, 125830. https://doi.org/10.1016/j.foodchem.2019.125830
7. Kammerer D, Claus A, Carle R, Schieber A. Polyphenol screening of pomace from red and white grape varieties (Vitis vinifera L.) by HPLC-DAD-MS/MS. Journal of agricultural and food chemistry. 2004 Jul 14;52(14):4360-7. DOI: 10.1021/jf049613b