EDITORIAL

Grape Processing for Sustainable Development

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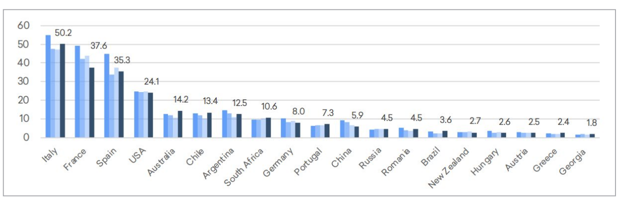
Grape processing by-products, such as pomace, seeds, and skins, are increasingly recognized for their potential in sustainable development practices. These by-products constitute a significant portion of agricultural waste and are rich in valuable phenolic compounds. In 2021, the grape processing industry contributed to the creation of substantial organic waste, which, if not managed sustainably, could result in environmental degradation. By leveraging advanced extraction technologies and sustainable management practices, the industry can transform this waste into valuable products, promoting environmental sustainability and providing socioeconomic benefits. This study underscores the importance of innovative, circular economy approaches in grape processing to address waste management and resource recovery.

Grape processing, particularly for wine production, is significant in several regions globally, including Europe (Italy, France, Spain), America (USA, Chile, Argentina), as well as Australia, South Africa, and China. Based on data from 2018 to 2021, wine production in Italy, France, and Spain collectively amounted to 123 million hectoliters (*Fig.1*). With its developing economy and rich wine production traditions, Georgia ranked 20th globally,

Fig. 1. *Main wine producing countries, 2018–2021 (MLN, HL) (Kvakhadze et al., 2022)*



producing 1.8 million hectoliters. Notably, Georgia saw a 16% increase in wine demand and production in 2021 compared with 2020, highlighting a promising future for the industry.

The main product of grape processing, wine, significantly benefits the regions where it is produced. This underscores the importance of aligning processing practices with the principles of sustainable development and the circular economy. Grape cultivation, along with processing and storage, involves a number of environmental considerations. Addressing these requires integrated approaches, which include training professionals involved in production and sales and establishing a robust legal framework.

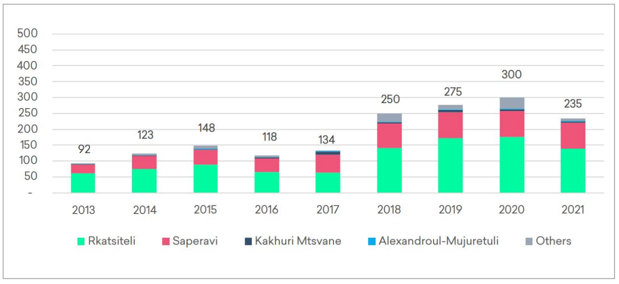
A critical first step is identifying potential environmental pollutants. This involves analyzing the chemical composition of waste products and exploring the potential uses for by-products. The grape cultivation stage consumes valuable resources such as water, fertilizers, and other organic and inorganic substances and also produces waste from vine pruning, such as stems and leaves.

At the processing stage, waste materials such as wastewater and seeds, skins, and stems are generated. Sustainability in this context involves applying waste-reduction technologies to wine production, continuously updating our knowledge alongside traditional winemaking techniques, and valuing the beneficial by-products of grape processing.

It is notable that wine producers currently utilize waste as a fertilizer or sell it to biogas companies as a renewable energy source. There is also a significant potential to use waste from wine production in food production to enhance the nutritional value of products like bread, cereals, and pasta. Additionally, waste products are used to produce alcoholic beverages post-distillation. For example, white wine pomace can be distilled to make grappa, a traditional Italian brandy, or chacha in Georgia.

The comprehensive application of mechanical, chemical, and biological processes facilitates the transformation of waste into valuable raw materials. This is crucial for achieving the 'zero waste' goal of the circular economy. Approximately 1.17 kilograms of grapes are needed to produce a standard 750-milliliter bottle of wine. After pressing, about 20% of that weight remains as skins, seeds, and stems. The specific composition of this 'grape pomace' varies based on the grape type, the wine produced, and the production method (*Fig. 2*).

Fig. 2. *Processed grapes species (000; TONS) (Kvakhadze et al., 2022)*



Deteriorating environmental quality, unhealthy nutrition, and other factors can disrupt balanced cellular processes in living organisms, leading to uncontrolled reactions with free radicals. However, the body's antioxidant protection system can prevent the development of these destructive free-radical processes. In this context, phenolic compounds play a crucial role. After carbohydrates and organic acids, phenolic compounds are the most abundant constituents in grapes, distributed as follows: 10% in the pulp, 60–70% in the seed, and 28–35% in the skin.

Grape processing by-products vary in phenolic compound content across different grape varieties, and their importance ranges widely. Grape seed polyphenols have been shown to reduce cardiovascular disease risk by inhibiting the oxidation of lipoproteins. It has been experimentally confirmed that antioxidant synergism is characteristic of products containing total grape polyphenols. Therefore, extracting soluble total polyphenols in the liquid phase is advisable when producing biologically active products from grape seeds. These seeds contain up to 22% fat and fat-soluble biologically active substances, and a technology has been developed that allows the food and cosmetics industries to obtain biologically active additives from them. Numerous studies confirm that the bioflavonoid concentrate from grape seeds is non-toxic and can be used long-term. This concentration is highly relevant, particularly for populations in regions contaminated with natural and artificial radiation, and is increasingly being included in their daily diets as a proactive health measure.In studies conducted in Georgia, extracts prepared from non-fermented and fermented seeds of common grape species using 80% ethyl alcohol were analyzed. The total phenolic content, determined by the Folin–Ciocalteu spectrophotometric method, was 3183.8 mg/100g in dry weight for unfermented grape seeds and 985.3 mg/100g in dry weight for fermented grape seeds. The fermentation reduced the phenolic content by about 2.5 to 3.0 times. Unfermented and fermented grape seeds can be suitable raw materials for biologically active substances. Their antioxidant activity was assessed by the DPPH method, showing that unfermented grape seeds had an antioxidant activity of 55.0% (F=125), and fermented grape seeds had 47.7% (F=25). Consequently, both unfermented and fermented seeds can be used as raw materials for extracts with high antioxidant activity, mainly because their antioxidant properties are derived from phenolic compounds, suggesting the potential for synergistic effects when mixing different types of grape seeds.

Further research into raw and fermented chacha is also promising, as are the results regarding using grape pomace as cattle feed, which has shown antioxidant and antimicrobial activity.

Recent studies have documented the antibacterial and antiseptic activities of grape pomace. Notably, quercetin, a phenolic monomer found in grape pomace extracts, can be polymerized with (4R,5R)-2,2-dimethyl-1,3-dioxolane-4,5-dicarbonyl dichloride to create a polymer that shows activity against Staphylococcus aureus. Additionally, although vine leaves are among the least studied by-products, they produce food ingredients. Their juice is also recommended for eye washing due to its antiseptic effects.

Grape skins are also rich in phenolic compounds. Green and sustainable subcritical water extraction techniques allow for the extraction of active compounds from grape stalks, adding value to this agricultural waste. These extracts can be used to develop active food packaging materials.

In light of current research, the grape processing industry must implement necessary measures regarding using generated waste as raw materials. These measures should consider socio-economic and environmental factors to promote circular economy approaches.

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