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# A Systematic Review on Post Harvest Handling and Application of Grapes (*Vitis spp.)*

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## Abstract

Grape is a significant crop of fruit in many countries. There is much food based on grapes present in the market, and statistics reveal that over 75% of global grape cultivation is destined for the wine sector. Grape pomace is a plentiful byproduct of the wine business that comprises residual skin, stalks, and seeds and accounts for around 25% of the total grape mass used in the fermentation system. In nations where winemaking is more important, such as France, Italy, and Spain, yearly grape pomace production can reach about 1200 tonnes/year. A reducing waste policy is required to achieve a sustainable winemaking process. Several studies have been conducted on this topic, with grape pomace being used as a source of beneficial and technological substances that could be used in the livestock feed, cosmetic, pharmaceutical, or food industries to enhance stability and nutritional properties, as well as in the cosmetic manufacturing, where this oil is widely used. This study will look at the existing winemaking environment and the benefits of implementing a waste management policy, as well as comparable extraction technologies and a variety of uses for grape pomace.

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## 1. Introduction

Grape is one of the most important classical fruits all over the world. It can be used in raw or formulated food products such as raisins, wine, juice, jam, vinegar, jelly, and seed oil. In 2019, the global production was 77 million tonnes with a harvested area of 6.9 million tonnes. China ranked first with a production of 14.2 million tonnes followed by Italy (7.9 million tonnes) and the United States of America (6.2 million tonnes) (Mishra et al., 2022). The grape berry contains basic tissue of three types in terms of winemaking: skin, flesh, and seed, with the flesh providing the majority of the wine. The makeup of these tissues varies significantly, and as a result, they contribute to the total wine composition in diverse ways (Teixeira et al., 2013). As a result, the wine composition may be altered simply by changing the size of the berry: berries small in size will often have a higher proportion of skin and seed-derived chemicals in wine. The quantity of seed-originated components in wine can also be influenced by the seeds number in the berry. The number of seeds in an optimal grape is four, but the exact number is frequently fewer because nutritional and environmental circumstances during the time of flowering limit fertilization success and thus the seeds number per berries (González-Barreiro et al., 2015).

The robust climbing vine Vitis vinifera bears fruit in clusters that typically contain 15–300 individual grape berries and can reach heights of 50 feet. The grape is a straightforward fruit with two chambers (locules) encased in the ovary wall (pericarp). Depending on the variety, the oval fruit has a diameter ranging from 5 to 25 mm. The stem, which may reach a length of 35 m, has leaves that are 5–23 cm wide and pale green soft pulpy berries with a few seeds, pulp, and skin. Seeds make up 0–10% of the overall fruit weight, and skin makes up 5–12%. Grapes' exterior colors range from yellow, green, and red to purple and black (Zhang et al., 2021; Hussain et al., 2021). Grape berry development is well known to consist of two consecutive sigmoidal growth stages divided by a lag phase: berry production and ripening of berry. The berry is formed during the initial period and it lasts after flowering for around 60 days, seed embryos are created, and the berry is formed (Hussain et al., 2021; Deluc et al., 2007). Cell growth is rapid during the initial weeks, and the total cell number within the berry is established by the conclusion of this period. The degree of cell growth has some impact on the final size of the fruit. The berry becomes softer and changes color during the start of the second sigmoidal growth stage (veraison). It was roughly twice in size throughout this time. The berry's demands of grape are met by a circulatory system made of xylem and phloem constituents that runs through its stem or pedicel. Water, nutrients, growth regulators, and minerals are transported from the plant root to the remaining vine via xylem vessels. According to current research, the xylem is operational in grapes early in the development (up to veraison), but has reduced or no functionality thereafter (Zhang et al., 2021; Vitalini et al., 2011). Phloem particularly transports sucrose (photosynthate) from the canopy, plays a minor role early in berry formation but becomes the principal source line after veraison. Although rises in berry volume after veraison are associated with higher content of sugar, there are many grape variants in which a rise in carbohydrate composition during the final steps of ripening is not followed by an increment in berry density but is instead due to berry shrinking, apparently due to transpirational water loss. This failure of the fruit to stay hydrated suggests that the phloem capillaries feeding the berries of these types get clogged at this time of year (González-Barreiro et al., 2015; Vitalini et al., 2011).

## 2. Volatile compounds and grape aroma

Although some odorant chemicals that contribute to wine production are created by yeasts during fermentation from nonvolatile compounds or obtained from precursors throughout wine aging, a substantial number also are seen in the grape and go through fermentation unmodified or with slight alterations. These molecules produce the varietal scent of wines (Etiévant, 2017). The term " unique aroma" does not state that every grape variety has its unique set of volatiles; rather, a given fragrance component or precursor can be found in a range of grape musts and wines.

Most of these chemicals are thought not to develop sugar levels. Most significant families of fragrance and taste compounds are organic acids, terpenoids (sesquiterpenoids, proanthocyanidins, monoterpenoids, and C13 norisoprenoids), and other precursors of aromatic compounds, thiols, and esters (Singh et al., 2022). Grape berries appear to lack structural mechanisms for retaining lipophilic volatile chemical substances (Etiévant, 2017; Ebeler & Thorngate 2009).

### *2.1 Volatiles in red grapes*

The maximum amount of volatile compound concentration in red grapes is attained at maturity, as determined by the ratio of sugar and acidity, and remains stable in the weeks afterward (Etiévant, 2017; Vitalini et al., 2011; Ebeler & Thorngate 2009). Esters characterize early berry development, middle development is characterized by aldehydes, and alcohols characterize late development; terpenes (primarily eucalyptol, R-humulene, and caryophyllene) characterize early development, while derivatives of benzene like 2-phenyl ethanol and 2-phenylethanal seemed later. Alcohols have a higher herbaceous odor threshold than comparable aldehydes, as well as a stronger proclivity during vinification to create fruity esters due to carboxylic acids, therefore late dominance is preferred. Chemically, the transformation of volatiles during the development of berry indicates a strong dependence on the activity of enzymes and sensitivity than on the level of unsaturated fatty acid; in particular, the reliance on the deposition of the products of alcohol dehydrogenase, acetyltransferase, and the lipoxygenase path that leads raises the possibility of influencing aroma profiles due to enal isomerase activity in grapes and wines (Etiévant, 2017; Ebeler & Thorngate 2009). Perhaps more immediately, the increasing dominance of alcohols and aldehydes means that the alcohol: aldehydes ratio can be utilized to time harvest to improve grape and wine flavor and aroma.

## 3. Postharvest handling

### *3.1 Sorting*

Grape sorting can be done manually or automatically. Manual sorting necessitates the participation of multiple people and takes a long time. The initial sorting takes place in the vineyard. The grapes are destalked before being placed on the sorting table, which vibrates to shift the berries. The destemmer is used to remove leaves, stalks, snails, and discolored berries during sorting. After that, the grapes are expelled and placed in the bioreactor/fermenter without their leaves or stalks. Sorting done electronically is costly, but it saves time and effort. Fruit is put onto one horizontal belt conveyor and then dumped onto another (Vitalini et al., 2011).

### *3.2 Packaging*

When the gathered amount exceeds demand, table grapes must be packed and delivered right immediately and appropriately kept. Packing protects table grapes during shipment and handling. Corrugated or solid fiberboard cartons are commonly used for packaging. For the protection of grapes from bruising, a protective liner or a layer of bubble pad is placed in the carton at the bottom, followed by a polyethylene lining. Bunches of these weighted lots are packed in tiny, hygienic food-grade polyethylene pouches that are thin and clean. Single or multiple bunches weighing about 350 or 650 g are contained in each bag. No bunch is placed into a pouch if it weighs less than 150 g. The grapes are then placed on a sulfur dioxide-generating pad that is covered in absorbent tissue paper and at the temperature of 4°C precooling is done (Etiévant, 2017; Ebeler & Thorngate 2009).

### 3.3 Storage

*3.3.1 Precooling*

The goal of precooling is to limit the amount of heat in the field. To keep grapes fresh for as long as possible, field heat must be removed as soon as possible after harvesting. Within 4–6 hours following harvest, the maintained temperature in the packing house is 18–20°C, and the grapes are sent to pre-cooling units. In the pre-cooling chambers, the temperature should be brought down to 4°C in 6–8 hours of harvested grapes. The quality of the grapes will be compromised if they are not brought down to this temperature as soon as possible (Etiévant, 2017).

*3.3.2 Cold storage*

After pre-cooling, the grape guard pads (sulfur dioxide) which are dual-releasing, with their absorber surface facing downward and coated with plastic sheet lining, are placed on the sealed plastic pouches. The boxes are sealed and moved to cold storage chambers with a temperature of 00.50°C and a humidity of 932%, respectively. Maintaining freshness and avoiding decay requires a temperature of 0°C and a humidity of 95%. At 2°C, berries, pedicels, and rachis suffer from freezing damage, whereas at slightly high temperatures, deterioration may occur. During storage and travel, extreme caution should be exercised to keep the temperature and humidity under strict control. It is critical to place the boxes in cold storage in such a way that all of the berries in each box chill uniformly (Etiévant, 2017; Ebeler & Thorngate 2009).

*3.3.3 Transport*

The grapes must be kept cool during their travel from the field to the buyer. The temperature within the box must remain at the same minimum level as it was in transit. Berries should be carried in refrigerated trucks from the farm to the airport or seaport and stored in the airport's cold store. To maintain the quality of the grapes, the cargo plane should be kept at a cold storage temperature (Ebeler & Thorngate 2009).

## 4. Grape's processing

### 4.1 Raisins

Raisins are made by drying fruit using hot air or sun radiation. The most common approach for raisin production is to use sunlight. Raisins have been dried from grapes since 1490 BC (Wang et al., 2016). Grapes are currently harvested off the vine, placed on trays between rows of vine, and dried in the sunlight for two or three weeks. The trays are gently folded into bundles and roasted in the sun for a few additional days when the moisture level reaches 15%. After that, they're carried onto a belt conveyor, where huge stems are separated, stacked in large bins made of wood to equalize moisture, and delivered to packing plants (Etiévant, 2017; Ebeler & Thorngate 2009).

### 4.2 Wine production

Wine is made from fresh grapes that have undergone complete or partial alcoholic fermentation, whether or not they have been pressed. This practice has been carried out in the Tigris-Euphrates basin since the time of the earliest settlements thousands of years ago. Vitis vinifera, a Mediterranean grape, originated in this location and has since spread throughout the Mediterranean. Wine is grown and enjoyed on nearly every continent. It includes beneficial elements including flavonoids, which protect against cardiovascular disease, and tannins, which have antimicrobial properties and an astringent impact. Wine is made in many different ways across the world, with the three primary categories (white, red, and dessert) dictating the process of vinification (Etiévant, 2017; Ebeler & Thorngate 2009).

**Table 1: Grape pomace composition**

| Compound | Content (g/100g) | References |
|---|---|---|
| Ash | 4.65 | (Yu & Ahmedna 2013) |
| Moisture content | 3.33 | (Bordiga et al., 2019) |
| Fiber | 46.17 | (Bosso et al., 2016) |
| Lipids | 8.16 | (Hussain et al., 2021) |
| Proteins | 8.49 | (Wang et al., 2016) |

## 5. Grape pomace utilization

One of the world's most frequently grown crops is grapes, with wine contributing to more than 75% of global grape productivity. The skin, minute parts of the stalk, stem, seed, residual pulp, and yeast cells from the winemaking fermentation make up 20-30% of the original grape mass. The various portions and constituents of grape pomace are mentioned in Figure 1. Grape pomace is made up of 38-52 percent seeds and 5-10 percent skins, respectively. Table 1 shows the makeup of various grape pomace kinds (Beres et al., 2017). Grape pomace has been underutilized due to an absence of alternative beneficial and economical uses. Historically, pomace obtained from wine production has been utilized as fertilizer, manure, or animal feed. It's also used to make several forms of "wine alcohol," which is a component of well-known and valued liquors, distilled spirits, and liqueurs. Pomace has also been used in vineyard soils as compost to increase carbon content, nitrogen, and trace minerals (Hussain et al., 2021; Wang et al., 2016). However, the utilization of pomace as fertilizer, manure, and animal feed has limitations because it doesn't fully tap into the market for this by-product and contains antinutritive substances that reduce agricultural yields and increase animal weight. Only 3% of fruit pulp is used for livestock feed, waste-based compost, and thermal insulation in buildings. Combustion and dumping of pomace inland fields are damaging to the environment because polyphenol compounds increase their resistance to biological breakdown and lower the pH of the pomace (Beres et al., 2017; Sagar et al., 2018).

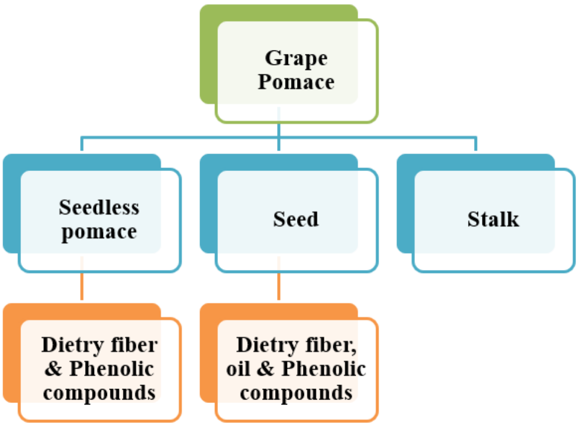


**Figure 1: Main fractions of grapes pomace and various compounds.**

### *5.1 Phenolic components in grape pomace*

The polyphenols present in grape pomace are Resveratrol, flavonols, anthocyanins, condensed tannins, and flavonols/catechins, and have antioxidant effects. Free radical scavengers derived from grape pomace have the potential to protect from cardiovascular disease, cancer, diabetes, oxidative stress in cells, and pathogen proliferation. The various phenolic compounds are represented in **figure 2** **(**Beres et al., 2017)**.** The total phenolic content (TPC) of grape pomace ranges from a minimum of 0.12 to a maximum of 7.48 g GAE/100 g dry matter (DM), with antioxidant activity ranging from 20 to 75 mM Trolox equivalents. Grape seeds have the highest concentration of phenolic chemicals (60–70%), followed by skin (28–35%), and pulp (less than ten percent). Procyanidins, epigallocatechin, gallic acid, catechin, and epicatechin are the predominant phenolics in rape peels, whereas epicatechin, gallic acid, epigallocatechin, and catechin are the key polyphenols in seeds (Sagar et al., 2018).

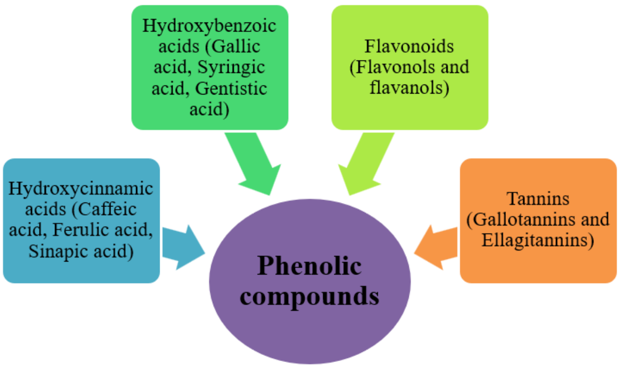


**Figure 2: Phenolic compounds found in grapes.**

#### *5.1.1 Application of phenolics*

Grape pomace extracts are available as liquid extracts, concentrates, and powders for use in culinary, pharmaceutical, cosmetic, and other sectors. Grape pomace was used as a food preserver against *Escherichia coli* O157:H7, *Campylobacter coli, Staphylococcus aureus, Bacillus cereus,* and *Salmonella infantis*, as well as an antibacterial/antimicrobial agent, and as a functional supplement grape pomace is used to improve drinks and as a component in an osmotic solution to produce dried fruit with increased phenolic content in the food sector (Rubio et al., 2020). It can also be used to boost the antioxidant content and shelf life of chitosan edible films. Grape pomace was used in food products to substitute synthetic antioxidants and to minimize acrylamide generation during the Maillard process in chip dehydration (Wang et al., 2016). Anticancer, anti-aging effects, and cholesterol-lowering have been discovered in grape pomace. There are other cosmetic goods containing grape polyphenolics, such as night-day creams, anti-wrinkle creams, mattifying fluids, the Pure Super Grape face serum, and protection fluid, which states the usage of polyphenols derived from grape seeds (Rubio et al., 2020; Zhang et al., 2021).

### *5.2 Dietary fiber (DF) from grape pomace*

DF has been acknowledged for its low energy contribution and health benefits. It is the most common compound of dried wine pomace, with percentages ranging from 43% to 75%. Polysaccharides and lignin present in cell-wall make up the majority of DF (Wang et al., 2016). Grape seeds have higher fiber content than grape skins, and pomace of red wine has a higher fiber content than white wine pomace. In both wine pomace (white and red), insoluble dietary fiber (IDF), particularly insoluble lignin in acid, is the primary component of DF, and fiber contains significant amounts of tannins and proteins (Rubio et al., 2020; Zhang et al., 2021). Grape pomace comprises fiber as well as phytochemicals, which can prevent future cancer and heart disease. Grape skin, for example, is a complex lignocellulosic containing a considerable percentage of hemicellulosic sugars that, when hydrolyzed, yield solutions comprising a wide variety of glucose-xylose monomers (Zhang et al., 2021). Grape pomace dietary fibers can be utilized in a variety of food products, including confectionary, bakery, beverage, and meat products, as well as in the pharmaceutical and cosmetic industries, providing a variety of health advantages. Popsicles, cereal bars, cookies and biscuits, extruded snacks, and cakes have all used grape pomace and seed flours (Bordiga et al., 2019). These pomace-enhanced goods are high in fiber, have antioxidant capacity, and are well received by customers. The grape fiber of Pinot Noir can be added to salad dressings and yogurt to boost fiber and phenolic content, as well as retard lipid oxidation and lengthen shelf life. It was discovered that adding grape pomace to codfish and shellfish reduced color, flavor, and textural alterations as well as lipid oxidation during freezer storage. The use of grape DF in chicken breast burger patties and fish muscles increased the products' oxidative stability and radical scavenging performance due to antioxidant activity. Furthermore, grape fiber addition to red wine making removed up to 38% of the tannins created throughout the process due to the grape fiber's tannin absorption capabilities (Rubio et al., 2020; Zhang et al., 2021).

### *5.3 Grape seed oil (GSO)*

GSO is well-known in the United States and other nations, having been used for decades in a variety of applications, including cosmetics making and as a cooking oil or specialty salad. During batch frying, grape-seed oil has a mild taste with fruity undertones, a high smoke point (216°C), good digestibility, and a minor increase in viscosity (Yang et al., 2021). Grape seeds contain an oil concentration of 8%–15% (w/w) and are abundant in unsaturated fatty acids, particularly linoleic and oleic acids, which account for >89% of the overall composition of the oil. Linoleic acid is an important fatty acid that has biological effects when coupled with its isomers, known as conjugated linoleic acids (Kumar et al., 2022; Rubio et al., 2020; Zhang et al., 2021).

*5.3.1 Application of grapeseed oil*

Due to its high percentage of unsaturated fatty acids, grapeseed oil provides various benefits for human consumption. It has high levels of vitamin E (which helps to lower the risk of arteriosclerosis), high levels of linoleic acid (essential for prostaglandin synthesis, which regulates platelet activation and inflammatory responses), and low levels of cholesterol (Garavaglia et al., 2016). As a result, consuming it may help avoid heart and circulation issues. Hepatoprotective, neuroprotective, and hepatic cholesterol-lowering properties are among the advantages of grapeseed oil. According to Ismail et al., feeding rats with liver and brain damage grape-seed oil had a protective impact against acute liver injury. This effect was related to the oil's strong anti-inflammatory, antioxidant, and antiapoptotic properties (Yang et al., 2021). It's capacity to scavenge free radicals, enhance the activity of antioxidant enzymes, reduce the levels of xanthine oxidase gene transcription and inhibit inflammatory responses and inducible nitric oxide synthase have neuroprotection against oxidative stress and inflammatory cascades in the brain. Rats administered grape-seed oil showed positive benefits on liver cholesterol levels, good acceptance among the rats, and a notable decrease in feed intake (Rubio et al., 2020; Zhang et al., 2021).

## 6. Conclusion

Grapes are one of the most valuable fruits in the world since they are used to make wine, grape-seed extract, jam, dried grapes, juice, jelly, vinegar, and grape-seed oil, among other things. The final usage varies in every country, based on the region's religious and political interests. Grapes have one of the largest technological and labor inputs of any fruit. Grapes are exceedingly sensitive and perishable from fresh fruit, with a high loss during harvest and distribution. As a result, grapes are processed into juice and raisins to reduce waste and increase marketability and profit from grape farming. Wine and juice production accounts for 50–75 percent of total grape output. Although pomace is high in phenolics and antioxidants, it is neglected. Many types of research have demonstrated that DF, phenolics, and grape-seed oil may be extracted and utilized to increase stability and nutritional properties in the animal feed, pharmaceutical, cosmetic, and food sectors. To make grape farming more sustainable, it's important to reduce the number of resources used in cultivation and processing, as well as waste creation, and to make good use of by-products. This is an overview of grape postharvest handling, processing, and by-product usage in the grape/wine processing sector to reduce waste and promote sustainability.

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