Winemaking By-products

Subjects: Food Science & Technology

Contributor: Marica Troilo

The winemaking by-products and waste, such as wine lees, grape stalks, and vine shoots, are generated from vinification process and after pruning. For their high content in functional and bioactive compounds, they can be recycled into food chain as functional additives to improve the quality of wines and to obtain innovative functional foods and sustainable food packaging, contributing to the sustainability of the wine sector.

winery by-products bioactive compounds dietary fiber polyphenols natural additives

1. Introduction

Winemaking produces a large quantity of wastes and by-products in a short period of time [1], corresponding to approximately 30% w/w of the starting grapes [2][3], represented by grape pomace, grape seeds, grape stalks, and wine lees as well as wastewater [4][5]. These by-products are considered highly polluting due to the presence of organic substances, pH, salinity, and heavy metal content, thus having negative repercussions on environmental and economic sustainability [3][6][7].

Grape pomace is the solid residue obtained following the pressing and the fermentation process [8][9], represents the 20-25% (w/w) of the total weight of the grape used for wine production and consists mainly of skin, pulp, stalks residual and seeds [4][10]. Traditionally grape pomace is used to produce feed, fertilizer, or different types of distillates [9][11][12][13]. However, in recent years, due to its chemical composition, grape pomace was considered a promising alternative to obtain high added value products [13]. Seeds are rich in antioxidant compounds, such as vitamin E [14] and phenolic compounds, phytosterols, fibers, proteins, carbohydrates, and minerals, but especially in lipids. Grape skin and pulp, instead, are a rich source of fibers and phenolic compounds including protocatechuic, gallic, vanillic, and caftaric acid, flavonols such as quercetin, myricetin and kaempferol and anthocyanins, whose presence is closely dependent on the vinification procedures and grape variety considered [15][16].

As already reported, winemaking also generates grape stalks, following destemming, and wine lees, the residue that forms after wine fermentation at the bottom of recipients. Grape stalks (about 7%, w/w of grape total weight) are usually removed before the fermentation phase to avoid excessive wine astringency [5][17]; they are a source of phenolic compounds such as tannins, flavan-3-ols, hydroxycinnamic acids, monomeric and oligomeric flavonols, and stilbenes, [17][18] and lignocellulosic compounds such as hemicellulose, cellulose, and lignin [3][19][20]. Wine lees (about 5%, w/w of grape total weight), instead, contain mainly ethanol, tartaric acid, phenolic compounds, and yeast cells [8][21].

In addition, the agronomic practice of pruning generates an enormous quantity of agricultural wastes, principally vine shoots, with a production estimated per year of about 1-2 tons per hectare [22]. They are usually shredded and spilled as soil conditioner, to improve the fertility, or used as biomass to produce energy. More recently, they are used as source of bioactive compounds (dietary fibers, phenols, proteins, lipids, hydrocolloids) for food, pharmaceutical and cosmetic industries, due to the nutritional benefits [8][23]; while grape leaves due to the presence of organic acids, lipids and polyphenols can be used in the cosmetic industry [5]. The increasing attention paid to the human health led researchers towards the recovery and the identification of bioactive compounds in vegetable matrices such as by-products. These bioactive compounds are mainly represented by polyphenols – secondary metabolites produced by plants under stress conditions and involved in the defense against pathogens, environmental stress, and ultraviolet radiation [14][17] – and by dietary fiber defined as carbohydrate polymers with 10 or more monomeric units, which are not hydrolyzed by the endogenous enzymes in the small intestine of humans [24] (Figure 1).

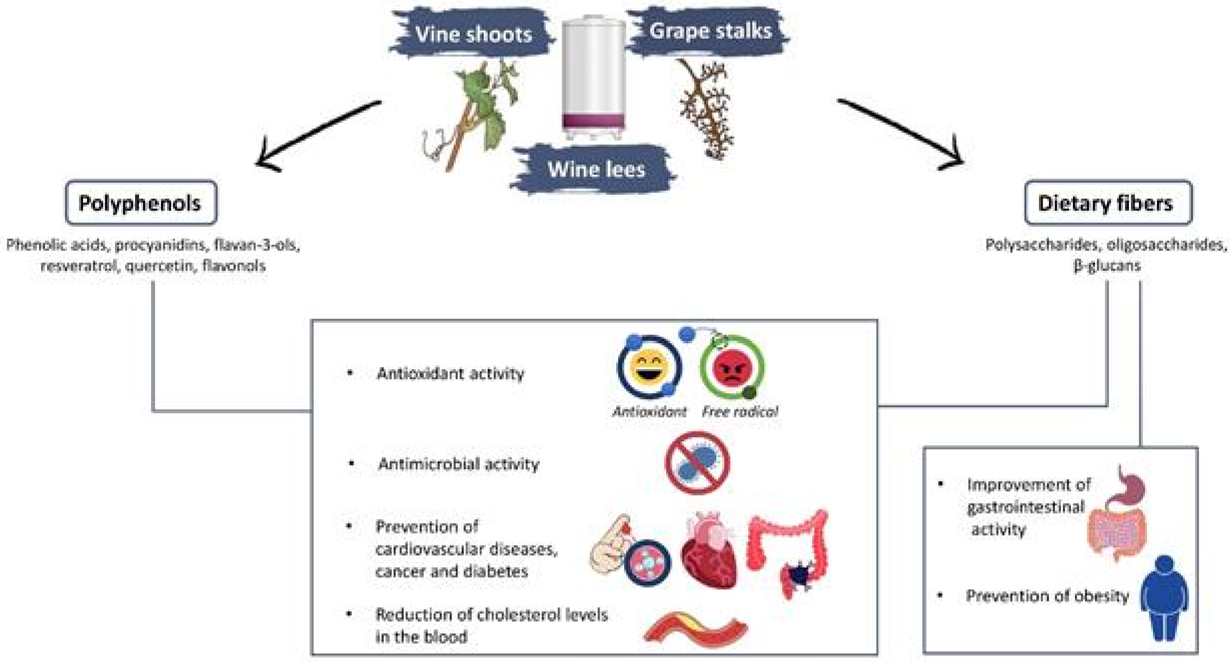

Figure 1. Effects of phenolic compounds and dietary fiber on health

Regards winery by-products, four main categories of polyphenols were identified: (i) phenolic acids, present in form of hydroxybenzoic and hydroxycinnamic acids [4][12]; (ii) flavonoids, divided into different classes: flavones, flavanons, flavonols, isoflavones, anthocyanins, and proanthocyanidine [13]; (iii) tannins; and (iv) stilbenes mainly represented by trans-resveratrol and ε-viniferina [10][17][25]. Numerous studies highlighted the beneficial effects of phenolic compounds, which exert antimutagenic, anticarcinogenic, anti-inflammatory, and antioxidant activity [10][12]. Specifically, trans-resveratrol, catechin, epicatechin, quercetin and phenolic acids have been studied for involvement in the prevention of cardiovascular diseases, cancer, diabetes, osteoporosis, neurodegenerative diseases, in the reduction of low-density lipoproteins (LDL) and in the consequent increase of high-density lipoproteins (HDL) [14][17][26][27].

In addition, an important role on human health is also played by dietary fibers whose recommended consumption is about 25-30 g per day [28], which is generally taken as a result of the ingestion of cereals, fruits, and vegetables. Due to modern dietary habits, this value is hard to be reached; for this reason, it is necessary to take alternative sources of dietary fibers to achieve the recommended daily amount. An adequate fibers intake was associated with the prevention of cardiovascular diseases, hypertension, diabetes, and obesity [29][30], and with the reduction of glycaemic responses and cholesterol levels in the blood [31]. Further, one of the main benefits is the improvement of gastrointestinal activity in terms of motility by modulating gastrointestinal transit time, the faecal weight and the faecal acidity [31], followed by the satiety promotion and the modulation of the immune responses of the intestinal mucosa [10]. Dietary fiber, as well as polyphenols, can also exert an antioxidant and antimicrobial action. In the food sector, microbial activity and lipid oxidation are the first indices of food spoilage, that give rise to concerns for the food industry and for consumers [32].

2. Food Applications

The remarkable amount of winemaking sector by-products led researchers to look for alternative uses to enhance them. In Table 1 are reported the possible applications of grape stalks, vine shoots and wine lees as food ingredients to ensure or improve some qualitative characteristics of foods, such as wine and ice cream, acting as anti-oxidants and antimicrobials, and/or increase their nutritional value, being a source of fiber.

Table 1. Applications of vine shoots, grape stalks and wine lees or their extracts in food and beverage.

Aims	Source	Result	References
SO_2 substitution in wine (Stilbenes, phenolic acids, flavanols and tannins)	GS	Increase antioxidant and antimicrobial activity in wine model.	[33]
	VS	Improvement of color intensity, sensory characteristics until 12 months of storage.	[34]
	VS	Improvement of color intensity, phenolic compounds, and quality of wine.	[35]
	VS	Stabilization of anthocyanins and improvement of the chromatic properties of wine, polyphenol stabilization and aromatic profile of wine.	[36]

	VS	Change of the aromatic profile and color of white wine.	[37]
	GS	Increase of antioxidant and antimicrobial activity in treated wines; increase attributes related to floral and fruity aroma.	[38]
	GS	Increase of phenolic compounds, astringency and bitterness and decrease of color intensity.	[39]
	VS	Positive modification of flavor of model wine.	[40]
	VS	Improvement of chemical composition of wines in terms of phenolic substances and antioxidants.	[41]
Improvement of wine quality (Phenolic compounds)	GS	Improvement of antioxidant activity and phenolic content of wines and increase of herbal notes in taste and flavor.	[42]
Production of grape stems-based liqueur (Phenolic compounds)	GS	Improvement of phenolic compound, antioxidant activity and intensity of color of liqueur after 90 days of maceration.	[43]
Production of fortified cereal bar (Protein)	WL	Improvement of protein content of cereal bars; small difference in color and taste.	[44]
Production of high-added value ice cream (Phenolic compounds and dietary fiber)	WL	Improved ice cream structure and properties; increased antioxidant and inhibitory effect towards the oxidation of human erythrocyte membranes.	[45]
	WL	Increase of phenolic content and improvement of physical, functional, and rheological properties.	[46]

	WL	Improvement of the physical-chemical, rheological, and sensory properties of ice cream.	[47]
	WL	Production of ice-creams with physical-chemical and sensory properties comparable to control ice-creams; increase of survival rate of *Lactobacillus acidophilus* during the 60 days of storage.	[48]
Synthetic additives substitution in hamburger (Phenolic compounds)	WL	Increase of antioxidant and antimicrobic activity and phenolic compounds in burger.	[49]
Inhibition of food pathogens (Phenolic compounds)	GS	Inhibition of *Listeria monocytogenes*, *Staphylococcus aureus*, *Salmonella enterica* subsp*. enterica* serovar Typhimurium, and *Escherichia coli O157: H7* in lettuce and spinach.	[50]
	GS	Reduction of adhesion potential and *Listeria monocytogenes* motility on food contact surfaces (steel and polypropylene).	[51]
	GS	High antimicrobial activity after 64 days of storage, against bacteria gram + and gram -.	[52]

GS, Grape stalks; VS, Vine shoots; WL, Wine lees.

2.1 Substitution of Sulfur Dioxide in Winemaking

Sulfur dioxide (SO_2) is one of the most used additives in the winemaking industry, for its antioxidant and antimicrobial activity. In fact, it is used to control unwanted microorganisms and enzymatic activities during the winemaking, controlling oxidative processes and unwanted fermentations [34][53]. However, its excessive use is associated with adverse effects on human health, related to dermatitis, urticaria, bronchoconstriction and anaphylaxis, and defects related to organoleptic alterations such as neutralisation of aromatic compounds and appearance of defects in wine, increasing unpleasant flavors and smells, and increasing turbidity [38][53]. In recent years, there is a growing tendency to use wine by-products, such as grape stalks and vine shoots – due to the presence of phenolic acids (caffeic acid, gallic and p-cumaric acid), flavonoids (catechin, epicatecin and luteolin) and stilbenes (trans-resveratrol and its trans-ε-viniferin dimer) – to replace SO_2, thus acting as natural antioxidant and stabilizers of wine, contrasting the formation of aggregates between proteins and SO_2, cause of opacity and instability [54][55][56].

Grape stalks extract rich in stilbenes was added by Ruiz-Moreno et al. [33] in amount of 50 and 80 mg/L in a model wine in order to both reduce the SO_2 in winemaking and study the effect on the aroma. The results showed a higher antioxidant effect and a lower antimicrobial effect against *Saccharomyces cerevisiae* and *Hanseniaspora uvarum*, and higher effect again *Candida stellata* and *Botryotinia fuckeliana*, compared to SO_2. The olfactometric profile evaluated by gaschromatography–olfactometry technique, instead, was similar to the typical one of wines. Raposo et al. [34], instead, used a commercial extract of stilbenes obtained from vine shoots in order to preserve the quality of a red wine studying the effectiveness at bottling and the storage in bottle for twelve months. The addition, in amount of 86 mg/L of wine (25 mg/L of total stilbenes), increased the intensity and purity of the color and led to a high score at sensory analysis, evaluated at bottling. Moreover, the use of commercial stilbenes improved the aroma of wines and preserved volatile compounds, showing more note of black and mature fruit. However, after aging the extract did not allow to preserve the quality, compared to wines treated with SO_2. Based on these results, in a subsequent research the authors evaluated the optimal dose to increase the qualitative parameters and the sensory attributes, at two concentrations of added extract, 175 mg/L of wine (50 mg/L of the total stilbene content) and 430 mg/L (100 mg/L of the total stilbene content) during twelve months of storage in bottle. The obtained results were similar to the SO_2 treated wines, but with differences in phenolic composition and color intensity. The wines obtained, in fact, had high concentrations of vinyl-pyranoanthocyanins and B-type vitisins, two stable color compounds resistant to oxidation and a lower concentration of free anthocyanins. Moreover, the addition of extract led to a modification of sensory attributes related to black fruit, caramel, and woody when 430 mg/L of extract was used, which also led to a decrease of scores related to global quality [35]. The same quantities tested by Ruiz-Moreno et al. [36] preserved phenolic compounds and improved the chromatic characteristics of wines and did not adversely affect the aromatic composition and sensory properties, showing high concentrations of β-damascenone, an odorant associated with descriptors such as fruity, honey and baked apple, and slight astringent notes. In the same way, Cruz et al. [37] reported that quantities of 138 mg/L of commercial stilbenes added in white wines at bottling, positively influenced the sensorial characteristics, identifying white fruit attributes and higher aromatic intensity, without any defects despite slight negative effects on color, until six months of storage.

The effect of the use of extracts from grape seeds and stalks in solely or in combination with colloidal silver complex was evaluated by assaying the antioxidant and antimicrobial activity, and determining color, phenolic and volatile composition, and sensorial profile of white wines [38]. Wines treated with extracts of grape stalks rich in hydroxycinnamic acids, catechin, epicatechin, and procyanidin B1 and B2 showed no differences in terms of antioxidant activity and total yeasts, lactic and acetic bacteria count respect to the wine treated with SO_2. The chromatic parameters were increased by the addition of 0.5 g/L of grape stalks extract and 0.5 g/L of grape stalks extract and 1 g/L of colloidal silver complex; while from a microbiological point of view, no differences were found compared to control wines (treated with SO_2). On the other hand, the phenolic and volatile composition of wines was modified using extracts, showing higher quantities of flavonols and ethyl esters and lower concentrations of acetaldehyde. In addition, the grape stalks extracts affected sensory attributes, increasing the scores related to fruity and floral. The effect of addition of grape stalks on the color and phenolic content in red wine was evaluated also by Pascual et al. [39]. The use of grape stalks increased the concentration of catechins, gallocatechins, and proanthocyanidins, but led to decrease the intensity of color and increase the astringency and bitterness of wine. Other authors also report that the volatile and phenolic composition may also be influenced by the addition of vine shoots. Cebrián-Tarancón et al. [40][41], in fact, studied the chemical composition of model [40] and real wines [41] after the use of toasted and not toasted vine shoots, in different particle sizes and at different maceration time. Positive effects were reported especially after 35 days of maceration and using toasted vine shoots at the concentration of 12 g/L, obtaining wines with high levels of vanillin, trans caftaric acid, caffeic acid, and trans resveratrol. Overall, the ability to preserve the quality of wines and to contribute to the sustainability of the wine chain, allows to use these by-products as an alternative to the classic wine additives as to improve the phenolic profile, despite slight negative effects on color and astringency of wines.

2.2 Production of high-added value foods

As a result of the growing global interest in the relationship between nutrition and health, recent studies focused on the development of innovative food products [44][57]. Some researchers have analyzed the possibility of integrating agro-food by-products to produce foods improved by nutritional point of view.

For this purpose, Borges et al. [44] added wine lees to produce cereal bars. Wine lees represent a precious by-product linked to the presence of insoluble carbohydrates (from cellulosic and hemicellulosic fractions), phenolic compounds, lignin, but especially proteins, that makes wine lees nutritionally very rich [44][47]. To increase the nutritional value of the bars, the authors used wine lees subjected to an autolysis process to break the yeast cell walls, to facilitate the release of accumulated proteins inside. The results showed that the addition of this by-product at 2,5 and 5% allows to obtain cereal bars that contribute to the recommended daily protein intake; from a sensory point of view, instead, the addition of wine lees made the sample darker but acceptable to the taste by consumers, without finding substantial differences compared to unfortified cereal bars.

The impact of adding wine lees to ice cream production, has been assessed by Hwang et al. [45], through the addition of 50, 100, and 150 g/kg of wine lees homogenized with distilled water. The results showed that the addition of 50 g/kg of wine lees improved the characteristics of the ice cream, leading to a decrease in specific gravity, pH, firmness, lightness, and freezable water amount and a concomitant increase in viscosity, melting rate, yellowness, and fat destabilization. In addition, the fortified product showed higher antioxidant activity, confirming that the compounds present in wine lees were stable during the production process. However, the addition at higher amounts determined a negative effect related to the increase of particle size of fat globules and overrun (the amount of air incorporated during the batch freezing). Pundhir et al. [46], instead, added 35 g/kg of wine lees to produce a fortified ice cream with low sugar content. The product showed an increased phenolic content with improved physical, functional, and rheological properties while a decrease in pH, specific weight, and overrun due to increased viscosity and an increase in the destabilization index of fats were also observed. The sensory analysis showed a higher color intensity and overall pleasantness than control without extract, as also found by Sharma et al. [47].

Microbiological aspects related to the addition of wine lees in ice cream were investigated by Ayar et al. [48], who evaluated the vitality of *Lactobacillus acidophilus (ATCC 4357D 5)* and *Bifidobacterium animalis subsp. lactis (ATCC 27536)* after 1, 15, 30, and 60 days of storage. The presence of dietary fiber from wine lees, had a positive effect on the survival of *L. acidophilus* during storage, but slightly decreased the count of *B. animalis subsp. lactis* whose decrease was less than 1.0 log CFU/g, however showing concentrations greater than 6 log CFU/g, such as to define ice cream as a probiotic (EC Regulation No 1924/2006). Moreover, the addition of wine lees improved the physico-chemical and sensory characteristics, as described in previous studies.

Wine lees have also been tested as preservatives to replace the most commonly used additives in meat products. This kind of food tends to oxidize rapidly during storage, so Alaracon et al. [49], estimated the effect of adding wine lees at 2.5 and 5% in deer burgers packaged in modified atmosphere at 4 °C. The fortification has countered lipid and protein oxidation, due to increased phenolic content and antioxidant activity. Moreover, the addition of wine lees, had an antimicrobial effect against aerobic psychotrophic bacteria, and modified the organoleptic characteristics of the products. After sensorial analysis, in fact, the hamburgers had attributes like wine and bakery notes, considered pleasant at low intensity, due to the increase of benzene compounds, esters and acids present initially in wine lees. The addition of lees preserved the typical color of meat, with a low decrease in values of redness (a*) compared to the control samples.

2.3 Improvement of alcoholic beverages quality

The quality of the wine was improved by Miljić et al. [42], by adding grape seeds and stalks during the vinification in red. The presence of stalks increased phenolic content and antioxidant activity compared to control wines; however, the experimental wine showed pronounced herbal notes which reduced consumer acceptability when 50% of grape stalks were used, unlike the addition of 25%, which improved sensory characteristics and increased acceptability.

An innovative liqueur obtained from red fruit and fortified with grape stalks, was produced by Barros et al. [43], who used this by-product as a source of polyphenols. The liqueur was obtained by adding 50 g of grape stalks powder in marc grape spirits and sugar, subjected to a maceration phase, and analysed after 90 and 180 days. The product obtained had a higher antioxidant activity due to the presence of bioactive compounds (ortho-diphenols, flavanols, flavonols and anthocyanins), compared to a liqueur obtained without the addition of grape stalks. The highest value of antioxidant activity was achieved after 90 days of maceration, also showing a change in color parameters. The value of lightness (L*) decreased due to the precipitation of particles of plant material that increased turbidity; the values of redness (a*) and yellowness (b*) instead, increased obtaining an innovative liqueur with an attractive color.

2.4 Inhibition of food pathogens

The inhibiting effect of grape stalks polyphenols was assayed against the growth of some food pathogens, such as *Listeria monocytogenes*, *Staphylococcus aureus*, *Salmonella enterica* subsp*. enterica* serovar Typhimurium and *Escherichia coli O157: H7*. As an alternative to synthetic antimicrobials grape stalks extracts were applied on samples of fresh leafy vegetables (lettuce and spinach). The results related to antimicrobial activity of extract, showed a high inhibition efficacy at a concentration of 25 g/L, especially against *E.coli O157: H7* and *Salmonella enterica*, showing a reduction of about 2 logarithmic units [50].

In a subsequent study, Vázquez-Armenta et al. [51] evaluated the effect of grape stalks extracts, compared to synthetic disinfectants, on motility, surface energy and adhesion of *Listeria monocytogenes* on food contact surfaces, such as stainless steel and polypropylene. The results obtained after the use of 18 and 20 mg/mL of grape stalks extract on both surfaces, showed a greater reduction in pathogen adhesion than the control; the presence of grape stalks extracts, probably induced the synthesis of exopolysaccharides, responsible for the inhibition of motility, adhesion, and biofilm formation. In addition, a greater impact of phenolic compounds such as ferulic, gallic and caffeic acid, compared to flavonoids such as catechin and rutin on the inhibition of *Listeria monocytogenes*, was showed. The in vitro antimicrobial activity of grape stalks after 64 days of storage against positive and negative Gram bacteria was studied by Gouvinhas et al. [52]. In particular, antimicrobial activity was tested against *Listeria monocytogenes*, *Staphylococcus aureus*, *Enterococcus faecalis*, *Pseudomonas aeruginosa*, *Escherichia coli* and *Klebsiella pneumoniae*, known as foodborne pathogens. The high phenolic content, in particular ortho-diphenols and flavonoids, allows therefore to use the extracts as antimicrobials for the high inhibitory power shown, in some cases greater than commercial antimicrobials.

3. Food Packaging Formulations

In recent years, the massive use of plastic materials has inevitably led to an increase in issues related to environmental pollution and the disposal of these materials [58]. To tackle this problem, interest in sustainable packaging made with biopolymers from renewable agro-industrial sources, widely available and cheap, is growing [59][60][61]. In Table 2 are reported the possible applications of vine and winery by-products as fillers for food packaging.

In order to find a substitute for expanded polystyrene (EPS) in the trays, Engel et al. [58] added 18.4% (w/w) of grape stalks, known for their richness in lignocellulosic fibers, and glycerol (as plasticizer) to the polymer fraction (cassava starch-based foams). This increased the tensile strength and elasticity of starch-based foams, through the interfacial interaction that occurs between the matrix and the fibers, obtaining foams with good mechanical properties, low density, increased moisture resistance and hydrophobicity. In a subsequent study, the same authors carried out tests of applicability on low moisture foods (cake) of biodegradability of polymer matrix added with 7% (w/w) of grape stalks [62]. The applicability tests on foods, compared to the use of expanded polystyrene (control), highlighted the appearance of deformations in correspondence of the contact points between cake and packaging and the increase in moisture in the first days of storage; however, after nine days of storage the samples showed no significant difference in moisture content. These results showed a possible use of the innovative packaging for foods with low moisture content, as an alternative to expanded polystyrene materials for short-term storage. The study on biodegradability, instead, showed that amorphous structure of the innovative packaging contributes to rapid biodegradation, useful for reducing environmental problems and the disposal of waste and by-products.

El Achaby et al. [63] studied the possibility of producing cellulose nanocrystals (CNCs) from vine shoots composed of about 70% of holocellulose (cellulose and hemicellulose) and 20% of lignin. After extraction, the CNCs were added in amount of 1, 3, 5, and 8% (w/w) as reinforcements for the production of materials with carboxymethyl cellulose as a biopolymer matrix. The mechanical properties of the obtained material highlighted a final structure with a high crystallinity (82%) and thermal stability, a good colloidal stability in water, thus obtaining a biopolymer with good properties of elasticity and tensile strength.

Vine shoots were further applied as fillers of a matrix of poly (3-hydroxybutyrate-3-hydroxy-valerate) (PHBV), by adding 20% (w/w) of grounded vine shoots [64]. As a result, an acceleration of the biodegradation kinetics of the material in the soil, as well as a packaging with good structure and morphology properties were found. Nanni et al. [65][66] in two subsequent studies tested the use of wine lees as fillers at 10, 20, and 40 phr (parts for hundred parts of polymer) in biodegradable biopolymers, such as poly(3-hydroxybutyrate-cohydroxyhexanoate) (PHBH), poly (3-hydroxybutyrate-cohydroxyvalerate) (PHBV); and polybutylene succinate (PBS). The obtained results on tensile and creep tests, scanning electron microscopy, differential scanning calorimetry seemed to be promising. In fact, the addition of wine lees increased the Young's modulus without decreasing the tensile strength, due to the good adhesion between wine lees particles and the matrix.

Table 2. Applications of wine by-products as filler to improve food packaging.

Matrix	Source	Result	References
Cassava starch-based foams	GS	Foams with good mechanical properties and increased moisture resistance.	[58]
Cassava starch-based foams	GS	Good mechanical and biodegradable packaging properties and low moisture resistance.	[62]
Carboxymethyl cellulose	VS	Increase of elastic modulus and tensile strength, crystallinity and high thermal stability of biopolymer incorporated with cellulose nanocrystals from vine shoots.	[63]

PHBV	VS	Complete biodegradation with fillers consisting of vine shoots are exhausted.	[64]
PHBH and PHBV	WL	Production of biopolymers, such as PHBH and PHBV with good thermal, mechanical, rheological, and morphological characteristics.	[65]
PBS	WL	Production of biopolymers, such as PBS with good thermal, mechanical, rheological, and morphological characteristics.	[66]

PHBV, Poly (3-hydroxybutyrate-3-hydroxy-valerate); PHBH, Poly(3-hydroxybutyrate-cohydroxyhexanoate); PBS, Polybutylene succinate; GS, Grape stalks; VS, Vine shoots; WL, Wine lees.

4. Conclusions

The different researches examined in this review show a growing interest in vine and winery by-products, which are no managed as wastes but as a source of functional compounds to be exploited in the production of innovative food and packaging. The presence of bioactive compounds, such as polyphenols and dietary or lignocellulosic fiber, allows to use these by-products or their extracts as i) antioxidant or stabilizing agents, replacing the most used oenological additives; ii) antimicrobial agents, against food pathogens; iii) phenolic content improvement; iv) alternative to petrochemical polymers, ensuring the environmental sustainability. Their valorisation, therefore, allows to give a second life to the winery by-products, contributing at the same time to the reduction of production cost and residual quantity. In fact national legislations, international regulatory frameworks, and directives concerning waste management indicate waste prevention/minimization and by-product valorization as key strategies for the effective management system and sustainability of the food industry.

References

1. Bustamante, M.A.; Moral, R.; Paredes, C.; Pérez-Espinosa, A.; Moreno-Caselles, J.; Pérez-Murcia, M.D. Agrochemical characterisation of the solid by-products and residues from the winery and distillery industry. Waste Manage. 2008, 28, 372–380, doi:10.1016/j.wasman.2007.01.013.
2. Rondeau, P.; Gambier, F.; Jolibert, F.; Brosse, N. Compositions and chemical variability of grape pomaces from French vineyard. Ind. Crop. Prod. 2013, 43, 251–254,

doi:10.1016/j.indcrop.2012.06.053.

3. Dávila, I.; Robles, E.; Egüés, I.; Labidi, J.; Gullón, P. The biorefinery concept for the industrial valorization of grape processing by-products. In Handbook of Grape Processing By-Products I. Academic Press 2017, 29-53, doi:10.1016/B978-0-12-809870-7.00002-8
4. Beres, C.; Costa, G.N.S.; Cabezudo, I.; da Silva-James, N.K.; Teles, A.S.C.; Cruz, A.P.G.; Mellinger-Silva, C.; Tonon, R.V.; Cabral, L.M.C.; Freitas, S.P. Towards integral utilization of grape pomace from winemaking process: A review. Waste Manage. 2017, 68, 581–594, doi:10.1016/j.wasman.2017.07.017.
5. Ahmad, B.; Yadav, V.; Yadav, A.; Rahman, M.U.; Yuan, W.Z.; Li, Z.; Wang, X. Integrated biorefinery approach to valorize winery waste: A review from waste to energy perspectives. Sci. Total Environ. 2020, 719, 137315, doi:10.1016/j.scitotenv.2020.137315.
6. Devesa-Rey, R.; Vecino, X.; Varela-Alende, J.L.; Barral, M.T.; Cruz, J.M.; Moldes, A.B. Valorization of winery waste vs. the costs of not recycling. Waste Manage. 2011, 31, 2327–2335, doi:10.1016/j.wasman.2011.06.001.
7. Galanakis, C.M. Recovery of high added-value components from food wastes: Conventional, emerging technologies and commercialized applications. Trends Food Sci. Technol. 2012, 26, 68–87, doi:10.1016/j.tifs.2012.03.003.
8. Kalli, E.; Lappa, I.; Bouchagier, P.; Tarantilis, P.A.; Skotti, E. Novel application and industrial exploitation of winery by-products. Bioresour. Bioprocess. 2018, 5, 46, doi:10.1186/s40643-018-0232-6.
9. Bordiga, M.; Travaglia, F.; Locatelli, M. Valorisation of grape pomace: an approach that is increasingly reaching its maturity – a review. Int. J. Food Sci. Technol. 2019, 54, 933–942, doi:10.1111/ijfs.14118.
10. Yu, J.; Ahmedna, M. Functional components of grape pomace: Their composition, biological properties and potential applications. Int. J. Food Sci. Technol. 2013, 48, 221–237, doi:10.1111/j.1365-2621.2012.03197.x.
11. Bordiga, M.; Travaglia, F.; Locatelli, M. Valorisation of grape pomace: an approach that is increasingly reaching its maturity–a review. J. Food Sci. Technol. 2019, 54, 933-942, doi: 10.1111/ijfs.14118
12. García-Lomillo, J.; González-SanJosé, M.L. Applications of Wine Pomace in the Food Industry: Approaches and Functions. Compr. Rev. Food Sci. Food Saf. 2017, 16, 3–22, doi:10.1111/1541-4337.12238.
13. Mattos, G.N.; Tonon, R.V.; Furtado, A.A.L.; Cabral, L.M.C. Grape by-product extracts against microbial proliferation and lipid oxidation: a review. J. Sci. Food Agr. 2017, 97, 1055–1064, doi:10.1002/jsfa.8062.

14. Barba, F.J.; Zhu, Z.; Koubaa, M.; Sant'Ana, A.S.; Orlien, V. Green alternative methods for the extraction of antioxidant bioactive compounds from winery wastes and by-products: A review. Trends Food Sci. Technol. 2016, 49, 96–109, doi:10.1016/j.tifs.2016.01.006.
15. Pintać, D.; Majkić, T.; Torović, L.; Orčić, D.; Beara, I.; Simin, N.; Mimica–Dukić, N.; Lesjak, M. Solvent selection for efficient extraction of bioactive compounds from grape pomace. Ind. Crop. Prod. 2018, 111, 379–390, doi:10.1016/j.indcrop.2017.10.038.
16. Rodríguez Montealegre, R.; Romero Peces, R.; Chacón Vozmediano, J.L.; Martínez Gascueña, J.; García Romero, E. Phenolic compounds in skins and seeds of ten grape Vitis vinifera varieties grown in a warm climate. J. Food Comp. Anal. 2006, 19, 687–693, doi:10.1016/j.jfca.2005.05.003.
17. Teixeira, A.; Baenas, N.; Dominguez-Perles, R.; Barros, A.; Rosa, E.; Moreno, D.A.; Garcia-Viguera, C. Natural bioactive compounds from winery by-products as health promoters: A review. Int. J. Mol. Sci. 2014, 15, 15638–15678, doi:10.3390/ijms150915638.
18. Ping, L.; Brosse, N.; Sannigrahi, P.; Ragauskas, A. Evaluation of grape stalks as a bioresource. Ind. Crop. Prod. 2011, 33, 200–204, doi:10.1016/j.indcrop.2010.10.009.
19. Prozil, S.O.; Evtuguin, D.V.; Lopes, L.P.C. Chemical composition of grape stalks of Vitis vinifera L. from red grape pomaces. Ind. Crop. Prod. 2012, 35, 178–184, doi:10.1016/j.indcrop.2011.06.035.
20. Spigno, G.; Pizzorno, T.; de Faveri, D.M. Cellulose and hemicelluloses recovery from grape stalks. Bioresource Technol. 2008, 99, 4329–4337, doi:10.1016/j.biortech.2007.08.044.
21. Dimou, C.; Kopsahelis, N.; Papadaki, A.; Papanikolaou, S.; Kookos, I.K.; Mandala, I.; Koutinas, A.A. Wine lees valorization: Biorefinery development including production of a generic fermentation feedstock employed for poly(3-hydroxybutyrate) synthesis. Food Res. Int. 2015, 73, 81–87, doi:10.1016/j.foodres.2015.02.020.
22. Sánchez-Gómez, R.; Zalacain, A.; Pardo, F.; Alonso, G.L.; Salinas, M.R. Moscatel vine-shoot extracts as a grapevine biostimulant to enhance wine quality. Food Res. Int. 2017, 98, 40–49, doi:10.1016/j.foodres.2017.01.004.
23. Spigno, G.; Marinoni, L.; Garrido, G.D. State of the art in grape processing by-products. Elsevier Inc. 2017, doi:10.1016/B978-0-12-809870-7.00001-6
24. Joint FAO/WHO Food Standards Programme, Secretariat of the CODEX Alimentarius Commission: CODEX Alimentarius (CODEX) Guidelines on Nutrition Labeling CAC/GL 2–1985 as Last Amended 2010. Rome: FAO; 2010.
25. Karakaya, S. Bioavailability of phenolic compounds. Crit. Rev. Food Sci. 2004, 44, 453–464, doi:10.1080/10408690490886683.
26. Bhise, S.; Kaur, A.; Gandhi, N.; Gupta, R. Antioxidant property and health benefits of grape byproducts. J Post Harvest Technol. 2014, 2, 1–11.

27. Vislocky, L.M.; Fernandez, M.L. Biomedical effects of grape products. Nutr. Rev. 2010, 68, 656–670, doi:10.1111/j.1753-4887.2010.00335.x.
28. Tolve, R.; Pasini, G.; Vignale, F.; Favati, F.; Simonato, B. Effect of Grape Pomace Addition on the Technological, Sensory, and Nutritional Properties of Durum Wheat Pasta. Foods 2020, 9, 354, doi:10.3390/foods9030354.
29. Anderson, J.W.; Baird, P.; Davis, R.H.; Ferreri, S.; Knudtson, M.; Koraym, A.; Waters, V.; Williams, C.L. Health benefits of dietary fiber. Nutr. Rev. 2009, 67, 188–205, doi:10.1111/j.1753-4887.2009.00189.x.
30. Tomé-Carneiro, J.; Gonzálvez, M.; Larrosa, M.; García-Almagro, F.J.; Avilés-Plaza, F.; Parra, S.; Yáñez-Gascón, M.J.; Ruiz-Ros, J.A.; García-Conesa, M.T.; Tomás-Barberán, F.A.; et al. Consumption of a grape extract supplement containing resveratrol decreases oxidized LDL and ApoB in patients undergoing primary prevention of cardiovascular disease: A triple-blind, 6-month follow-up, placebo-controlled, randomized trial. Mol. Nutr. Food Res. 2012, 56, 810–821, doi:10.1002/mnfr.201100673.
31. Zhu, F.; Du, B.; Zheng, L.; Li, J. Advance on the bioactivity and potential applications of dietary fibre from grape pomace. Food Chem. 2015, 186, 207–212, doi:10.1016/j.foodchem.2014.07.057.
32. Jayaprakasha, G.K.; Selvi, T.; Sakariah, K.K. Antibacterial and antioxidant activities of grape (Vitis vinifera) seed extracts. Food Res. Int. 2003, 36, 117–122, doi:10.1016/S0963-9969(02)00116-3.
33. Ruiz-Moreno, M.J.; Raposo, R.; Cayuela, J.M.; Zafrilla, P.; Piñeiro, Z.; Moreno-Rojas, J.M.; Mulero, J.; Puertas, B.; Giron, F.; Guerrero, R.F.; et al. Valorization of grape stems. Ind. Crop. Prod. 2015, 63, 152–157, doi:10.1016/j.indcrop.2014.10.016.
34. Raposo, R.; Ruiz-Moreno, M.J.; Garde-Cerdán, T.; Puertas, B.; Moreno-Rojas, J.M.; Gonzalo-Diago, A.; Guerrero, R.; Ortíz, V.; Cantos-Villar, E. Grapevine-shoot stilbene extract as a preservative in red wine. Food Chem. 2016, 197, 1102–1111, doi:10.1016/j.foodchem.2015.11.102.
35. Raposo, R.; Chinnici, F.; Ruiz-Moreno, M.J.; Puertas, B.; Cuevas, F.J.; Carbú, M.; Guerrero, R.F.; Ortíz-Somovilla, V.; Moreno-Rojas, J.M.; Cantos-Villar, E. Sulfur free red wines through the use of grapevine shoots: Impact on the wine quality. Food Chem. 2018, 243, 453–460, doi:10.1016/j.foodchem.2017.09.111.
36. Ruiz-Moreno, M.J.; Raposo, R.; Puertas, B.; Cuevas, F.J.; Chinnici, F.; Moreno-Rojas, J.M.; Cantos-Villar, E. Effect of a grapevine-shoot waste extract on red wine aromatic properties. J. Sci. Food Agr. 2018, 98, 5606–5615, doi:10.1002/jsfa.9104.
37. Cruz, S.; Raposo, R.; Ruiz-Moreno, M.J.; Garde-Cerdán, T.; Puertas, B.; Gonzalo-Diago, A.; Moreno-Rojas, J.M.; Cantos-Villar, E. Grapevine-shoot stilbene extract as a preservative in white wine. Food Packag. Shelf Life 2018, 18, 164–172, doi:10.1016/j.fpsl.2018.10.008.

38. Marchante, L.; Loarce, L.; Izquierdo-Cañas, P.M.; Alañón, M.E.; García-Romero, E.; Pérez-Coello, M.S.; Díaz-Maroto, M.C. Natural extracts from grape seed and stem by-products in combination with colloidal silver as alternative preservatives to SO2 for white wines: Effects on chemical composition and sensorial properties. Food Res. Int. 2019, 125, 108594, doi:10.1016/j.foodres.2019.108594.

39. Pascual, O.; González-Royo, E.; Gil, M.; Gómez-Alonso, S.; García-Romero, E.; Canals, J.M.; Hermosín-Gutíerrez, I.; Zamora, F. Influence of grape seeds and stems on wine composition and astringency. J. Agr. Food Chem. 2016, 64, 6555–6566, doi:10.1021/acs.jafc.6b01806.

40. Cebrián-Tarancón, C.; Sánchez-Gómez, R.; Carot, J.M.; Zalacain, A.; Alonso, G.L.; Salinas, M.R. Assessment of vine-shoots in a model wines as enological additives. Food Chem. 2019, 288, 86–95, doi:10.1016/j.foodchem.2019.02.075.

41. Cebrián-Tarancón, C.; Sánchez-Gómez, R.; Cabrita, M.J.; García, R.; Zalacain, A.; Alonso, G.L.; Salinas, M.R. Winemaking with vine-shoots. Modulating the composition of wines by using their own resources. Food Res. Int. 2019, 121, 117–126, doi:10.1016/j.foodres.2019.03.032.

42. Miljić, U.; Puškaš, V.; Vučurović, V.; Razmovski, R. Acceptability of wine produced with an increased content of grape seeds and stems as a functional food. J. Inst. Brew. 2014, 120, 149–154, doi:10.1002/jib.123.

43. Barros, A.; Gouvinhas, I.; Machado, N.; Pinto, J.; Cunha, M.; Rosa, E.; Domínguez-Perles, R. New grape stems-based liqueur: Physicochemical and phytochemical evaluation. Food Chem. 2016, 190, 896–903, doi:10.1016/j.foodchem.2015.06.047.

44. Borges, M.S.; Biz, A.P.; Bertolo, A.P.; Bagatini, L.; Rigo, E.; Cavalheiro, D. Enriched cereal bars with wine fermentation biomass. J. Sci. Food Agr. 2020, doi:10.1002/jsfa.10664.

45. Hwang, J.Y.; Shyu, Y.S.; Hsu, C.K. Grape wine lees improves the rheological and adds antioxidant properties to ice cream. LWT Food Sci. Technol. 2009, 42, 312–318, doi:10.1016/j.lwt.2008.03.008.

46. Pundhir, A.; Sharma, A. K.; Banerjee, K.; Jogaiah, S.; Somkuwar, R. G. Improvement in functional, rheological and sensory properties of low sugar ice cream by adding fine wine lees. Progress. Hortic. 2018, 50, 118-123, doi:10.5958/2249-5258.2018.00028.3.

47. Sharma, A.K.; Kumar, R.; Azad, Z.R.A.A.; Adsule, P.G. Use of fine wine lees for value addition in ice cream. J. Food Sci. Technol. 2015, 52, 592–596, doi:10.1007/s13197-013-1007-x.

48. Ayar, A.; Siçramaz, H.; Öztürk, S.; Öztürk Yilmaz, S. Probiotic properties of ice creams produced with dietary fibres from by-products of the food industry. Int. J. Dairy Technol. 2018, 71, 174–182, doi:10.1111/1471-0307.12387.

49. Alarcón, M.; López-Viñas, M.; Pérez-Coello, M.S.; Díaz-Maroto, M.C.; Alañón, M.E.; Soriano, A. Effect of wine lees as alternative antioxidants on physicochemical and sensorial composition of

deer burgers stored during chilled storage. Antioxidants 2020, 9, 1–17, doi:10.3390/antiox9080687.

50. Vázquez-Armenta, F.J.; Silva-Espinoza, B.A.; Cruz-Valenzuela, M.R.; González-Aguilar, G.A.; Nazzaro, F.; Fratianni, F.; Ayala-Zavala, J.F. Antibacterial and antioxidant properties of grape stem extract applied as disinfectant in fresh leafy vegetables. J. Food Sci. Technol. 2017, 54, 3192–3200, doi:10.1007/s13197-017-2759-5.
51. Vazquez-Armenta, F.J.; Bernal-Mercado, A.T.; Lizardi-Mendoza, J.; Silva-Espinoza, B.A.; Cruz-Valenzuela, M.R.; Gonzalez-Aguilar, G.A.; Nazzaro, F.; Fratianni, F.; Ayala-Zavala, J.F. Phenolic extracts from grape stems inhibit Listeria monocytogenes motility and adhesion to food contact surfaces. J. Adhes. Sci. Technol. 2018, 32, 889–907, doi:10.1080/01694243.2017.1387093.
52. Gouvinhas, I.; Santos, R.A.; Queiroz, M.; Leal, C.; Saavedra, M.J.; Domínguez-Perles, R.; Rodrigues, M.; Barros, A.I.R.N.A. Monitoring the antioxidant and antimicrobial power of grape (Vitis vinifera L.) stems phenolics over long-term storage. Ind. Crop. Prod. 2018, 126, 83–91, doi:10.1016/j.indcrop.2018.10.006.
53. Guerrero, R.F.; Cantos-Villar, E. Demonstrating the efficiency of sulphur dioxide replacements in wine: A parameter review. Trends Food Sci. Technol. 2015, 42, 27–43, doi:10.1016/j.tifs.2014.11.004.
54. Chagas, R.; Ferreira, L.M.; Laia, C.A.T.; Monteiro, S.; Ferreira, R.B. The challenging SO2-mediated chemical build-up of protein aggregates in wines. Food Chem. 2016, 192, 460–469, doi:10.1016/j.foodchem.2015.07.052.
55. Gorena, T.; Saez, V.; Mardones, C.; Vergara, C.; Winterhalter, P.; von Baer, D. Influence of post-pruning storage on stilbenoid levels in Vitis vinifera L. canes. Food Chem. 2014, 155, 256–263, doi:10.1016/j.foodchem.2014.01.073.
56. Zwingelstein, M.; Draye, M.; Besombes, J.L.; Piot, C.; Chatel, G. Viticultural wood waste as a source of polyphenols of interest: Opportunities and perspectives through conventional and emerging extraction methods. Waste Manage. 2020, 102, 782–794, doi:10.1016/j.wasman.2019.11.034.
57. Siró, I.; Kápolna, E.; Kápolna, B.; Lugasi, A. Functional food. Product development, marketing and consumer acceptance-A review. Appetite 2008, 51, 456–467, doi:10.1016/j.appet.2008.05.060.
58. Engel, J.B.; Ambrosi, A.; Tessaro, I.C. Development of a cassava starch-based foam incorporated with grape stalks using an experimental design. J. Polym. Environ. 2019, 27, 2853–2866, doi:10.1007/s10924-019-01566-0.
59. Davis, G.; Song, J.H. Biodegradable packaging based on raw materials from crops and their impact on waste management. Ind. Crop. Prod. 2006, 23, 147–161, doi:10.1016/j.indcrop.2005.05.004.

60. North, E.J.; Halden, R.U. Plastics and environmental health: The road ahead. Rev. Environ. Health 2013, 28, 1–8, doi:10.1515/reveh-2012-0030.

61. Difonzo, G.; Troilo, M.; Squeo, G.; Pasqualone, A.; Caponio, F. Functional compounds from olive pomace to obtain high-added value foods-A review. J. Sci. Food Agr. 2021, 101, 15-26, doi:10.1002/jsfa.10478.

62. Engel, J.B.; Ambrosi, A.; Tessaro, I.C. Development of biodegradable starch-based foams incorporated with grape stalks for food packaging. Carbohyd. Polym. 2019, 225, 115234, doi:10.1016/j.carbpol.2019.115234.

63. el Achaby, M.; el Miri, N.; Hannache, H.; Gmouh, S.; ben youcef, H.; Aboulkas, A. Production of cellulose nanocrystals from vine shoots and their use for the development of nanocomposite materials. Int. J. Biol. Macromol. 2018, 117, 592–600, doi:10.1016/j.ijbiomac.2018.05.201.

64. David, G.; Michel, J.; Gastaldi, E.; Gontard, N.; Angellier-Coussy, H. How vine shoots as fillers impact the biodegradation of PHBV-based composites. Int. J. Mol. Sci. 2020, 21, doi:10.3390/ijms21010228.

65. Nanni, A.; Messori, M. Effect of the wine lees wastes as cost-advantage and natural fillers on the thermal and mechanical properties of poly(3-hydroxybutyrate-co-hydroxyhexanoate) (PHBH) and poly(3-hydroxybutyrate-co-hydroxyvalerate) (PHBV). J. Appl. Polym. Sci. 2020, 137, 48869, doi:10.1002/app.48869.

66. Nanni, A.; Messori, M. Thermo-mechanical properties and creep modelling of wine lees filled Polyamide 11 (PA11) and Polybutylene succinate (PBS) bio-composites. Compos. Sci. Technol. 2020, 188, 107974, doi:10.1016/j.compscitech.2019.107974.