OIV COLLECTIVE EXPERTISE

MANAGING BY-PRODUCTS OF VITIVINICULTURAL ORIGIN

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This document, drafted and developed on the initiative of the OIV, is a collective expert report. The images in this publication were taken in January 2018 at «Quinta das Faias» (Portugal), except the image on page 10: provided by António Graça.

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SCOPE

This report is intended to discuss the use and the definition of different types of by-products in vine producing areas worldwide.

Some questions of principle arise, such as:

- What are the by-products and sub-products obtained from vitivinicultural practices?
- What are their main applications and which ones are used in the agriculture industry?
- Are all production processes generating by-products and their possible applications widely known?

The following document was drafted by members of the Vine Protection and Viticultural Technics group (PROTEC) in collaboration with members of Viticulture Commission.

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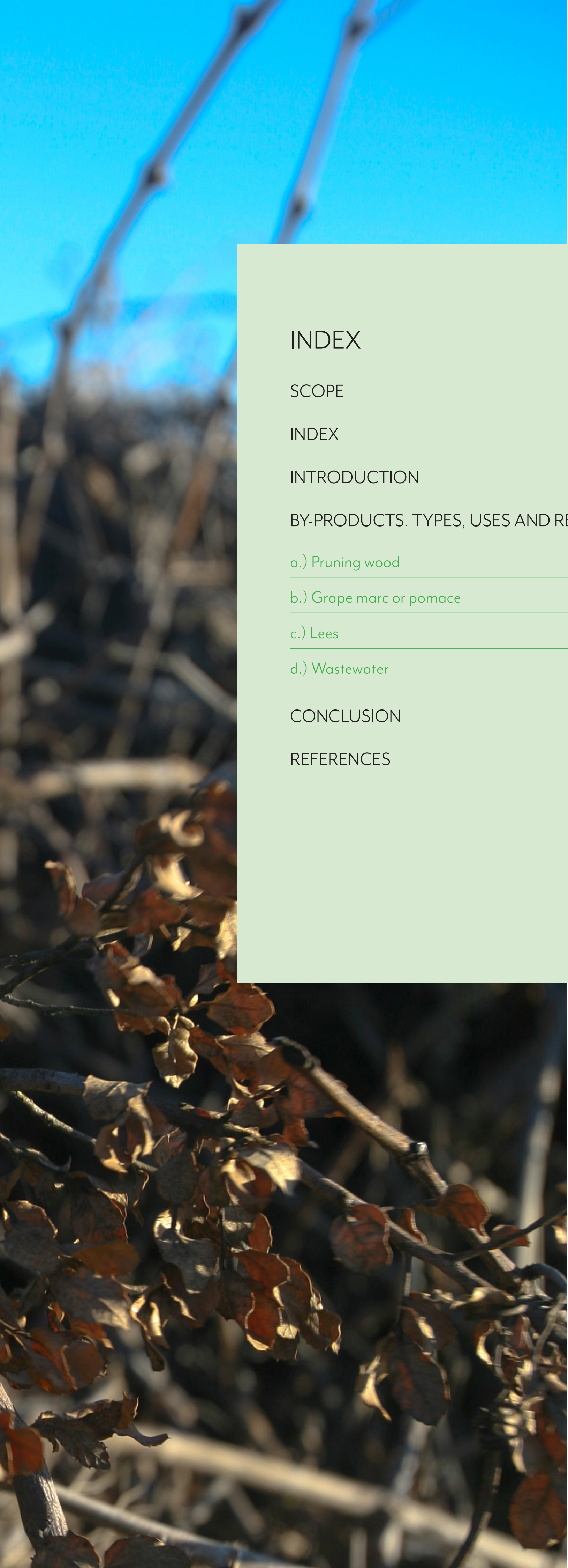

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INTRODUCTION

There is increasing interest in the valorization of secondary products generated at different points and stages of the production chain in the grape and wine industry. Discussions have taken place on a number of occasions at state and local government level about the accumulation of secondary products and their possible negative environmental impacts. In vitivinicultural regions that generate large volumes of secondary products, their removal is becoming not only an environmental and ecological problem, but also an economic one, which can reduce competitiveness of the entire sector. Chattopadhyay *et al*. (in Poonam Singh nee' & Pandey, 2009) estimated that the production of 100 Kt of must/ wine will cause 38.9 Kt of wine grape secondary products.

Definitions

By-products need to be defined with respect to their nature and use. However, it is often difficult to define them under legal rules or general frameworks. Qualitative description of each viticultural product has therefore been added to elucidate their limitations and potential.

These products can be classified as follows (Figure 1):

a.) Wastes

- Produced as a result of a vitivinicultural process and with a negative environmental impact.
- Not suitable for recycling or processing so as to obtain some added value.

b.) Residues

- Produced as a result of a vitivinicultural process and without a negative environmental impact.
- Not suitable for recycling or processing so as to obtain some added value.

c.) Sub-products

- Produced as a result of a vitivinicultural process and with or without a negative environmental impact.
- Suitable for recycling or processing so as to obtain some added value.

d.) By-products

- Produced as a result of a vitivinicultural process, but as a secondary product.
- With well-defined economic and industrial value (added value).

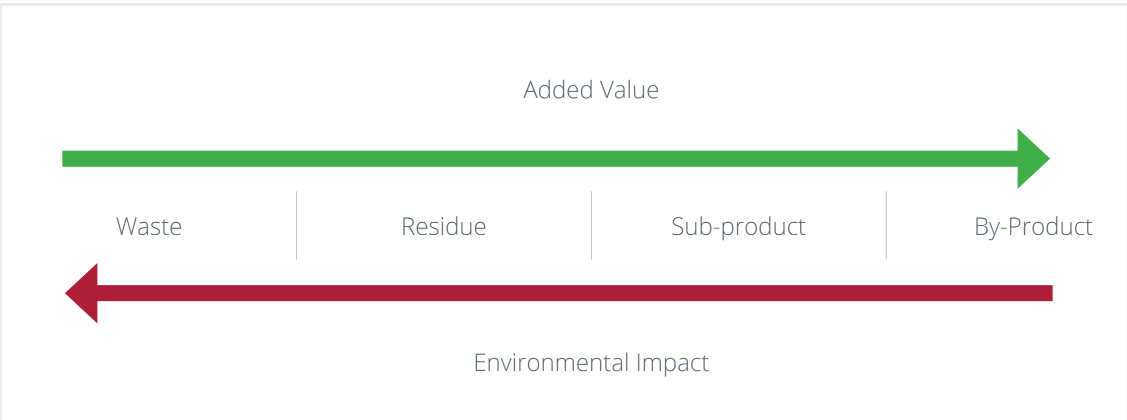


Figure 1. Vitivinicultural products and by-product classification (Source: Secretariat Viti OIV, 2014).

BY-PRODUCTS. TYPES, USES AND RECOMMENDATIONS

The main by-product from viticultural activity (Figure 2) is the pruning wood, which can be used to improve the organic matter directly in the vineyard or by compost process, or it can be converted into wood pellets for heating or electric energy production. The principle by-products in the winery are the grape marc, which comprises grape stalks, seeds and skins left after the crushing, draining and pressing stages of wine production, and lees (Jin and Kelly, 2009).

In order to describe these products, we distinguish the following sources, their uses and recommendations:

a.) Pruning wood.

Pruning residues are usually mulched and left in the field to increase the organic matter content and serve as a source of nutrients (Novello, 2014): these can improve soil texture and structure conditions. Sometimes the addition of these nutrients to the soil is termed as the unbalances in the structure of the soil, but the slow release during the decay process usually has no negative effects, some negative impacts are possible on soil biota or potential sorption of residual herbicides and pesticides, heavy metals, etc.).

Because the C/N ratio is lower compared to other compost resources, **pruning wood** composting or other wine residues have some environmental (lower impact) and agronomic advantages (presents a high and stable agronomic value). These advantages could be economically favourable since the use of synthetic fertilizers can be reduced (i.e. energy savings).

In some countries, burning these residues in the field is prohibited. It is potentially hazardous because of the release of cancerous compounds such as polycyclic aromatic hydrocarbons, and greenhouse gases. In order to decrease the environmental impact produced by this kind of residue, some researchers have proposed the use of pruning wood as a source of renewable sugars, which could then be converted into a variety of products (Devesa-Rey *et al*., 2011). Several biochemical and thermochemical processes have been proposed for this purpose, not only for obtaining sugars, but also to extract other components such as phenols and phenolic acids, which could be of considerable interest to pharmaceutical and agri-food companies.

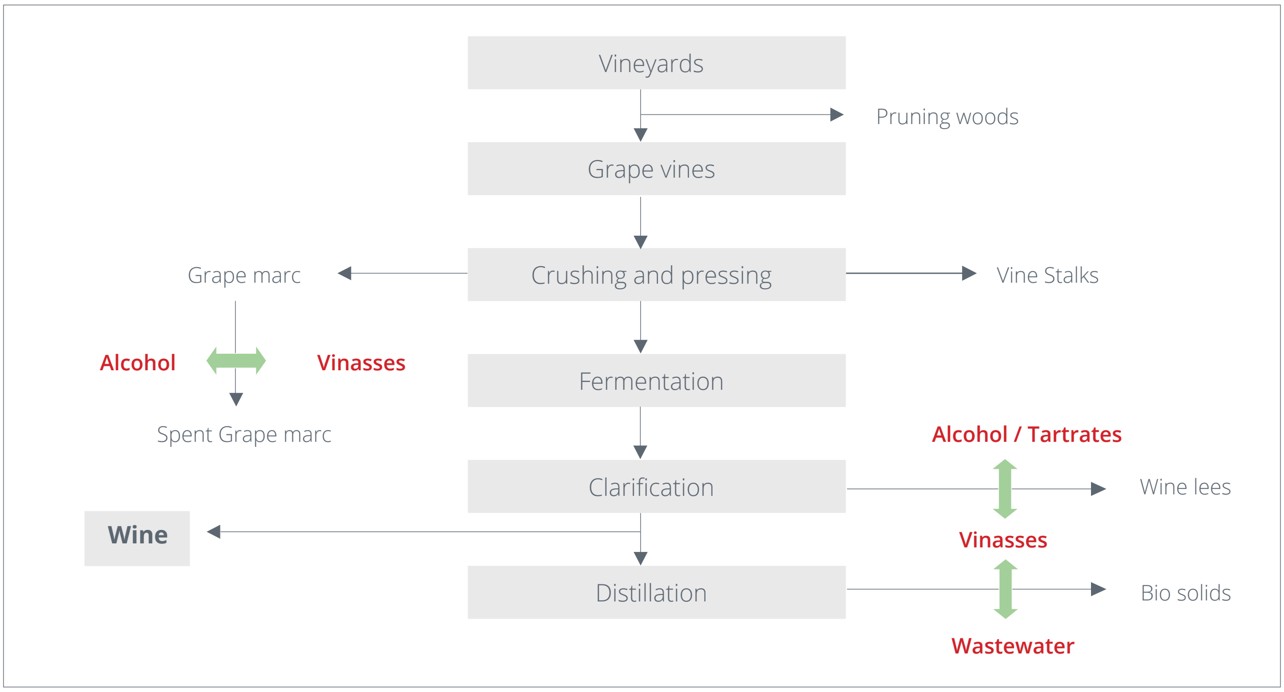
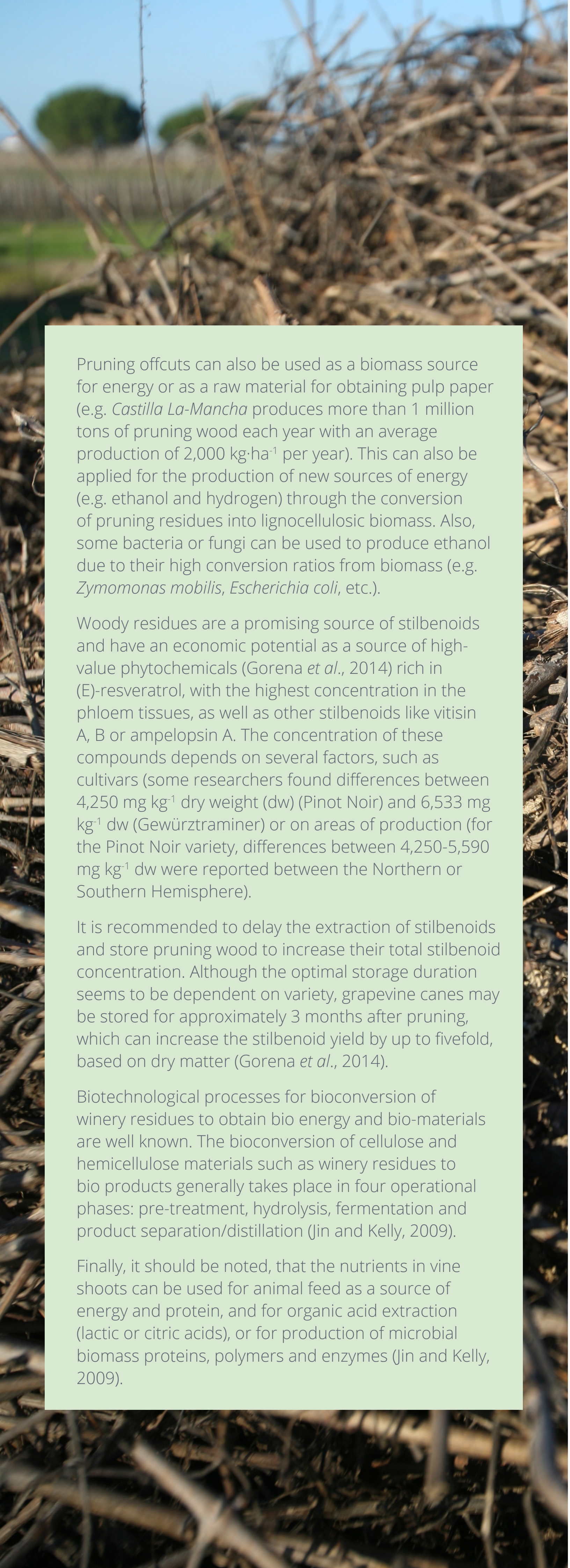


Figure 2. Vine, wine and distillations waste products (adapted from Jin and Kelly, 2009).



Pruning offcuts can also be used as a biomass source for energy or as a raw material for obtaining pulp paper (e.g. *Castilla La-Mancha* produces more than 1 million tons of pruning wood each year with an average production of 2,000 kg·ha^{-1} per year). This can also be applied for the production of new sources of energy (e.g. ethanol and hydrogen) through the conversion of pruning residues into lignocellulosic biomass. Also, some bacteria or fungi can be used to produce ethanol due to their high conversion ratios from biomass (e.g. *Zymomonas mobilis*, *Escherichia coli*, etc.).

Woody residues are a promising source of stilbenoids and have an economic potential as a source of high-value phytochemicals (Gorena *et al*., 2014) rich in (E)-resveratrol, with the highest concentration in the phloem tissues, as well as other stilbenoids like vitisin A, B or ampelopsin A. The concentration of these compounds depends on several factors, such as cultivars (some researchers found differences between 4,250 mg kg^{-1} dry weight (dw) (Pinot Noir) and 6,533 mg kg^{-1} dw (Gewürztraminer) or on areas of production (for the Pinot Noir variety, differences between 4,250-5,590 mg kg^{-1} dw were reported between the Northern or Southern Hemisphere).

It is recommended to delay the extraction of stilbenoids and store pruning wood to increase their total stilbenoid concentration. Although the optimal storage duration seems to be dependent on variety, grapevine canes may be stored for approximately 3 months after pruning, which can increase the stilbenoid yield by up to fivefold, based on dry matter (Gorena *et al*., 2014).

Biotechnological processes for bioconversion of winery residues to obtain bio energy and bio-materials are well known. The bioconversion of cellulose and hemicellulose materials such as winery residues to bio products generally takes place in four operational phases: pre-treatment, hydrolysis, fermentation and product separation/distillation (Jin and Kelly, 2009).

Finally, it should be noted, that the nutrients in vine shoots can be used for animal feed as a source of energy and protein, and for organic acid extraction (lactic or citric acids), or for production of microbial biomass proteins, polymers and enzymes (Jin and Kelly, 2009).

b.) Grape marc or pomace.

Most grape production is used for wine-making and the major solid by-product generated is grape marc or pomace. Grape pomace consists of three different components: seeds, stalks and skins left over after the crushing, draining and pressing stages of wine production. Grape marc is usually processed to produce alcohol and tartaric acid, and during this process a new ligno-cellulose by-product is formed called spent grape marc (SGM). The latter may be used as fuel for heating, as soil mulches and as organic amendments. It is a complex lignocellulosic material, one of the most abundant and worthless winery wastes, generated both in winery and distillery (e.g. washing grape marc to obtain alcohol and tartrates; European Regulation 479/2008) process (Moate *et al*., 2014). The chemical composition of grape pomace is rather complex: alcohols, acids, aldehydes, esters, pectins, polyphenols, mineral substances, sugars etc. are the most represented classes of compounds (Ruberto *et al*. 2008 in Mamma *et al*., 2009). Anthocyanins, catechins, flavonol glycosides, phenolic acids and alcohols and stilbenes are the principal phenolic constituents of grape pomace (Pinelo *et al*. 2006). Taking into account that about 34.7 MT of grape production worldwide (OIV, 2016) is used in winemaking and, wine-making generates grape pomace as a by-product estimated as 13% by weight of the grapes (Pinelo *et al*. 2006); approximately 5 million tons of grape pomace would need to be treated within a few weeks during the harvest to maximize its commercial value (FAOSTAT-FAO Statistical Database, 2005; Corbin *et al*., 2015). However, some polluting characteristics of these residues, such as low pH and a high content of phytotoxic and antibacterial phenolic substances, which resist biological degradation, could cause problems, although there might be technological solutions to them.

One of the main destination of the pomace is distillation (Novello, 2015). Besides distillation, grape pomace is most commonly used as fodder or fertilizer but others are exploring options of selling the used pomace to biogas companies for the creation of renewable energy.

Grape marc could also be used as a substrate by *L. pentosus* to produce lactic acid and along with organic solvents and/or supercritical carbon dioxide to extract phenolic compounds with antioxidant properties oil, or tannins, etc.

Grape pomace has also been found to be suitable for pectinase production by *Aspergillus awamori* (Botella *et al*. 2007 in Poonam Singh nee and Pandey, 2009).

Grape marc as a compost needs conditioning treatments, before its use for agricultural purposes, because it contains large amounts of organic matter and macronutrients (such as K), but also polyphenols, which may exert phytotoxic and antimicrobial effects. Their antioxidant and antimicrobial properties were considered to be of particular importance for application as natural food preservatives. Skin wine pomace, whole wine pomace and seed wine pomace products have shown useful to inhibit fat oxidation, which also suggests their potential applications in fatty food with a high tendency to rancidity, thereby extending their shelf life (García-Lomillo *et al*., 2014).

It is well known that the main by-product of viticultural activity is woody pruning of grapevines. The combined potential with winery byproducts, residues or wastes (i.e. lees cakes, spent grape marc or vinasse biosolids) in vermicomposting has been investigated using *Eisenia andrei* (Nogales *et al*. 2005 in Garg and Gupta, 2009).

Winery wastes show potential as raw substrate in vermicomposting technology, and feasibility of such wastes in large scale studies can be explored. Several classes of compost (vermicompost, mushroom compost, etc.) are currently developing and using nowadays.

Finally, there are other less known, but relevant, uses of grape pomace like the metal adsorption capacity of these substrates (e.g. Cd) or like biosurfactants. In recent years, grape marc has also been proposed as a raw material for bioenergy production (Toscano *et al*., 2013), and it has been used to generate butanol and biogas (Cáceres *et al*., 2012; Law and Gutierrez, 2013) or bioethanol (Rodríguez *et al*., 2010; Corbin *et al*., 2015), giving a polyphenol enriched fraction which can be used as a fertilizer or in animal feed.

In conclusion, grape pomace is produced in large quantities in wine production, probably with insufficient thought given to added commercial value, with the issue of disposal being an important environmental consideration.

Skins

Grape skins as by-products of the winemaking process are a good source of natural antioxidants. The antioxidant activity of the skin extracts exceeds that of the musts, because they contain less phenolic concentration. The anthocyanin fraction is the largest contributor to the antioxidant activity in the skins. Both, musts and skin extracts protect yeasts efficiently against oxidation, but especially if obtained from grapes dehydrated for a long time. Grape skin can be used as a natural source of antioxidants (López de Lerma *et al*., 2013).

Stalks

Stalks (anatomically the grape rachis) usually represent 12% of total amount of winery residues and contain high cation levels (K and Fe mainly), however some of them are potentially toxic components (e.g. Na and Pb). Therefore, conditioning treatments are needed, such as biodegradation activators (e.g. rests of hen droppings, pig litter, manure, urea, etc.) together with water and high temperature, before the stalks are used in biochar or bioenergy process. They can also be used for soil amendment (Bustamante et al., 2008), producing different effects depending on the soil type, such as modifying the soil salinity and the organic C mineralization. The C/N ratio of the residues is one of the most important factors in soil N dynamics due to the low N mineralization (immobilization) of grape stalks. However, this by-product can be used to protect the soil and conserve organic carbon (Novello, 2014).

Stalks can also be used for the production of human food and high-fiber feed, as bio-sorbents for removing Cr from aqueous solutions or for the recovery of phenols and phenolic antioxidants like p-hydroxybenzoic acid, which show certain anti-microbial, bacterial and fungal activity at low concentrations. So these extracts can be useful in the agro-food industry for diseases management.

Seeds

Alternatively, grape seed oil (for human consumption, industrial lubrication, etc.) and seed meal (for animal feed) could be produced from the marc. However, several works (Rose *et al*., 2009) suggest that the grape seed oil and the seed meal may contain unacceptably high levels of pesticides that were applied to the vines prior to harvest. Grape pomace has traditionally been used to produce grape seed oil, a practice that continues today in small amounts

A great range of products such as ethanol, tartrates, citric acid, grape seed oil, hydrocolloids, and dietary fiber are recovered from grape pomace (Schieber *et al*. 2001 in Mamma *et al*., 2009).

c.) Lees.

Wine lees accumulates at the bottom of wine fermentation tanks. This by-product is used to make alcohol and/or tartrates, resulting in solid lees cakes after their extraction. During alcohol production from the above by-products large quantities of viscous, acidic wastewaters known as vinasse are generated.

Lees can be used as a supplement in animal feed; substrate for lactic acid production; tartaric acid production; to control fungal phytopathogens (e.g. *Fusarium oxysporum* or *Trichoderma viride*); a source of protein rich fungal biomass or to produce plant growth substrates with other vine residues (canes, skins, etc.).

Additionally, yeast extract (not from lees directly) is an excellent nutritional source for many microorganisms. It also contains calcium tartrate, ethanol, pigments and β 1-3 glucans (Novello, 2014).

d.) Wastewater.

The wastewater generated from wine lees and grape marc is referred to as vinasses, and is characterized by a high content of solids composed mainly of dead yeast, grape pulp, skin and seeds (Devesa-Rey *et al*., 2011), but they have a variable composition along the season.

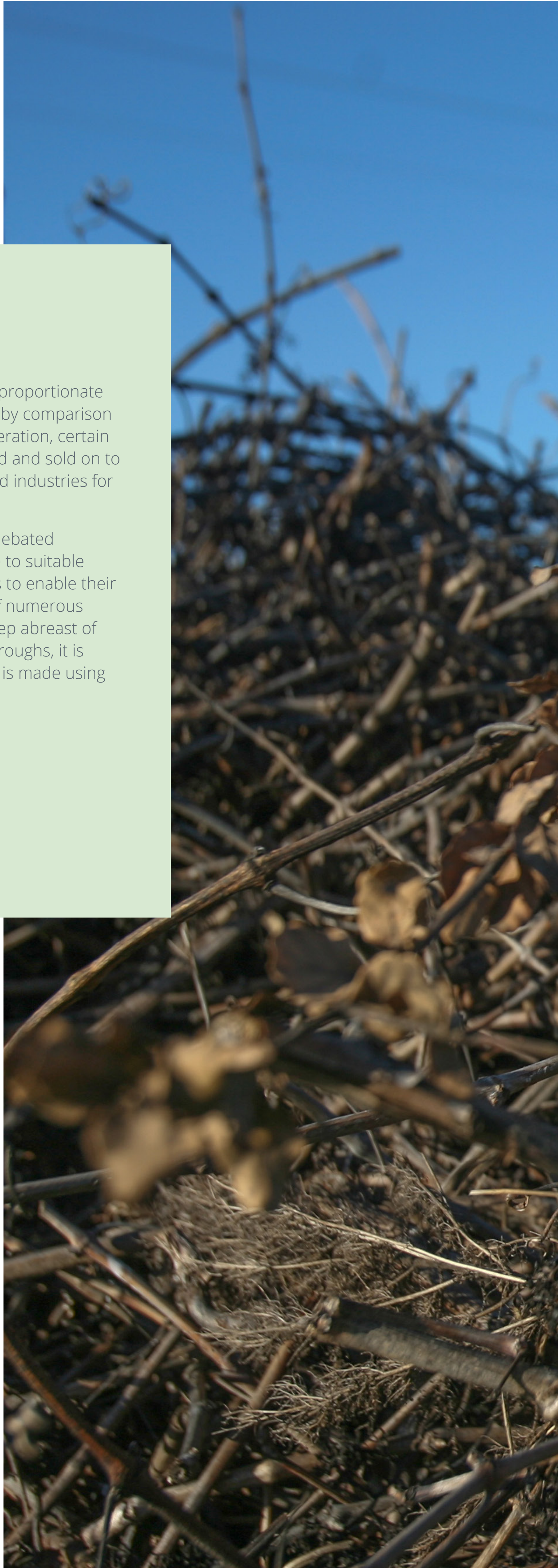
Wastewater usually comes from the discharges from grape crushing (solids and N, P, K) and pressing; transferring from/to tanks, cleaning (needs more sanitizing methods due to soda, chloride, etc.); bottling, and from other places in a winery such as floors, sidewalks or squares (Novello, 2014). Due to its high organic matter (OM) load, it is obligatory in many jurisdictions to purify or recycle wastewater before its application. The methods used for this process are biological depuration (constant air flux, high quantity of energy and water and high volumes of sludge); anaerobic digestion (less efficiency and sensitive to pH and temperature) and phytodepuration (low costs, quite efficient, biomass production, but high surface and long time is needed) are used for that. Its main agronomical use is to dilute pesticides for vineyard spraying (Novello, 2014) or for filling and washing of the sprayers.

Other uses are currently being studied in specific previous projects.

CONCLUSION

Although the global vitivinicultural sector contains a disproportionate number of small and medium sized enterprises (SMEs) by comparison with major businesses, it is clear that with better[1] cooperation, certain by-products with proven added value could be collected and sold on to other users such as the pharmaceutical and animal feed industries for further processing (Novello 2015).

In the first instance, it is suggested that the matter be debated with a view to identifying opportunities for adding value to suitable vitivinicultural by-products and for establishing markets to enable their proper distribution. As, currently, this topic is subject of numerous and intense research, it is advisable that, in order to keep abreast of recent developments, knowledge-creation and breakthroughs, it is recommended that a search for recent research works is made using online syndicating tools such as
Google Scholar
(https://scholar.google.pt),
Research Gate (https://www.researchgate.net),
CiteSeerX (http://citeseerx.ist.psu.edu),
WorldWideScience (https://worldwidescience.org/) or
Microsoft Academic (https://academic.microsoft.com).



[1] Following economic analysis, in many countries, collection systems have been successfully established with the dual aim of reducing landfill and benefiting the environment.

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