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Chapter

Introductory Chapter: New Challenges and Innovations in Grape and Wine Production

António M. Jordão

1. Introduction

According to the Report of Global Market Trajectory & Analytics [1], in 2022, the global market value for all wine styles (still, sparkling, and fortified) is expected to reach US$326.6 billion and keep growing at annual rates above 4%. Thus, grape and wine production is a very relevant agricultural activity and represents an important economic sector in the international trade. For wine, after the year of 2020 where there was a large trade disruption world over, the lifting of restrictions due to the COVID-19 pandemic has set the world wine export market on its path to reconciliation. According to the OIV statistics published in 2022, it was possible to obtain in 2021 a value of 111.6 mhl for world wine exports. This was the largest exported volume of wine ever recorded in history. At the same time, world wine exports in 2021 have increased by 4% compared with 2020 and have boosted even more in terms of value with 34.3 billion EUR, registering a yearly increase of 16% [2]. This large economic increase results from a global area of vineyards estimated at 7.3 mha in 2021. This area compared with 2020 shows a very slow decrease of −0.3%. In addition, all this world area under vines refers to the total surface area planted with vines for all purposes (wine and juices, table grapes, and dried grapes), including young vines that are not yet productive.

It is important to note that grape and wine sectors are not only relevant in economic terms but also historically and culturally. In fact, since antiquity, grape is one of the earliest domesticated fruit crops and has been widely cultivated and appreciated for its fruit and wine. Moreover, there is evidence that grapevine cultivation and winemaking dating back to at least 5800 BC [3]. According to Myles et al. [4], grapevine cultivation emerged in the Near East before spreading to Europe and subsequently for other parts of world. In recent years, this historical and cultural richness has also been the object of a strong economic use, namely through wine tourism.

Therefore, despite the economic relevance and long historical past, the production of grapes and wine faces a high number of challenges that lead to an increasing commitment to innovation and sustainability of the entire production chain. Thus, there are several challenges, such as a change in production methods through a reduction in the use of crop protection products and an increase in biocontrol solutions and biostimulants in the different practices of viticulture. On the other hand, the production of wines using a proper identification of the coadjutants used and the reduction in the use of several products with a negative impact on human health, namely the use

of sulfur, are other challenges. However, one of the most important challenges of wine industry is related with climate change, particularly through global warming and its impacts on grapevines and their characteristics. In fact, global warming is responsible for many of the problems facing winegrowers around the world. The impact of climate change is currently responsible for several problems in all world regions, such as early grape harvests that are becoming increasingly common. In this case, grape harvesters must work in extremely hot weather conditions, resulting in more frequent breaks and production losses and, at the same time, higher sugar content in the grapes. This last consequence induces a production of wines with higher alcohol levels and at the same relevant changes in the wines' aromas. In addition, early bud break (as early as March) is weakening the vine stock, exposing it to a greater risk of frost until April or even May. Also, frequent droughts and reduced water availability have led to an increase in vine plant destruction. Furthermore, there are also new challenges related with human resource for winegrowers. Thus, in many regions, particularly in Europe, there is a reduction in the available labor force. Consequently, the hiring of foreign workers is an increasing trend, especially for the works in viticulture and during the grape harvest. The future at this level could involve the increasing use of vine robots, thus reducing the necessary work force, but also allowing for an increasing precision viticulture. The use of vineyard robots, which is still uncommon practice around the world, offers several advantages. In that case, robots make tasks less difficult, optimize working time (winegrowers can devote their time to activities with more added value), and increase the profitability.

Finally, new challenges related with the sustainability and circular economy are presented to the wine industry. If compared with other chains, the wine industry is considered of low environmental impact [5]. According to OIV (International Organization of Vine and Wine), sustainable vitiviniculture is defined as a "*global strategy on the scale of the grape production and processing systems, incorporating at the same time the economic sustainability of structures and territories, producing quality products, considering requirements of precision in sustainable viticulture, risks to the environment, products safety and consumer health and valuing of heritage, historical, cultural, ecological and landscape aspects.*" Thus, from this definition, the sustainability of wine sector includes diverse aspects of organic, biodynamic, and integrated production, but at the same time also incorporates the history, the culture, the landscape, and all intangible aspects that characterize the wine production and consumption. In addition, the progress in grape and wine production also has a strong component in the circular economy, where the use of waste and its recovery also present increasing challenges. In a simple way, the circular economy is based on a general idea where waste coming from an activity should be passed to another activity with an important valorization on an infinite loop. Thus, from the vineyard and from the wine production process, various residues can be valued, for example, pruning residues, stalks, pomace, and lees. From these residues, several advances have emerged through the introduction of various technologies, making it possible to develop and obtain various products, such as pellets, biomass, alcohol, biogas, grape seed oil, tartaric acid, and several bioactive compounds (resveratrol, tannins, etc.) used in food and pharmaceutical industries.

2. Innovations in grape and wine production

Without innovative developments over innumerable generations, wines as we know them would not exist. Over the last few years, several innovations have been

introduced in the production of grapes and wines. In viticulture, the innovations produced have included the introduction of new production techniques (including different viticultural practices and a better use of water resources) with a view to improving the profitability of grape production and dealing with climate change, the use of new strategies to combat diseases and pests, the development of hybrid grape varieties (including new varieties) well adapted to the new environmental conditions, and also the introduction of new technologies linked to precision viticulture. All these developments try to answer to four fundamental objectives: improvement in the quality of the grapes, reduction in the production costs through mechanization, protection of the environment, and response to climate change.

In terms of soil management, there are several works where a combination of different techniques, such as chemical weeding, soil tillage, and cover-cropping [6, 7], has been developed. In addition, it is well known that an adequate nitrogen supply of the grapevines was proved to play a key role in plant fertilization, and at the same time, nitrogen deficiency could impair the wine quality [8]. In addition, high grape nitrogen deficiencies also affect fermentation kinetics and wine flavors [9]. Thus, several innovative works ranging from plant biology to factors linked to N regulation have been conducted to contribute to the implementation of sustainable practices in the vineyards.

Currently, the management of available water is essential for the sustainability of agricultural activity and consequently for the viticulture. Thus, several innovations have been introduced in terms of rational water management in vineyards. These innovations involve the use of drought-tolerant and drought-resistant rootstocks, a correct canopy management, an adequate irrigation strategy, the use of different sensors for better water management (e.g., the use of electromagnetic induction sensors), and the introduction of remote sensor technologies [10]. In addition, several studies reported that moderate water restriction in vineyards is also favorable for the wine quality [11].

For vine training, a special interest was given to the winter pruning, keeping in mind the respect for the sap flows and trying to limit the expansion of several diseases, namely the wood diseases. Thresholds of leaf/fruit ratios were established and the canopy management during the summer, such as leaf removal and shoot tipping, was adapted accordingly. Related with vine diseases, in recent years there has been a rapid development of strategies to combat these sanitary problems in vineyards based on the use of biocontrol products. Thus, the practical combat has included the use of natural products of mineral, plant, or microbial origin, the implementation of strategies related with the antagonistic microorganisms, and the use of plant defense inducers. All these strategies have contributed to reduce viticulture's dependence upon synthetic fungicides [12, 13].

Also related with the use of new plant material more resistant to disease and drought, the use of hybrids in viticulture is currently being discussed. The introduction of this new grapevine plant material introduces new perspectives to reduce the use of pesticides and increase the adaptation of vines to climate change [14].

In the winery, the recent developments of sensor technologies offer the possibility to control all the relevant parameters for a correct winemaking process and to guarantee a high quality of wine produced. These new technologies help winemakers to have a set of information in real time, not only during fermentation but also during wine aging, which help them to make the best decisions throughout the wine production process. Recently, new knowledge about the fermentation process has led to the introduction of strong innovations in wine production processes. In the

past, *Saccharomyces* spp. yeasts were almost the only option for used during alcoholic fermentation. This was due to the high ability to metabolize all grape juice sugar into ethanol. However, several results proved that also the use of *non-Saccharomyces* strains can improve the wine quality. In this context, the use of these new strains of yeasts contributes positively to improve the wine acidity, aromatic complexity, contributing at the same time for low levels of acetic acid and ethanol produced, among other positive effects [15]. Thus, in the past years, the main manufactures started to commercialize dry non-*Saccharomyces* strains in the market of oenological products containing different yeast species (e.g., *Torulaspora delbrueckii*, *Schizosaccharomyces pombe*, and *Pichia kluyveri*).

In recent years, due to greater control over alcohol consumption in some countries (related with health problems associated with the consumption of alcoholic beverages), as well as due to new trends in wine consumption, several techniques have been developed for the reduction of ethanol content in wines with excessive alcohol content [16]. In addition, climate change has also contributed in some warmer regions to the production of grapes with excessive amounts of potential alcohol. Also related with the effects on health because of the consumption of alcoholic beverages, several studies have been carried out for the production of wines with reduced sulfur content (or even sulfur free), but at the same time maintaining the wine quality. Thus, several alternative technologies have been developed and compared, such as pulsed electric fields (PEF), high-pressure processing (HPP), power ultrasound (US), ultraviolet irradiation (UV), high-pressure homogenization (HPH), filtration, and low electric current (LEC). All these technologies have been explored with the aim to obtain adequate microbial inactivation and at the same time maintaining the wine quality [17].

To induce better performance to clarify and stabilize wines, new natural, non-allergenic, and non-animal fining agents have been developed by the different manufactures helping winemakers to obtain wines with high quality [18]. At the same time, recent developments in filtration technologies have been introduced to help winemakers to reduce the problems of precipitation of unstable proteins present in white wines after bottling. This problem can cause cloudiness, which is generally considered commercially unacceptable [19].

Finally, for wine aging, different technologies and winemaking practices have also been developed. Several options have been made available, such as wine aging using wood fragments, combination of micro-oxygenation with wood fragments, different options in wine aging on lees, the improvement of wine aging in bottles, and mechanisms in acceleration of wine aging using different technologies (physical methods involving ultrasonic waves, gamma rays, electric fields, nanogold photocatalysis, and high-pressure treatments) [20].

In conclusion, all these challenges contribute to the continuous innovation in the production of grapes and wines and the consequent concern with their quality and at the same time increase in the sustainability in all production chains. Together, consumer and market demands are increasing, thus inducing the necessary investment in constant innovation.

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Author details

António M. Jordão[1,2]

1 Polytechnic Institute of Viseu, Agrarian Higher School, Viseu, Portugal

2 Chemistry Research Centre of Vila Real (CQ-VR), Vila Real, Portugal

*Address all correspondence to: antoniojordao@esav.ipv.pt

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