ENERGY SAVING IN WINEMAKING: IMPACT OF ALCOHOLIC FERMENTATION

OIV

AUTHORS

Adriaan OELOFSE (ZA)
Antonio MORATA (ES)
Carmen GONZALES CHAMORRO (ES)
Claudine DEGUEURCE (FR)
Fabienne REMIZE (FR)
Hatice KALKAN YILDIRIM (TR)
Manfred GROSSMANN (DE)
Patrizia ROMANO (IT)
Shalamitsky MAXIM (RU)
Tiziana NARDI (IT) – Coordinator of the Working Group
Vladimir JIRANEK (UK)

COORDINATORS

Neslihan IVIT, OIV Oenology & Methods of Analysis Head of Unit
Jean-Claude RUF, OIV Scientific Coordinator

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OIV - International Organisation of Vine and Wine
Hôtel Bouchu dit d'Esterno
1, Rue Monge
F-21000 Dijon - France www.oiv.int
E-mail: oenologie@oiv.int

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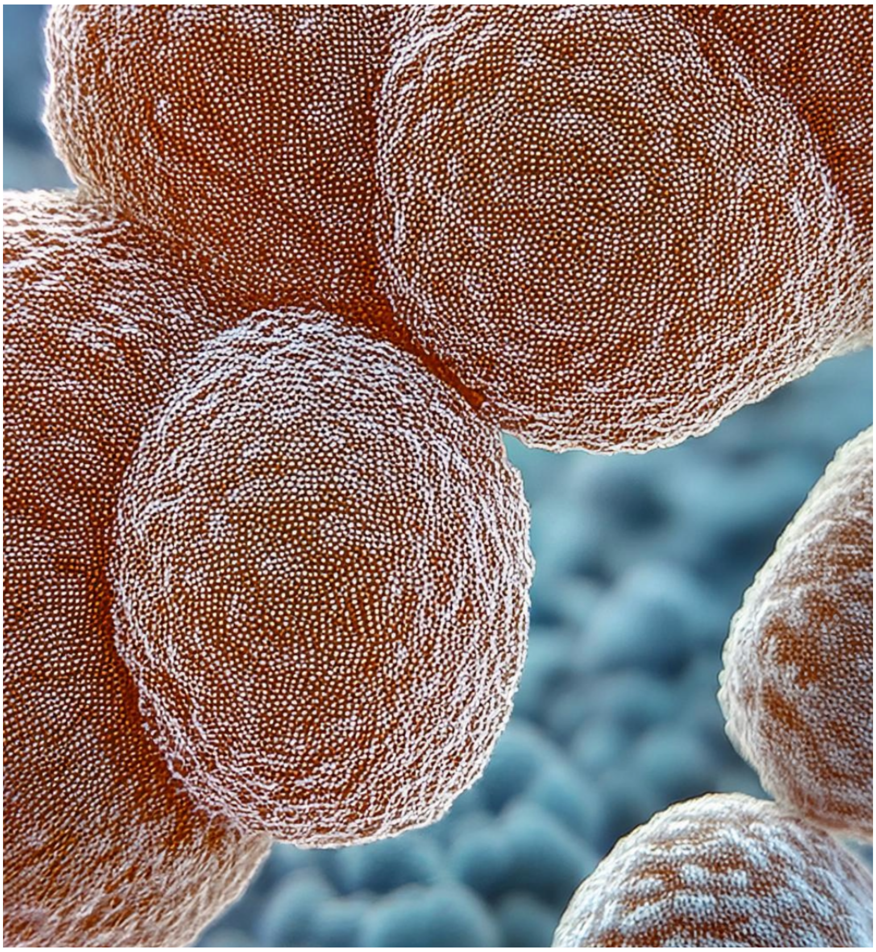
BACKGROUND

According to Axis 1 of the OIV Strategic Plans 2020-2024 "Promote environmentally friendly vitiviniculture", one role of the OIV is to evaluate production methods to implement solutions that limit the use of inputs and improve environmental performance in vitiviniculture (II.B.7). More precisely, in the hereunder instance, to collect and disseminate scientific information and encourage research on the use of microbial resources for improving sustainability in winemaking.

The Microbiology Expert Group recognized the importance of having information on the aforementioned topic, and that many aspects should be taken into account. A working group was established, coordinated by Italy and including France, Germany, Spain, South Africa, Russia and the General Secretariat of the OIV to prepare a literature review on the research advances on energy savings achievable during the fermentation processes in winemaking. The working group further considered the discussion paper during several sessions.

This document does not attempt to cover all the issues and facts in detail, but rather to outline the applications of temperature increase in fermentation, by highlighting some of the information currently available for wine production.



SCOPE OF THE DOCUMENT

The aim of this document is to assemble in a single document the main important elements on the impact of exploiting microbial resources to reduce the expenditure of energy of the winemaking process, and some of the recent studies conducted on this topic, namely those focusing on microbial transformations such as fermentations.

INTRODUCTION

Several programs for wine life cycle assessment have recently started to account, among other inputs used along the winemaking phases, equivalent emissions for electricity consumption in the vinification phase, which is in turn influenced by microbial transformations and their management **[1–3]**. This notwithstanding, the lack of knowledge of energy efficiency opportunities, provides an important obstacle to improving efficiency, even though many operators in the wine sector are interested in innovative approaches for energy saving [4].

Heat removal significantly impacts energy demand in the winery and is related to the temperature control of wine tanks during the fermentation process and the wine maturation phase. The majority of the electricity used by wineries (about 90%) is consumed by refrigeration systems for process cooling, that is, fermentation control, cold stabilization, and cold storage [5,6]. The fermentation process takes place at a controlled temperature for quality purposes, to which the wine needs to be cooled at the beginning of fermentation and throughout the process; and the fermentation reaction also generates heat that needs to be removed [5]. Overall, fermentation temperature control accounts for as much as 45% of the total energy demand of wineries [7,8].

ENERGY SAVINGS AND ALCOHOLIC FERMENTATION

Regarding alcoholic fermentation, it is known that different fermentation management systems lead to wines with different characteristics depending upon yeast strain, fermentation temperature, oxygen and nitrogen management [9–11]. The exploitation of microbial resources to improve sustainability of the winemaking process, nonetheless, is a very recent approach and only a few research studies have addressed it [2]. Indeed, only a few works addressed the quantification of required heat dissipation during alcoholic fermentation, coupling innovative thermal protocols with rationally chosen yeast strains [2,4,8].

Yeasts and wine aroma at different temperatures

The literature has extensively described the effect of temperature on yeast metabolism during wine fermentation [2]. In the last decade, however, it has been recognized that the effect of low temperature on yeast aroma production varies greatly for different strains of yeast *Saccharomyces cerevisiae*. In fact, it is not universally true, as we tended to think years ago, that only at low temperatures there is a high production of aromas by all yeasts: the results in the available literature are various and not always consistent one with each other. This is easily comprehensible if we examine the conditions under which the different researchers conducted their experimental trials: as shown in Table 1, in fact, the yeast strains tested are different, as well as the aromatic families analysed and the must conditions used (varieties, sugars, assimilable nitrogen, sometimes synthetic must). In addition, the 2 or 3 temperatures tested in each scientific work show rather high differences between them, as appropriate in research studies in which even "extreme" situations are compared.

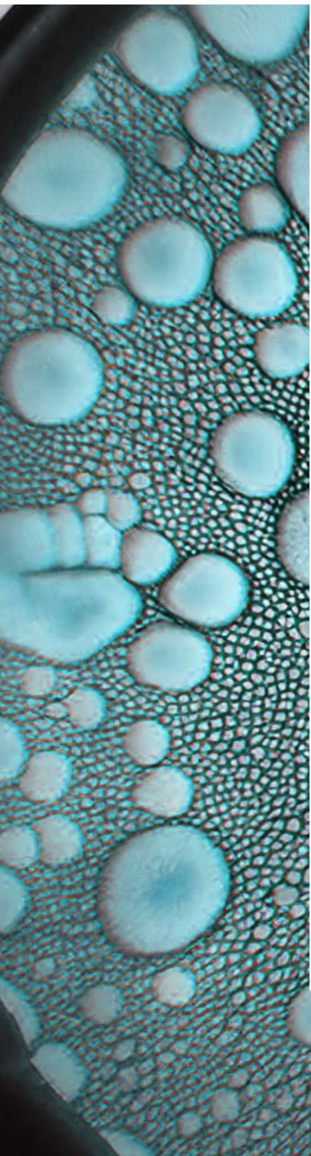
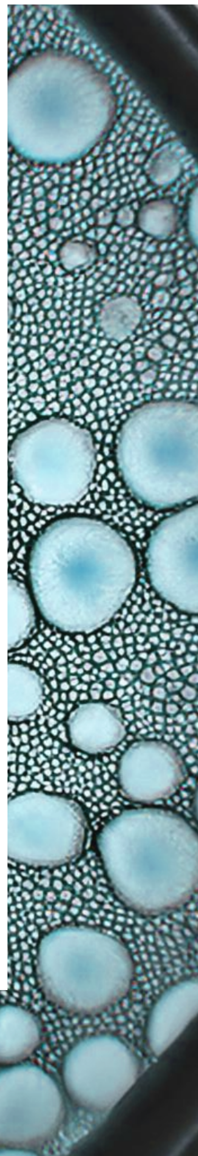
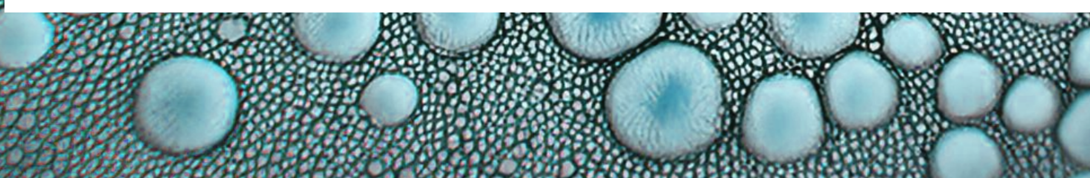




TABLE 1 - Conditions tested in the main scientific studies investigating the impact of temperature on the production of yeast aromas in alcoholic fermentation.

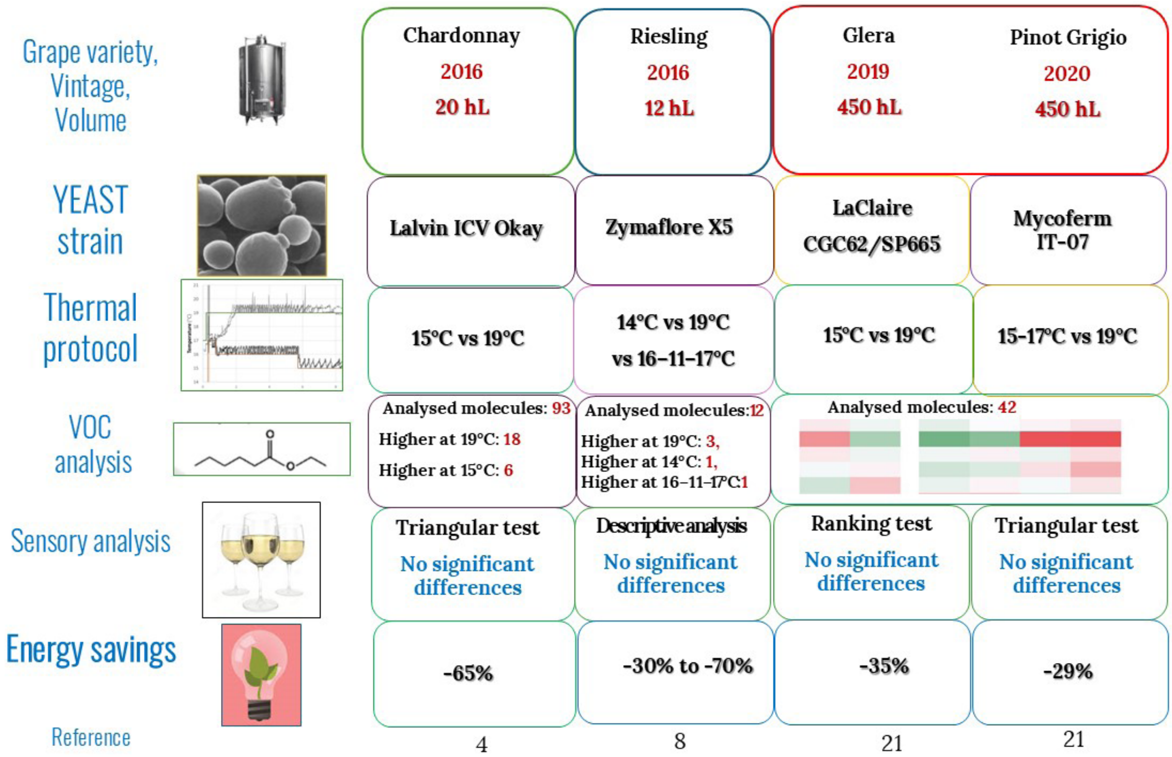
Publication	Temperature	Yeast strains	Size	Must	Aromatic molecules
Torija et al. 2003[12]	13°C vs 25°C	S. *cerevisiae* A e B, S. bayanus C	2l	Concentrated must diluted, pH 3.70, SO2 55 mg/L	Fermentative
Masneuf et al. 2006 [13]	13°C vs 20°C vs 24°C	VL3, VIN13, X5, H9	1l	Synthetic must, YAN 190 mg/L	Thiols
Beltran et al. 2008 [14]	13°C vs 25°C	QA23	80l & 1l	Moscatel, YAN 205 mg/L, synthetic must, YAN 300 mg/L	Fermentative
Molina et al. 2007 [15]	15°C vs 28°C	EC1118	1l	Synthetic must, YAN 300 mg/L	Fermentative
Gobbi et al., 2013 [16]	20°C vs 30°C	*Lanchancea thermotolerans* 101 + *S.cerevisiae* EC1118 (combination)	2l	Sangiovese cultivar, must 224g/L	Fermentative (spicy aroma)
Deed et al. 2017 [17]	12.5°C vs 25°C	EC1118, L-1528, M2, X5	1l	Sauvignon blanc, YAN 281 mg/L	Gene transcription
Rollero et al. 2015 [18]	20°C vs 24°C vs 28°C	K1M, EC1118, FC9, D47, ECA5	1l	Synthetic musts, different YAN	Fermentative
Massera et al., 2021[19]	15°C vs 25°C	Autochthonous, TANGO, VL3	80l	Merlot, YAN 182 mg/L	Varietal, fermentative
Du et al., 2022 [20]	10°C vs 15°C vs 20°C	AWRI796, QA23, F15, EC1118, ZX11	250ml	Synthetic must YAN 350 mg/L, Chardonnay	Fermentative

Imagining being in the cellar, on the other hand, the interest shifts to a more moderate temperature variation, so that even a modified thermal protocol still falls within the typical fermentation parameters of white wines. It is with this in mind that dedicated experiments have been conducted in recent years, in which the aim was to quantify the energy savings obtained in white vinification (sparkling wine bases or still wines) following a temperature increase of 3-4°C compared to the usual protocol.

In a first study conducted in 2016 by CREA (Italian Council for Agricultural Research and Economics) in collaboration with the University of Milan [4], the effect of fermentation temperature on the production of Chardonnay sparkling wine was tested. Fermentation was conducted at a temperature 4°C higher than the winery standard, i.e. 19°C instead of 15°C. Fermentations at the two temperatures were monitored for the quantification of the energy consumption, time of opening and closure of valves was also recorded, and the comparative evaluations were performed on the cooling fluid flow time of circulation. The results showed that the increase in temperature resulted in energy savings of about 65%, without compromising the quality of the wine. In particular, no significant differences were found in the main chemical parameters of the wine, nor in the sensory characteristics (triangular test with forced choice). In another study conducted in 2019 by a research group in Germany [8], the effect of fermentation temperature on the production of Riesling base wine was tested, comparing fermentations at 19°C, 17°C and 14°C. The results confirmed those of the previous study, showing that the increase in temperature produced maximal energy savings of about 70% (19°C vs 14°C), without compromising the quality of the wine. Finally, a third study was conducted on an industrial scale at larger volumes by the CREA - University of Milan group, and recently published [21], to give robustness and confirmation to the previously acquired data. In this study, conducted in 2019 and 2020, grapes of the Glera and Pinot Grigio varieties were used, the musts were fermented in 450 hL tanks, the energy savings varied in this case between 30 and 35%, always with confirmed oenological and sensory results. Overall, 4 different strains of selected dried yeasts were employed in the different studies, all properly showing a stable metabolism towards temperature change, in terms of oenological performances and aromatic profile.

It should be considered that temperature is one of the key parameters that influences the aromatic quality of wine during alcoholic fermentation and also significantly affects the efficiency of fermentation and the production of aromas by the different strains of S. cerevisiae. Therefore, the optimized results are also associated with the choice of the suitable starter culture that is capable of giving the expected aromatic results and fermentation performance.

Figure 1 • Effects of different thermal protocols on volatile organic compounds (VOCs), sensory properties, and energy savings during alcoholic fermentation of Chardonnay, Riesling, Glera, and Pinot Grigio using specific yeast strains..



POTENTIAL IMPACT OF ENERGY-SAVING PROJECTS ON WINE PRODUCTION

Overall, data from the studies reported show that the use of appropriately chosen selected yeasts and properly reasoned fermentation protocols can allow significant energy savings in white winemaking, without compromising the quality of the wine. These results suggest that wineries can adopt a more sustainable winemaking process with low energy consumption and that this choice may have a relevant impact on white-winemaking energy consumption, as tested for instance in the Italian context.

Indeed, the potential widespread of those effects was investigated through a survey involving several wineries: among others, questions about vinification volumes, usual fermentation temperatures and attitude towards energy saving innovations were asked to winemakers. Data coming from a first wide sample of wineries (n>120) are currently analysed [22,23]. Overall, around 80 % of a sample of winemakers representing an overall production of 1.300.000 hL, declared a willingness to increase their usual fermentation temperature if research data support energy saving expectations without compromising wine quality. The disposition to adopt more sustainable fermentation protocols by the interviewed winemakers confirms the interest of this research topic in order to provide more and more data to enable winemakers to implement innovative thermal protocols for energy saving purposes.

CONCLUSION

In this document, different approaches and applications regarding energy savings related to fermentation in winemaking are expressed. A rational and sustainable energetic approach towards fermentation management is outlined, together with its scope, microorganisms used, and their characteristics and thermal protocols employed. A summary of results obtained so far, opening to further potential applications, is provided with their corresponding references. As the range of yeast strains available for oenology is continuously evolving, and the same applies to technological tools for fermentation management, the latest advancements need to be followed and evaluated when their application is considered for wine production.

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