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SHORT COMMUNICATIONS

In a fully dealcoholised Chardonnay wine, sugar is a key driver of liking for young consumers

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ABSTRACT

Alcohol-free wines are generally sweetened with around 40 g/L of added sugar to counterbalance sourness, which can be perceived as being excessive in such beverages. For young consumers who would consume alcohol-free products for health purposes, high levels of sugar could be an obstacle. The aim of this work was to investigate this target consumer's appreciation of fully dealcoholised Chardonnay wines containing different levels of added sugar (0, 5, 10, 20 and 40 g/L). The results showed that liking significantly increased with sugar content, and that acceptability was only achieved in the sample containing 40 g/L of added sugar, with a liking score of between 5 and 6 on a 9-point scale. Liking scores were not affected by *gender*, *information provided* to panellists (specifically that they were evaluating alcohol-free wines), and *level of wine knowledge*. Those who gave the highest scores were occasional wine drinkers and daily soft drink consumers. Conversely, non-wine consumers and non-soft-drink drinkers gave lower liking scores. Though these insights need to be confirmed on more samples of fully dealcoholised wine, they can assist winemakers in developing alcohol-free products and in targeting the right young consumers.

KEYWORDS: dealcoholisation, spinning cone column, white wine, appreciation, sweetening, young consumers

INTRODUCTION

The global wine industry is currently experiencing a crisis due to a combination of events. Over the last decade, not only has the wine trade had to recover from the COVID-19 pandemic and a change to regulations concerning gifts and public expenses in China, but it has also suffered from the invasion of Ukraine in 2022, which led to a severe energy crisis, notably in Europe, a steep increase in inflation, and a decrease in household income and thus wine demand (Del Rey and Loose, 2023).

This crisis has been particularly felt in developed and traditional wine-making countries such as France, Italy and Spain, which have been facing a decrease in per capita apparent consumption for several decades now (Villanueva and Ferro, 2022). This decline is particularly marked for young people, who are seeking to reduce or stop their alcohol consumption for health purposes or out of fear of addiction (Caluzzi *et al*., 2021).

As a result of the success of beer without alcohol and a need to re-stimulate the market (Anderson, 2023), there is an increasing interest in alcohol-free (no) or in a lesser extent in reduced-ethanol (low) wines, known as NOLO wines (Shaw *et al*., 2023). A limited number of physical processes for fully dealcoholising wine, such as reverse osmosis or thermal distillation (vacuum distillation or spinning cone column), are presently available (Pickering, 2000; Sam *et al*., 2021; Silva, 2024).

The elimination of ethanol in wine is known to induce a decrease in viscosity, in body and fullness, while increasing tannin aggressiveness (Jordão *et al*., 2015; Longo *et al*., 2017; Schmitt and Christmann, 2022). Depending on the technology used, such ethanol removal can reach up to 20 % of the initial wine volume, and also contribute to concentrating non-volatile compounds, such as polyphenolics or organic acids (Belisario-Sanchez *et al*., 2009). However, consumers generally do not perceive the difference between a wine with a moderately reduced ethanol concentration (≈ 9 % v/v) and a standard wine (Masson and Aurier, 2008; Meillon *et al*., 2010). The most complete study to date on the subject established that the consumer rejection threshold (CRT) is 2.8 and 7 % v/v for Chardonnay (white) and Syrah (red) wines respectively (Geffroy *et al*., 2022), indicating an overall better acceptation of lower alcohol in white wines than in red wines.

Though the regulations regarding the term "dealcoholised wine" are still under debate by the International Organisation of Vine and Wine (OIV) and European Union, dealcoholised wine must be made using practices already authorised for wine. A product that has received an addition of glycerol or exogenous flavours cannot bear this denomination and must be labelled "beverage made from dealcoholised wine". In both cases, one of the most common strategies for re-balancing the in-mouth sensations of ethanol-free wines is sweetening using sucrose (Schmitt *et al*., 2023). Indeed, a benchmark study conducted in February 2024 on 99 commercial references of such products, which are available for purchase online in France, reported them to have an average sugar content of 40.9 ± 17.3 g/L (M. Podworny, unpublished).

When applying the caloric values of sucrose (4 kcal/g) and ethanol (7 kcal/g), as proposed by the Food and Agriculture Organization (FAO), and the volumetric mass of ethanol at 20 °C (789 g/L), the energy uptake supplied by a 100 mL-glass can be estimated as being 16 and 72 kcal for an alcohol-free wine sweetened at 40 g/L and a dry wine at 13 % v/v respectively.

However, despite this nutritional advantage and health-related motivation for consuming alcohol-free wines, concern is being expressed by some consumers, notably those of the younger generation, regarding the negative impacts of sugar intake on body image, notably on weight (Joo *et al*., 2017). Therefore, these levels of sugar could become an obstacle.

The main aim of this work was to investigate young consumer appreciation of reduced sugar concentrations in fully dealcoholised Chardonnay wines, young consumers being a promising target market for fully dealcoholised wines (Filter and Pentz, 2023). Taking into account the consumers' negative *a priori* previously reported for reduced-alcohol wines (Masson and Aurier, 2008; Pickering, 2000; Vasiljevic *et al*., 2018), the impact of the information given to the consumers was assessed as well. It was also hypothesised that the frequency of soft drink consumption would modulate the liking of the tested products, as demonstrated in previous work (Jayasinghe *et al*., 2017), highlighting the relationship between sweet taste intensity and intake and hedonic liking.

MATERIAL AND METHODS

1. Fully dealcoholised wine

The fully dealcoholised wine used for the study was obtained from a Chardonnay base wine representative of wine made in the South of France in the Protected Geographical Indication (PGI) Pays d'Oc. The base wine was sourced from a local cooperative cellar and was characterised by floral notes and a good overall balance in the mouth. Ethanol content was determined by ebulliometry (Dujardin-Salleron, Noizay, France). All the other factors were determined using a Winescan™ (Foss France SAS, Nanterre, France) revealing the following values: alcohol 13.8 % v/v, titratable acidity (TA) 5.3 g/L expressed as tartaric acid, pH 3.39 and residual sugar below 2 g/L.

To produce a fully dealcoholised Chardonnay wine, 200 L of this base wine were treated through spinning cone column (SCC) technology using a pilot plant model SCC1,000 (Flavourtech, Reading, United Kingdom). A first run was conducted at a feed flow rate of 300 L/h at 33 °C to recover an extract of the aroma with the highest volatility. In a second run, dealcoholisation on the aroma-reduced retentate was carried out at 100 L/h and 42 °C. External stripping rates (ESRs), which represent the percentage of the initial volume removed following treatment, were estimated as 1.3 % for the first run and 33.0 % for the second. After these two runs, the ethanol concentration of the retentate was below 0.1 % v/v and thus considered as null, while that of the aroma fraction was 47.2 % v/v.

TABLE 1. Composition of the samples containing different concentrations of sugar tasted by the young consumers during the study. Quantities are given in mL for a 750-mL bottle.

Fraction	Added sugar concentration				
	0 g/L	5 g/L	10 g/L	20 g/L	40 g/L
Fully dealcoholised wine	495.8	495.8	495.8	495.8	495.8
Aroma fraction	8.0	8.0	8.0	8.0	8.0
Distilled water	246.2	241.8	237.4	228.6	210.9
Rectified grape must	0.0	4.4	8.8	17.6	35.3

Five wine products containing different levels of added sugar (0, 5, 10, 20 and 40 g/L) and 0.5 % v/v of ethanol were obtained by mixing the fully dealcoholised wine, aroma fraction, distilled water and rectified grape must concentrate (850 g/L; Grap'Sud, Cruviers-Lascours, France) in the proportions shown in Table 1. As commercial alcohol-free wines are generally deacidified or reformulated to decrease the sensation of acidity (Schmitt et al., 2023), the decision was made to add distilled water to compensate for the concentration effect and improve the mouth-feel balance. Before water addition, TA and pH were 6.65 g/L (expressed as tartaric acid) and 3.27 respectively, and after water addition they were 5.10 g/L and 3.29 respectively. An informal tasting session organised by a group of four experts confirmed that the resulting wines were of good aromatic quality and were generally well-balanced, including the control sample that was not sweetened.

All the samples produced were analysed for their sugar content using the previously described method, and these analyses confirmed that the targeted concentrations had been reached.

2. Data acquisition

A convenience panel composed of 143 French young consumers (89 female and 54 male) with a mean age of 20.9 years ± 2.5 was recruited from the École d'Ingénieurs de Purpan in Toulouse, France. No ethics approval was obtained, but all participants were asked to provide written informed consent prior to participating in the study. Eighty-six participants were informed they were about to evaluate alcohol-free wines, while the remaining fifty-seven did not receive any information. The detailed composition of the two-subgroups is shown in Table 2.

The tasting session took place in a neutral room and the spacing between the panellists ensured that no communication could occur. The samples were coded with a three-digit code and served using a Williams' Latin square design. A constant volume of 40 mL was poured at 18 °C in clear wine-tasting glasses. Consumers were asked to indicate their overall liking on a 9-point hedonic scale from 1, *I really dislike*, to 9, *I really like*.

After the tasting, the panellists had to provide demographic information and to respond to questions regarding their wine experience and knowledge, consumption behaviours for wine (regular and fully dealcoholised), soft drinks (juice and soda) and sugar using the questionnaire shown in Data S1.

3. Data treatment

The liking score was first analysed through a five-way ANOVA (added sugar concentration x information provided x gender x wine knowledge x frequency of wine consumption x frequency of soft drink consumption) with first-order

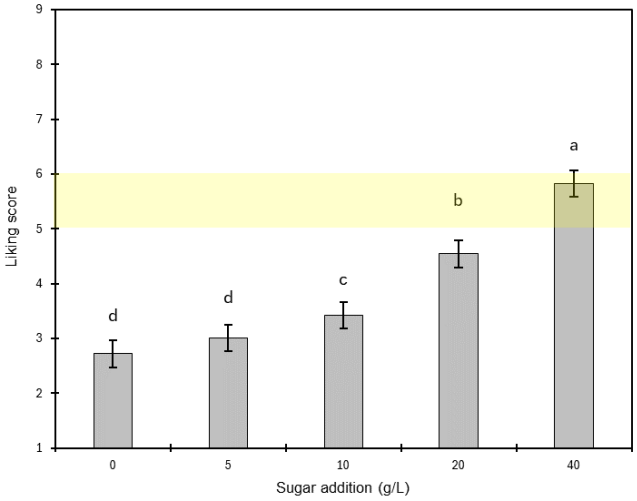


FIGURE 1. Impact of level of sugar addition on liking score (mean values ± 95% confidence interval). Different letters indicate means significantly different at $P < 0.05$ by Fisher's test. The yellow area on the graph represents the 5 to 6-point threshold of acceptance proposed by Francis and Williamson (2015).

TABLE 2. Age and years of experience in wine (regular and fully dealcoholised), soft drinks (juice and soda) and sugar consumption behaviours, for the sub-group of panellists that received or did not receive information.

Category		Informed (n = 86)	Not informed (n = 57)
Gender	Male (n = 54)	36	40
	Female (n = 89)	64	60
Age		21.1 ± 3.1	20.7 ± 0.9
Years of experience in wine consumption		4.6 ± 2.8	4.3 ± 2.5
Wine knowledge	No knowledge (n = 49)	33	37
	Interested, basic knowledge (n = 89)	64	58
	Passionate (n = 5)	3	5
Frequency of wine consumption	Several times a week (n = 32)	22	23
	Once a week (n = 57)	43	35
	Once a month (n = 15)	9	12
	Occasionally (n = 32)	21	25
	Never (n = 7)	5	5
Frequency of soft drink consumption	At least once a day (n = 17)	15	7
	Several times a week (n = 41)	24	35
	Once a week (n = 25)	19	16
	Occasionally (n = 54)	38	37
	Never (n = 6)	4	5
Had previously tasted a fully dealcoholised wine once	Yes (n = 17)	13	11
	No (n = 126)	87	89
Claim to control their sugar intake in their everyday life	Yes (n = 67)	45	49
	No (n = 76)	55	51
In comparison with a standard wine of the same quality, the amount they claim to be willing to spend for a fully dealcoholised wine	Less (n = 101)	70	72
	The same amount (n = 41)	29	28
	More (n = 1)	1	0

interactions using XLSTAT version 2022.4.1 (Addinsoft, Paris, France). As no significant interaction was observed, the model was rerun without first-order interactions.

RESULTS AND DISCUSSION

The level of sweetening had a significant effect on liking ($P < 0.0001$) with a gradual increase in score observed depending on added sugar concentration (Figure 1). This finding is consistent with a previous research conducted in Germany on a fully dealcoholised Riesling wine using a ranking test and a limited number of panellists (Schmitt *et al*., 2023). It is also somewhat consistent with another recent study that showed that young consumers are more likely to accept wines edulcorated with erythritol and rebaudioside than a dry control sample (Geffroy *et al*., 2024). Surprisingly, no significant differences were observed between the control sample and the sample sweetened at 5 g/L. It can be assumed that panellists in our study did not perceive any difference between the two samples despite sweetness thresholds having been determined at around 5 g/L in white wines (Blesić *et al*., 2021). However, as the overall balance completely differs between standard and alcohol-free wines, such threshold values are not very transposable.

It should be noted that the sample sweetened at 40 g/L is the only one that reached the 5 to 6-point threshold proposed by Francis and Williamson (2015), indicating overall acceptance. This could be a key finding for winemakers, as it reinforces the sweetening strategy used for alcohol-free wines and shows that a reduction in sugar concentrations would negatively affect acceptation. It is also worth considering that higher sugar additions (*i.e*., 60, 80 or 100 g/L) would have led to extremely different results, with either an increase or a decrease in liking. Indeed, consumer behaviour and responses are difficult to predict, as it has been demonstrated that liking

TABLE 3. Impact of demographic, information and consumption variables: significance and mean liking scores. Different letters indicate significant differences at $P < 0.05$ by Fisher's test.

Variable	*P* value	Mean liking	
Information provided	0.573	No (n = 57)	3.90 a
		Yes (n = 86)	3.90 a
Gender	0.060	Male (n = 54)	4.03 a
		Female (n = 89)	3.82 a
Wine knowledge	0.383	No knowledge (n = 49)	3.99 a
		Interested, basic knowledge (n = 89)	3.77 a
		Passionate (n = 5)	3.72 a
Frequency of wine consumption	< 0.001	Several times a week (n = 32)	3.69 b
		Once a week (n = 57)	3.95 ab
		Once a month (n = 15)	4.08 ab
		Occasionally (n = 32)	4.19 a
		Never (n = 7)	2.80 c
Frequency of soft drink consumption	< 0.0001	At least once a day (n = 17)	4.59 a
		Several times a week (n = 41)	3.75 b
		Once a week (n = 25)	3.72 b
		Occasionally (n = 54)	3.90 b
		Never (n = 6)	3.03 c

usually increases with sugar content, and reaches an optimum before decreasing at high sucrose concentrations (Daillant and Issanchou, 1991). Respondents were not asked to freely comment on what they liked or disliked about each tasted sample, and the contribution of the sweetness perception in overall liking was not investigated. Other sensory drivers of liking, such as the perception of sourness and the aqueous in-mouth perception, might also play a role (Jordão *et al*., 2015; Longo *et al*., 2017; Schmitt and Christmann, 2022).

The impact of demographic variables and consumption habits on liking scores is shown in Table 3. Unexpectedly, the information given to the consumers prior to tasting had no effect on their appreciation, which contradicts previous work that highlighted negative *a priori* towards wines with reduced ethanol concentrations (Masson and Aurier, 2008; Pickering, 2000; Vasiljevic *et al*., 2018). However, despite the sample with the highest sugar concentration being generally well-accepted, most of the consumers (70 %) claimed they were willing to spend less, while a minority (30 %) said they would to spend the same amount and even fewer that they would spend more (1 %) on a dealcoholised wine of the same quality as a standard wine. Nevertheless, this price positioning appears difficult to achieve given the costs associated with dealcoholisation treatments and the loss in volume generated by ethanol removal which is not always compensated for, despite the fact that such alcohol-free beverages can benefit from a lower value-added tax (VAT) rate in most countries compared to standard wines. It should also be pointed out that, in our case, the severe losses of more than 30 % of the initial volume could have been reduced through further distillation of the distillate.

Although no significant differences in liking score was observed between the male and female panellists at $P < 0.05$, males showed a tendency for better acceptability than females. This could be related to differences in sensory perception or cognition-based factors. A few studies have investigated the impact of gender on taste perception, with the most consistent work finding that sourness was perceived as being stronger by the females than by the males (Hyde and Feller, 1981). As such taste might be particularly pronounced in our samples, it cannot be excluded that this higher sensitivity resulted in female panellists having a lower liking. Another hypothesis could be that the observed difference is due to females having greater neophobia, as has been previously reported (Lopes *et al*., 2006), especially for those in the group that received information. However, in the present study, this is unlikely as the risk related to *gender* did not decrease upon removal of the subjects who did not receive any information ($P = 0.255$) from the ANOVA model.

Based on previous research (Pickering, 2000), we expected the consumers with the greatest wine knowledge, namely those who claimed they were passionate about wine in our study, to exhibit a more pronounced attitude of "snobbishness" towards these beverages. However, level of wine knowledge did not significantly impact the liking score.

Among the findings regarding the impact of frequency of wine consumption, of particular interest is the significant difference in liking between those who claimed they never consume wine and those who occasionally consume wine. The lower score observed for non-wine consumers is a key finding for winemakers and the wine industry, as it indicates that these consumers should not be targeted for alcohol-free wines. In contrast to occasional drinkers, young non-wine

consumers might simply reject standard dealcoholised wines for intrinsic taste reasons or negative *a priori*.

A significant relationship was expected between *added sugar concentration* and *frequency of soft drink consumption*; *i.e*., that the panellists who frequently consume soft drinks would give higher scores for the samples sweetened at the highest concentrations, as has been found in previous research (Jayasinghe *et al*., 2017). However, no such relationship was observed. Independently of level of sweetening, the panellists who gave the highest marks were those who consume soft drinks at least once a day, while those who were the most adverse were non-soft drink consumers. This suggests that alcohol-free white wines have similarities with juice and soda, some beverages being generally characterised by sugar concentrations of around 100 g/L and a pH of between 3.00 to 3.50 (Reddy *et al*., 2016; Walker *et al*., 2014). Though the samples tested in our study had a pH in the same range and a lower sugar concentration even for the most sweetened ones, the perceived sweetness and sweet/sour balance might not strongly differ to that of soft drinks, particularly sodas that are highly carbonated, considering that carbon dioxide can suppress the perception of sweetness (Hewson *et al*., 2009). This warrants future research into young soda drinkers' perception of sparkling alcohol-free wines, a category of dealcoholised wine that is highly available on the market.

The study was mainly sensory based, and the only information given to some of the panellists was the fact that they were tasting alcohol-free wines. It cannot be excluded that other types of information, such as sugar intake or the calories associated with each sample (*i.e*., information provided on the back labels of these types of beverages), could lead to distinct responses.

It is worth noting that the panel used for this study was a convenience sample consisting of French students in agricultural sciences who had similar social and cultural backgrounds, and in some cases family members working in the wine industry. Consequently, different results might have been obtained, if the study had included French consumers with more varied characteristics.

The base wine in the study was selected for being representative of Chardonnay produced within the PGI Pays d'Oc; however, our results are only valid for a specific fully dealcoholised wine obtained through SCC, and for which the concentration effect was compensated through water addition. Therefore, it would be worth verifying the results in further research on wines exhibiting distinct levels of sourness. In the same way, the appreciation of sucrose in alcohol-free red wines warrants exploration, since 1) the reduction in ethanol of these wines is known to strongly increase aggressiveness (Geffroy *et al*., 2022), and 2) residual sugars are almost completely absent in red wine.

CONCLUSION

This work shows that sugar is a key driver of liking in a fully dealcoholised Chardonnay wine. Acceptability, which was measured using a score of between 5 to 6 on a 9-point liking scale, was only reached for the sample spiked with 40 g/L of sugar, a level of sweetening commonly implemented in the industry for such beverages. Among the studied factors, the liking scores were not found to be impacted by *gender, information given* to the subjects and level of *wine knowledge*. The panellists who gave the highest liking scores were those who claimed to consume wine occasionally and soft drinks at least once a day. Conversely, lower liking scores were recorded for non-wine consumers and non-soft-drink drinkers. These preliminary findings could help winemakers formulate alcohol-free wines and target the appropriate young consumers.

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