Why do grape-based fruit wines could be "super" magic?

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Indroduction

The wine World should reflect in front of the global wine consumption statistics of the last fifteen years; indeed, in Europe, the consumption of wine is decreasing [1]. New alternatives of wine have been appearing on the market and the attractiveness of these products relies on the fact that they are inexpensive and easy to drink, with medium alcohol content (from 8% to 10.5%) and obtained blending wines and fruit juices or flavoring wines with artificial or natural aromas (red lollipop, peach, grapefruit, mandarin or black currant). In ancient China, alternative alcoholic beverages from hawthorn fruit, rice, and honey mead were already produced as early as ca. 7,000 BC [2]. The final products originated by non-grape musts are call "fruit wines"; they show different taste and nutritive values potentially providing numerous health benefits. More recently, fruits like apple, apricots, berries, cherries, currants, peach, pear, plum, strawberries, etc., have also been used for the production of alcoholic beverages [3]. Although fruit wines represent an ancient art, there are no scientific studies available that describe the production of beverages that are obtained by the co-fermentation of grape and fruit.

General aims

The formulation of new grape-based fruit wines could represent the basis for reducing post-harvest fruit losses and contribute to the economy of the existing wine industry. Actually, many of the fruits are consumed fresh, but some quantities of harvested fruits are wasted, overall during peak harvest periods. Therefore, the winemaking from fruit juice could be intended as an alternative to exploit the surplus of over-ripe fruit volumes for generating additional revenues for the fruit growers. Throughout the selection of useful yeasts that drive the alcoholic fermentation, the final products could be enriched in novel active bio-functional compounds not found in traditional wines as occurs in fruit wines [3]. The present study reports the results of the co-fermentation of grape musts and kiwi juice (*Actinidia chinenesis* var. Gold).

Production of grape-based kiwi wines

Alcoholic fermentations (AF) were triggered inoculating pure cultures of *Saccharomyces cerevisiae* EC1118 or *Torulaspora delbruekii* UMY196 yeast strains in four mixed-musts prepared by blending grape musts (Chardonnay and Cabernet Sauvignon) and kiwi juices at different proportion; grape:kiwi must 20:80 (v/v) and 40:60 (v/v). Experiments were carried out in duplicate in flask (200 mL) at 25±1°C. Batch fermentations (0.6 L) with grape:kiwi must 40:60 (v/v) inoculating *T. delbruekii* UMY196 were carried out in triplicate at 25±1°C. AFs in flasks and batch experiments were daily monitored by weight loss and they were considered completed when no weight changed was observed after two days. As far the batch cultures, while the contents of sugars (glucose and fructose) and ethanol were monitored during the AF. The aroma profile and the sensory evaluation was performed on final products.
A further microvinification trial was carried out with Cabernet Sauvignon must and kiwi juice in proportion 60:40 (v/v) fermented with *T. delbrueckii* UMY196. Lager volumes (4 L) were produced in triplicate following the same procedure described as above. The fermentation temperature was set at 18±1°C. The cell enumeration, content of sugars (glucose and fructose), total acidity, pH and organic acids were determined. Qualitative sensory analysis was carried as well as the test of consumers' acceptance.

Grape:kiwi fermentations

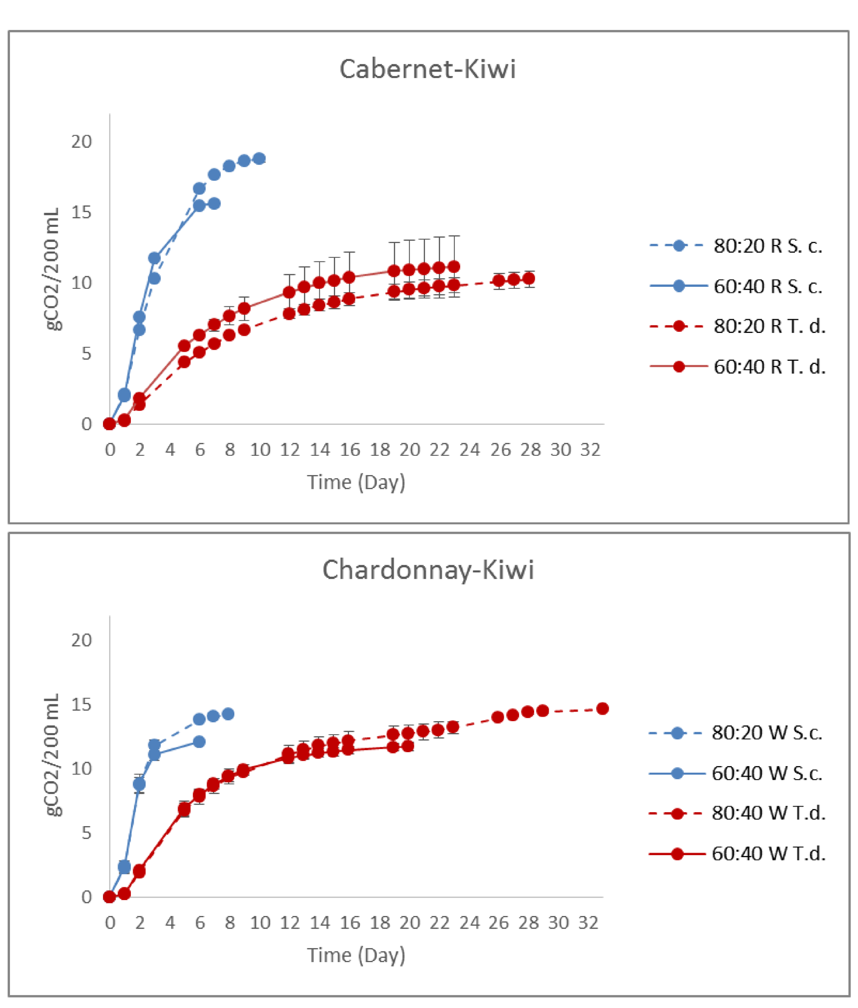

Figure 1. *Alcoholic fermentation trend in flask experiments.*

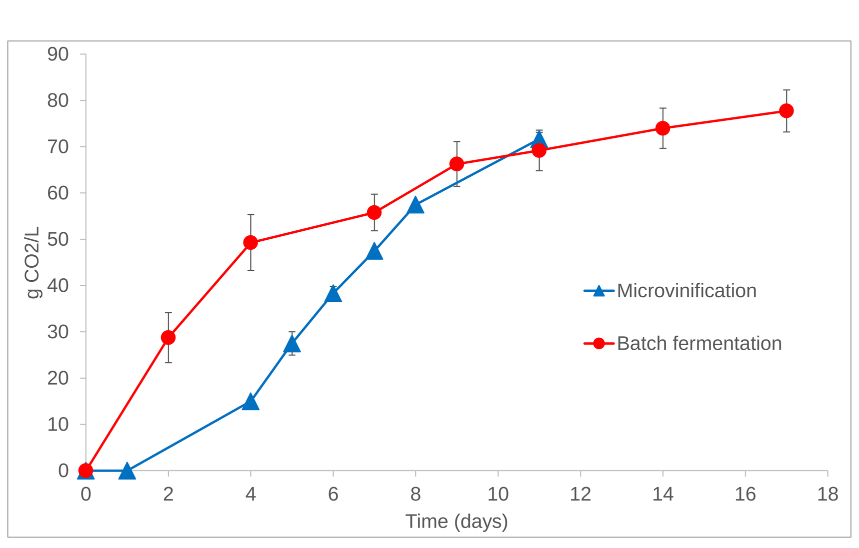

Figure 3. *Alcoholic fermentation trend in batch fermentation and microvinification experiments.*

Fermentation trials performed in flasks showed that each tested yeast species maintained a similar growth rate in both grape:kiwi must proportions that were assayed (Figure 1). As expected, *S. cerevisiae* completed the fermentations earlier than *T. delbruekii* (6-10 days versus 20-33 days, respectively). Moreover, *S. cerevisiae* was the most performing strains in terms of fermentative vigour (gCO_2 produced in 48h, 7.5 ± 1.0g). Regarding the fermentative power, it produced up to 10.8 and 9.6 g/L of ethanol in the musts with Cabernet Sauvignon grape and kiwi juice at proportions 80:20 and 60:40, respectively, depleting the available sugars (about 167 g/L). Due to a low initial sugar content of about 136 g/L in Chardonnay grape and kiwi juice, *S. cerevisiae* released 8.7 and 7.6 g/L of ethanol at the end of the AF of the musts at 80:20 and 60:40 ratios, respectively. *T. delbruekii* released 2.0 ± 0.4 g of CO2 in two days of fermentation in all the analysed musts. In both the proportions of Cabernet Sauvignon grape and kiwi juice, about 33% of the available sugars were not consumed bringing to a final alcohol amount of about 6.5 g/L. On the contrary, *T. delbruekii* exhausted the sugars in Chardonnay grape and kiwi juice with an ethanol production comparable to the one obtained for *S. cerevisiae* in the same growth condition (9.1 and 7.4% (v/v) of ethanol at the end of the AF of the musts at 80:20 and 60:40 ratios, respectively). Only small differences were found in pH values that ranged from 3.2 to 3.5 for the must 60:40 with Cabernet Sauvignon, while the total acidity resulted higher when the Chardonnay must was used. The content of tartaric acid was comparable among musts and wine; on the contrary, malic acid was higher in must and wine obtained with Chardonnay must. Moreover, the proportion 60:40 showed higher concentrations of citric acid related to the kiwi juice in which it was 16.2 ± 0.8 g/L.
Since sensory analyses indicated that the tests prepared in Cabernet Sauvignon grape and kiwi juice at the 60:40 ratio with *T. delbruekii* were the most equilibrated products as the residual sugars balanced the acidity (Figure 2), further batch fermentations and microvinifications were planned to verify a possible scale-up of the winemaking process (Figure 3). Results confirmed the data observed in flask experiments with minor deviations. In particular, the sugar consumption improved (20% vs. 33% of the available sugars were not used) and, consequently, the ethanol production increased up to about 9.6 ± 0.4% (v/v). Comparable pH, total acidity and organic acid profile were measured among flask and batch fermentations with exception for citric acid (7.87 ± 0.15 g/L for trials vs. 5.86 ± 0.14 g/L for batch trials) and acetic acid (0.61 ± 0.06 g/L for batch fermentation). Similarly, negligible differences were found in the microvinification experiment.
The qualitative aromatic profile showed 58 free flavour compounds and 20 glycosylated aromatic compounds. The most abundant aromas were 2-phenylethanol and isoamyl alcohol (13.98 mg/L and 11.22 mg/L, respectively) that are associated to honey, spice, rose descriptors for 2-phenylethanol and spirit and alcoholic notes for isoamyl alcohol. Considering the perception threshold, the Odour Activity Values (OAVs) were calculated. The most powerful odorants of kiwi wines were ethyl octanoate, phenylethanal, ethyl hexanoate, vinyl-guaiacol, benzaldehyde and nonanal for which the OAVs were 21.1, 3.3, 2.6, 2.2, 1.9 and 1.6, respectively. These findings were in accordance to the sensory analysis: the descriptors indicated by the enrolled expert judges were fruity (ethyl octanoate), honey and floral (phenylethanal), apple and peach (ethyl hexanoate), and citrus (nonanal).
The acceptability test carried out involving 100 consumers showed the kiwi wine was averagely appreciated with highest score related to the olfactory characteristics. Its taste was less appreciated probably affected by the high acidity due to the content of citric acid of kiwi wine. For this reason, the sensory analysis was also carried out on kiwi wine added with sucrose in order to reduce the perception of acidity (Figure 4). The increased sugar concentration led to a higher perception of citrus and fruity notes as well as to higher overall aroma persistence.

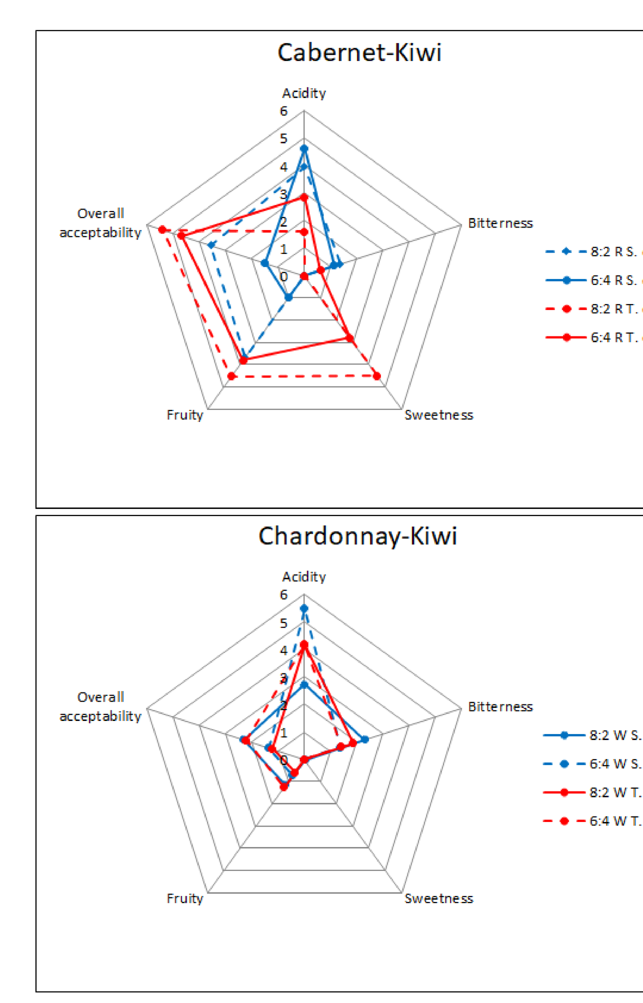

Figure 2. *Sensory analysis of kiwi wines obtained in fermentation flask experiments.*

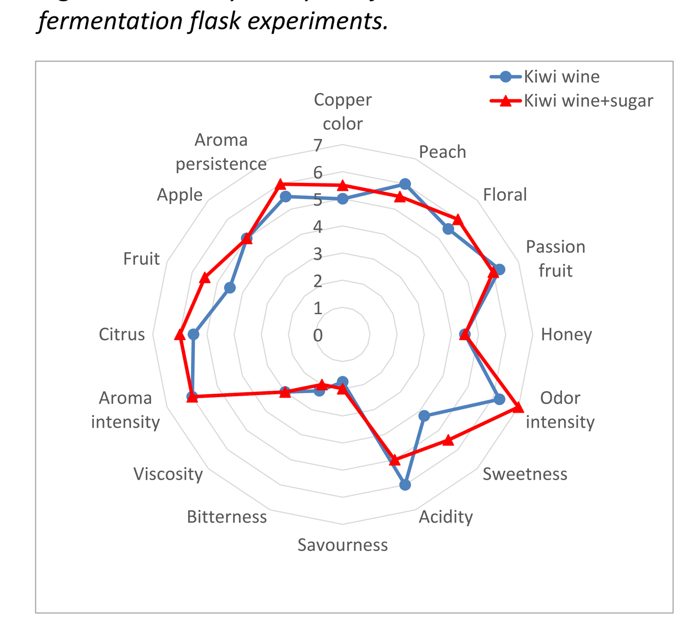

Figure 4. *Sensory analysis of kiwi wine produced in microvinification experiment.*

4. Conclusions and future works

The production of an alcoholic beverage obtained through the co-fermentation of grape must and kiwi juice was investigated. The resulting product was described in deep considering both fermentative capability and chemical composition. Not at last, the kiwi wine was considered acceptable by the consumers, especially for its appreciable flavouring impact.
The innovative approach of a grape-based fruit wine production by means of fermenting contemporarily grape must and fruit juice could be an effective response for limiting the fresh fruit waste. The sustainability of both wine and fruit crop fields can be achieved and improved since the production of grape-based fruit wine could directly transform the fruit surplus limiting the cost of waste management (**short-term impact**). The production of quality wine can be also ensured since the grape presenting lower quality criteria can be employed for this beverage, thus limiting the production of low quality wines potentially increasing the quote of unsold wines (**short-term impact**). The social and economic context of the wine sector can also profit from this product, with growth in employment and increase of the number of the companies and supplier involved (**medium-term impact**). Finally, an increasing number of consumers will be able to find remarkable advantages in these products because there is evidence that the intake of fruit is crucial for maintaining health, probably because of the antioxidant compounds present in fruits. Fruit containing high amounts of vitamin C, vitamin E and polyphenols, may be helpful in reducing risk factors related with cardiovascular disease. Also, the release by yeasts of bio-functional compounds (glutathione, melatonin, etc.) during the fermentation [3,4] can represent another health and economic benefit adding a value to these new products (**long-term impact**).
In conclusion, the whole productive chain, from fruit growers to the consumer can benefit in economic terms from the production of grape-based fruit wines.
Future perspectives will be the scale-up of the grape-based kiwi wine production up to reach the industrial scale.

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Acknowledgement
The authors gratefully acknowledge the financial support provided by the Linea 2-2016-Fondo Giovani Ricercatori (University of Milan, Milan, Italy).