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Resistant grape varieties and market acceptance: an evaluation based on experimental economics

Alejandro Fuentes Espinoza[1], Anne Hubert[1], Yann Raineau[2], Céline Franc[3], Éric Giraud-Héraud[1]

[1] INRA-GREThA, USC INRA 1441 / Institut des Sciences de la Vigne et du Vin - ISVV, 210 chemin de Leysotte, 33882 Villenave-d'Ornon, France
[2] Bordeaux Sciences Agro - Institut des Sciences de la Vigne et du Vin - ISVV / INRA-GREThA, USC INRA 1441, 210 chemin de Leysotte, 33882 Villenave-d'Ornon, France
[3] Unité de recherche Œnologie - USC INRA 1366 - EA 4577 / Institut des Sciences de la Vigne et du Vin. ISVV, 210 Chemin de Leysotte, 33 882 Villenave-d'Ornon, France

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Abstract

We analyze consumers' evaluations of white wines from resistant varieties, produced in the Languedoc winegrowing region of France (2016 vintage). We use the results from a laboratory experiment performed in Paris in June 2017, where a panel of more than one hundred and sixty consumers, regular buyers of this type of wine, were asked to evaluate a wine of the Bouquet 3159 grape variety (monogenic variety resistant to mildew and powdery mildew and optimized for quality) and compare it with two conventional wines of different quality levels, and with a certified organic wine of similar type and price. The environmental and health performances and the production methods of the different wines were quantified according to several indicators: treatment frequency indicator (TFI) and pesticide residue analysis.
The consumers first evaluated the wines after tasting, having been given only a minimum amount of information about the region of origin and the vintage, then again after receiving information on production methods and the levels of our indicators. The method used to lend credibility to individual valuations used experimental economics, via a mechanism based on direct disclosure of their willingness to pay (maximum purchase price for a bottle of wine according to available information). The results showed that, on a purely sensory level, consumers had difficulty in accepting wine from a resistant variety. We were then able to see that communication focusing on environmental and health performances very much improved the position of the resistant variety of wine, putting it ultimately at the top of the average qualitative evaluations. In economic terms, we show that this promotion results in high market share, gained from conventional wines. Market share losses were lower, however, for the premium conventional wine, suggesting that the higher quality wines would be less directly challenged by wines produced from resistant varieties.

Key words: wine, resistant varieties, treatment frequency indicator, pesticide residue analysis, willingness to pay, experimental economics

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*Corresponding author: eric.giraud-heraud@u-bordeaux.fr

Introduction

Grape varieties resistant to cryptogamic diseases are recognized as being innovative in reducing the use of viticulture inputs (see, for example Merdinoglu *et al.*, 2009). A great deal of debate at the agronomic level has focused on the most effective ways to sustain this resistance (e.g. Bouquet, 1980; Delmas *et al.*, 2016; Delmotte *et al.*, 2014) and on the qualitative improvement in the produce from these varieties with a view to marketing the resulting wines (Salmon *et al.*, 2017). In economic terms, analyses have focused on the expectations of producers (Lybbert and Gubler, 2008; Lybbert *et al.*, 2012) and on the reduction of costs linked with the use of these innovations (Binzen *et al.*, 2014). However, to our knowledge, no work has been done on consumers' acceptance of wines from resistant varieties. The main reason is that, as for many innovative products, consumer data does not yet cover a sufficiently long period and also that, particularly in the wine sector, it is always difficult to understand the real trade-offs consumers make between, on the one hand, purely qualitative aspects, intrinsic to the product, and on the other hand any extrinsic effects linked with the label and the information available to consumers on production methods (provenance, certifications, claims, etc.), especially when they relate to environmental performance.

This article presents a methodology for evaluating consumers' expectations and trade-offs in the context of experimental economics. The aim is to discover consumers' willingness to pay (WTP) (generally for a bottle of wine with different information configurations) in a controlled laboratory experiment (i.e. with no social interactions) and guaranteeing the credibility of the disclosures of willingness to pay using disclosure incentive methods (see, for example, Lusk and Shogren, 2007 for an overview of these methods). The general questions that we are asking are as follows:

- What is a consumer's willingness to pay for a wine from a resistant grape variety, compared with their willingness to pay for other conventional wines, from the same production region and at the same price level?
- What effect does information about environmental and health performances have on willingness to pay for wines from resistant varieties and on consumers' quality-price trade-offs?

Initial responses to these questions are provided in this article with the results from an experimental market held in Paris in June 2017. As part of a specific study on white wines from the Languedoc winegrowing region of France, we selected a wine from the Bouquet 3159 grape variety, produced at the *Institut National de la Recherche Agronomique*[1] (INRA). The 2016 vintage wine was compared with two types of conventional wine: one standard conventional wine from the same wine-producing estate, also marketed by INRA, and a 'premium' wine from another estate in the same production region, the Languedoc, but of a higher quality and price. We also selected an organic regional wine for this experiment to better position the 'resistant variety' option in relation to an alternative production method which is also committed to pesticide reduction, but which is nevertheless more traditional for consumers. The environmental and health performances of the production methods of the different wines were quantified using the treatment frequency indicator (TFI) and chemical and biological pesticide residue analyses.

Our results showed that, at a purely sensory level, consumers had difficulty in accepting wine from resistant varieties. The amount they were willing to pay is indeed significantly less than for traditional quality wines. However, information on the environmental and health performances resulted in a strong improvement in the market position of the wine from the resistant variety. By using actual selling prices and comparing them with consumers' willingness to pay, we then estimated the losses of market share for the conventional wines. We noted that these losses were considerably less for the quality wines, despite their poor environmental performance (TFI greater than 10) and health performance (presence of synthetic pesticide residues in the conventional wines and copper residue in the organic wine). Lessons for public policy concern consumer expectations in terms of environmental and health issues as today these are an integral part of wine quality.

Material and methods

There is currently a large amount of literature available on wine consumers' expectations in terms of environmental and health improvements in production methods. As Schäufele and Hamm (2017) recently highlighted in a review of this literature, these considerations regarding sustainable development are certainly becoming increasingly important for European and North American consumers and are gradually being reflected in their purchases (see also Delmas and Grant, 2014; Forbes *et al.*, 2009; Pomarici and Vecchio, 2014). Recently, a large number of these studies have focused on

[1] INRA-Pech Rouge, Experimental Unit (https://www1.montpellier.inra.fr/pechrouge/index.php/en/)

organic wines to evaluate the 'premium' achieved from this certification when associated with environmental labeling (e.g. Brugarolas *et al.*, 2005; Schäufele and Hamm, 2018). However, several authors have shown how difficult it is to gain a clear understanding of the true motivation of organic wine consumers who often interpret this certification as a sign of quality in general (e.g. Pagliarini *et al.*, 2013). Authors have also shown how difficult it is to measure consumers' true trade-offs between, on the one hand, the attributes of sustainable development and on the other, the organoleptic evaluation, which often predominates (Loureiro, 2003; Schmit *et al.*, 2013). It goes without saying that these results remain dependent on market specificities and consumer characteristics according to age, gender or income (e.g. Sellers-Rubio and Nicolau-Gonzalbez, 2016; Thomas and Pickering, 2005) and a large number of empirical studies will be needed to identify, if possible, some more general results.

More recently, Schäufele and Hamm (2018) focused on the very great difference between consumers' intentions and expectations and their real market purchases, as these often do not match their declared intentions and expectations (the famous "attitude-behavior gap"). Incentive methods that we find in the experimental economics literature can partially resolve this phenomenon by avoiding the 'social desirability bias' and taking consumers' income constraints into account (for applications to wine see, for example, Combris *et al.*, 2009; Vecchio, 2013). The laboratory experiment that we carried out is one of these experimental economics methodologies and it enables us to test innovative wines that have no historic consumption and purchase data. We chose to use a method involving direct disclosure of consumers' willingness to pay (Combris *et al.*, 2015), where consumers fixed minimum purchase prices, after comparing products that had been offered to them for sale. The wine that is sold to them is the one that maximizes their surplus (difference between WTP and sale prices, which is drawn at random, along the same lines as in the original method suggested by Becker *et al.*, 1964).

Here we describe our experimental protocol which starts with wine selection and the measurement of sustainable development indicators, in order to better control the effect of the information available to consumers when they disclose their willingness to pay.

1. Wine selection

The wines that we submitted to consumers for the comparison test were selected as follows. First, we selected a wine produced from a resistant variety, available for sale and optimized in terms of quality (monogenic variety partially resistant to mildew and totally resistant to powdery mildew). In France, the *Institut National de la Recherche Agronomique* (INRA) carries out this type of activity at its Pech Rouge experimental unit. Concentrating on available wines from the 2016 vintage, a jury of 10 professional tasters gathered at INRA Pech Rouge in December 2016 for a blind tasting and finally suggested focusing solely on the white wines from this winery, selecting the wine which was the best quality for the resistant varieties: this was a wine produced from the Bouquet 3159 grape variety, aromatic, but whose features did not contrast too strongly with the traditional Languedoc wines. A second white wine was selected from the same establishment, INRA Pech Rouge, and the same vintage, 2016, but this time produced from varieties authorized under the 'Aude' Protected Geographic Indication scheme for which this wine is eligible. Although the grape varieties were different, this 'standard conventional' wine from the domain could be considered, in the opinion of the tasting jury, as an adequate substitute for the resistant variety wine (as the differences in their characters were not too great). To complete the test we took the decision to select what we called a 'premium conventional' wine from the same winegrowing region, the Languedoc (but this time a Protected Designation of Origin 'Languedoc' wine), from the same vintage, 2016, and which could ideally be a higher quality substitute, with a high price level, while still remaining below the psychological price threshold of €10 (as we see below in Table 1, the ex-cellar price of this premium conventional wine at the time of the experiment was €8.90, while the resistant variety wine cost €6 and the 'standard conventional' wine sold for €4.70 at the property).

Apart from the organoleptic aspects, the second criterion that determined our selection was the performance of the wines in terms of reducing the use of phytosanitary products in the vineyard. This was why we also decided to select a wine with organic certification, a designation well known to consumers. Organic certification can indeed add value for what it represents in terms of the reduction in the use of pesticides, although for producers it remains expensive, and in certain cases carries risks.[2]

[2] Organic certification has seen significant growth in France and throughout the world (see the recent forecast by France Agrimer, 2017) but has experienced some uncertainties due to problems related to the emergence of grapevine diseases in some winegrowing regions and the use of copper, often considered as harmful, to overcome these cryptogamic diseases.

This organic wine that we added to the experiment, still from the 2016 vintage and the same winegrowing region of the Languedoc, is equivalent in price to the premium conventional wine (€8 per bottle ex-cellar). We shall see in the sections that follow that environmental and health performances can also be considered as relatively equivalent to that of the resistant variety wine, but in contrast, the detection of copper residues in this wine (since the use of copper is acceptable to avoid the growth of mildew) may lead to negative reactions regarding willingness to pay.

2. Treatment Frequency Indicator (TFI)

Measuring the environmental impacts of agriculture is a complex task, which is addressed in the literature through different families of methodological approaches: risk mapping, lifecycle analyses, development of agro-environmental indicators (Payraudeau and van der Werf, 2005). Within this family of agro-environmental indicators we distinguish state indicators, measuring environmental quality (downstream approach) and pressure indicators, based on agricultural practices, either measured or modeled (upstream approach) (Pingault *et al.*, 2009). These pressure indicators can cover different types and aspects of agricultural activity: crop rotation (and its impacts on biodiversity), use of irrigation, use of fertilizers and soil improvers and of course the use of pesticides.

Concerning measurement of the use of pesticides, Falconer (2002) reported the lack of widely recognized environmental indicators available to producers and especially to regulators in order to move towards more sustainable technical routes; designing and evaluating public policies that favor these indicators. There appears to be no indicator that successfully takes into account all the different parameters that have to be considered when judging the environmental impact of pesticide use: the doses used, the relative speeds of degradation of the products considered, their relative dispersion in the air, water, soil compartments and finally, their relative and combined toxicities (“cocktail effects” linked with interactions between the different active ingredients that are still not well understood) in relation to different living species (Bockstaller *et al.*, 1997; Levitan *et al.*, 1995; van der Werf, 1996).

The most commonly used indicators in this field deal first and foremost with the first of these factors: they are built around the comptability of doses applied by farmers. This is notably the case for the Treatment Frequency Indicator (TFI) for phytosanitary products, defined as the number of reference doses[3] applied on a cultivated plot during one growing season (Pingault *et al.*, 2009). This indicator is based on Danish research (Gravesen, 2003) which was later adapted in France by INRA and IRSTEA (Aubertot *et al.*, 2005; Champeaux, 2006).

$$\boldsymbol{TFI} = \frac{\boldsymbol{dose\ applied}}{\boldsymbol{reference\ dose}} \times \frac{\boldsymbol{surface\ area\ treated}}{\boldsymbol{total\ surface\ area}}$$

The TFI does not relate to the number of treatments carried out, but more precisely to the number of *reference doses* applied to a plot. Unlike the simple number of phytosanitary treatments, this index has the advantage of taking into account both the doses actually applied and the surface area actually treated. Finally, since this index corresponds to a ratio expressed in units, doses of different products can be added together and grouped into categories: “TFI fungicides”, “TFI herbicides”, etc. This is a useful distinction in order to understand the relative importance and the different uses of these pesticides for different crops and in different regions.

The difficulty of this kind of synthetic index, based on a simple principle of adding quantities of pesticides, still remains in the fact that the different products used are given equal consideration, whatever their degree of toxicity or persistence in the environment (Barnard *et al.*, 1997). In this respect, the TFI along with other non-weighted indicators of pesticide profiles are imperfect environmental and health indicators.[4] Nevertheless, their use has become extremely widespread, especially in France, with support from public authorities systematizing their use and taking readings through field surveys.[5] Despite its imperfections, this indicator is becoming the measure of effectiveness of French public policies, in the sense that a drop in TFIs must be able to objectivize an environmental improvement, and thus the arbitration process for product recommended doses becomes crucially important.

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[3] The most commonly used reference dose used is the recommended dose (French Ministry of Agriculture, 2015). This is determined in France by the *Agence nationale de sécurité sanitaire de l’alimentation, de l’environnement et du travail* (French Agency for Food, Environmental and Occupational Health and Safety - ANSES) and is included in the Marketing Authorization (MA) for the product as the maximum dose to be used.

[4] With the recent differentiation of so-called *bio-control* products, substances used as pesticides but which can be found in their natural state in the environment (like sulfur-based products in winegrowing), this means that the TFI can be refined into a “TFI for biocontrol products” and a “TFI excluding biocontrol products”. One point on the TFI for biocontrol products is then judged to be less damaging to health or the environment than one point on the TFI excluding biocontrol products.

[5] Recently, members of the AOC Bordeaux - Bordeaux Supérieur syndicate expressed their desire to include in the specifications the requirement that all members should measure and be aware of their TFI.

While the TFI concerns cultivation practices, the original feature of our own process is to attribute it to a finished product. This has been made possible by using the treatment record books for the plots on which the wines for the experiment were produced. For the sake of simplification, in the following we shall say that a wine has a TFI of X to denote the fact that it is produced from plots of which the average of their TFIs, weighted for the composition of the blend, is X.[6] More precisely, to get as close as possible to an environmental indicator, we shall consider TFIs excluding biocontrol products. Ultimately, we obtain the environmental performances shown in Table 1: the wine from the resistant variety had a TFI excluding biocontrol products of 2, for the 'standard conventional' wine it was 16.9, for the 'premium conventional' wine 12.7, and for the organic wine 2. Thus the organic wine had the same environmental performance as the resistant variety,[7] making comparison easier for consumers.

3. Pesticide residue analyses

The question of analyzing for the presence of pesticide residues in food products has long been a subject for discussion in the scientific literature. In the case of wine, analyses are more recent and follow on from the increasing awareness on the part of the media (and hence of consumers) of this question of using pesticides in wine production.[8] However, evaluation techniques are constantly evolving and we often observe considerable variation in results, depending on the analytical laboratory used and the evolution of the wines. For this reason, we used two different laboratories to perform these analyses:

- Unité Œnologie de l'Institut des Sciences de la Vigne et du Vin (ISVV), Université de Bordeaux, France.

- El Instituto de Investigación y Análisis Alimentario (IIAA) de la Universidad de Santiago de Compostela (USC), Spain.

The ISVV laboratory tested for the presence of 190 active substances and quantified the compounds detected. The IIAA quantified the pesticide residues in the four wine samples from a predefined list of 33 compounds. The IIAA also tested the wines for the presence of a dithiocarbamate metabolite, ETU (ethylene thiourea). However, in order to link practices in the vineyard and the compounds found in the wine, we decided to focus the analytical search on residues, mainly on the active ingredients applied to the plot. In addition, the information provided for consumers concerned only pesticide residues applied to the vines.

Note that at this stage, maximum residue levels (MRL), intended to guarantee a certain level of food safety in products for European consumers, do not yet exist for wine (see Appendix VI of Regulation 396/2005), only for wine grapes (in mg/kg). The results of our analyses cannot therefore be compared with regulatory limits specific to wine. In the absence of MRLs to provide a comparative reference value, we decided to provide consumers with information in terms of the number of residues present and their quantity. The weak signal for the ETU metabolite in the case of 'premium conventional' wine (the only wine to present with this metabolite) was not considered as it was below the limit of quantification (LOQ). Finally, copper was the only pesticide quoted. This prominence given to the name of the molecule was done deliberately, in order to assess whether the organic wine could indeed be penalized by the presence of copper (main stumbling block of this certification). No residue was detected for the wine produced from resistant variety. However, the 'standard conventional' and 'premium conventional' wines reported respectively six and three pesticide residues which were actually applied at the vineyard.

4. Recruiting consumers

Consumer selection was carried out by a specialist recruitment agency. The consumers were all recruited in the Paris region where the experimental laboratory was located. A certain number of filters were applied to achieve a balanced population:

- The panel had to be evenly distributed between men and women.

- The panel had to be evenly distributed in terms of age, and only target adults.

- The panel had to be representative of all socio-professional categories, limiting the proportion of students to a maximum of 10%.

- 100% of consumers had to buy wine at least once a week.

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[6] See also our detailed appendix, available on request from the authors.

[7] Note that using our scale, this wine "benefits" from the decision to select only the TFI excluding biocontrol products, thus excluding sulfur-based anti-powdery mildew products.

[8] See, for example, the article in *L'Obs* of 1st October 2017 *«Le vin conventionnel contient jusqu'à 12 pesticides. Le vin naturel, aucun»: plaidoyer pour le vin naturel («Conventional wine contains up to 12 pesticides. Natural wine contains none»: a plea for natural wine*), also that in *UFC Que Choisir* of 24 September 2013 «La peste soit des pesticides» (*A plague on pesticides*), or that in *60 Millions de consommateurs* dated 25 April 2012 "Des pesticides même dans le vin bio" (*Pesticides even in organic wine*).

Table 1. Characteristics of selected wines

Wines	**'Resistant variety' wine**	**'Standard conventional' wine**	**'Premium conventional' wine**	**'Organic' wine**
Code	309	417	575	231
Organoleptic quality	Standard	Standard	Superior	Standard
TFI (excluding biocontrol products)	2	16.9	12.7	2
Grape varieties	100% resistant grape variety Bouquet 3159	45% Sauvignon, 31% Viognier, 17% Chenin, 7% Arriloba	50% Roussanne, 30% Grenache Blanc, 20% Viognier	100% Viognier
Phytosanitary product residues	No residue of applied pesticide	Residues of 6 applied pesticides	Residues of 3 applied pesticides	Applied copper residues
Sale price (ex-cellar)	€6/bottle	€4.70/bottle	€8.90/bottle	€8/bottle

- 100% of those recruited had to be consumers of dry white wine at least twice a month.

- No person on the panel should be involved in the winegrowing sector.

Consumers were compensated by the recruitment company, and this payment was completely disconnected from our experiment. In the end, and taking these recruitment filters into account, the panel consisted of 163 consumers, 82 women and 81 men, with an average age of 50.8 years (standard deviation 11.8). The minimum age was 22 years and the maximum 81 years. There were 22 consumers in the 20-35 age bracket, 73 in the 36-55 age bracket, and 68 were aged over 56. The average age of the men was 51.9 years and of the women 49.9 years.Consumers were put into three groups according to their monthly income. The first group contained 60 consumers with earnings of less than €2000 per month. The second group contained 73 consumers with earnings of between €2000 and €4000 per month. Finally, the last group contained 30 consumers with earnings higher than €4000 per month. On average, the women on the panel earned more than the men.

5. Experimental economics protocol

The experiment took place in June 2017 in a sensory analysis room[9] in the Paris region, kept at an ambient temperature, with nine sessions held (each session included between 17 and 20 consumers) all taking place in the same week (comparable external conditions for the consumers). It should be noted that each consumer was paid €30 by the recruitment company, for their participation in this experiment (this payment was quite separate from the sale of wines during the experiment). Each consumer had received a letter at their home explaining the experimental conditions and the selling principle to be applied, with an explanation of the notion of willingness to pay and the proposed disclosure mechanism. This mechanism was explained once again at the session, using examples to ensure that they clearly understood it and the incentive to disclose their WTP, taking into account the level of information available about the products on sale. Before starting the experiment, it was explained to the consumers that the study was interested in their personal opinion, the aim being to collect at each stage their sensory and economic trade-offs. We also

[9] Room compliant with standard NF EN ISO 8589 of May 2010, "Analyse sensorielle - Directives générales pour la conception de locaux destinés à l'analyse" (*Sensory analysis – General directives for the design of premises to be used for analysis*)

made it clear that an absolute refusal to buy a wine at one time or another during the experiment would result in a WTP of zero.

The experimental protocol consisted in a comparison of the four wines, as we gradually provided more and more information on them (on this point, see Fuentes Espinoza, 2016): the consumers were asked to evaluate the wines at several different stages and at each stage we recorded the new WTPs for each wine, according to the information available on these wines at this stage of the experiment. Each step therefore corresponded to additional information, which could lead each consumer to re-evaluate their WTP if they so wished. As is customary in the field of experimental economics, we assured the consumers that none of the information provided was untrue and it could be verified at the end of the experiment.

At the start, all the consumers had a single piece of information, common to all four wines, on the fact that the wines were all from the Languedoc region of production and were a 2016 vintage. The purpose of this information was to provide consumers with a minimum framework for evaluation and cognitive structuring. Just before the start of the experiment, each wine was served in a clear tasting glass, with a standard quantity of 20 ml per glass, and so that at the time of the first and only tasting (step 1, see below) each wine was at a temperature close to 12°C. The wines were coded and arranged in random order at each tasting station, meeting the rules for the Latin square design.

To keep the economic incentive intact at each step and on each declaration made, participants were only informed at the beginning of the session that the final sale would relate to one of the steps in the experiment. With no more information than this, any one of the steps could therefore apparently be the one. An envelope, visible to everyone, was pinned to the wall before the participants came into the room. They were told at the beginning of the session that this envelope would be opened just before the sale and that it contained the number of the step to which the sale would relate. The incentive and the unveiling of the conditions of the sale were therefore made acceptable and concrete. Note that this principle is similar to the *ex ante* sale price fixing used in the *Prince* method developed by Johnson *et al.* (2015) to measure preferences. Finally, note that the consumers were not told the number of steps in the experiment thus avoiding the creation of expectations and strategic behavior between steps. As explained to the consumers at length during the first half-hour of the experiment, this selling stage guaranteed that at every step in the experiment everyone had to provide his or her actual WTP for each wine, taking into account the information available during the step under consideration and in a framework of comparison between the four wines offered.

The steps in the evaluation process were as follows:

Step 1 (Organoleptic evaluation): Each consumer carried out an organoleptic evaluation of each of the four wines (global evaluation considering the visual, olfactory and taste characteristics). Each consumer was asked to respect the individual tasting order proposed at each station (glasses arranged in a line, from left to right, with a different order at each station). The consumers then gave their evaluation for each wine giving a score on a non-calibrated hedonic scale of 0 to 10,[10] then their willingness to pay for a bottle of each wine.

Step 2 (TFI information): This step began with a short explanation of the use of phytosanitary products to protect crops and harvests, and their potential impact on the environment (soils, water, air) and man (residents, wine producers). After defining and explaining the notion of TFI (excluding biocontrol products), we gave the consumers the level for this indicator achieved for each wine (values shown in Table 1).

At the end of this step, consumers gave a new WTP for each wine (which may or may not be different from that given in step 1).

Step 3 (Information on type of viticulture): During this step, consumers were given definitions for the following terms:

- “conventional wine”, involving the use of synthetic phytosanitary products and those of natural origin; compliant with European regulations.
- “organic wine”, involving the use of phytosanitary products of natural origin only.[11]
- “resistant variety wine”, produced from a varietal innovation: non-traditional variety in the production region, but resistant to grapevine diseases, and allowing a very reduced use of phytosanitary products.

[10] We used a non-calibrated scale for the visual, olfactory and taste evaluation steps. Consumers indicated their response by drawing a vertical line across the horizontal line at the point that they thought best matched their perception of the wine they were evaluating.

[11] We did not elaborate on the notion of organic wine, especially on the question of the potential reduction in the use of sulfites. Our intention was to focus on the reduced use of pesticides at plot level.

For each of the four wines in the experiment, we provided information on how these definitions related to these wines. With this additional information, each consumer then re-evaluated their different WTPs, if they so wished.

Step 4 (Information on pesticide residues): During this step, we gave the consumers information on the presence or absence of several pesticide residues applied to the plot, as shown in Table 1. In the case of the organic wine, we told consumers that the pesticide found in limited quantities was copper, which is permitted in organic farming. In the light of this additional information, the consumers then revised their WTPs for each wine if they wished, as in the previous step.

Before the final step, consisting of the sale, two intermediate steps were introduced, although these results are not discussed here. During these two steps, consumers considered only two of the original four wines (organic wine and resistant variety), again giving their WTP for each bottle. First, they again gave two new series of WTPs for the organic wine and the resistant variety with no more information than at step 4. Next, we showed them the labels and back labels of these two wines then asked for new WTPs. In practical terms, these two steps made it possible to carry out the promised sale at the end of the protocol, a necessary step if a real economic incentive is to be created, while at the same time saving on the costs of the experiment. The sale in fact concerned one of these two wines (from the step number written in the envelope pinned to the wall), and thus the experimental team only needed to have these two wines in stock.

Final step (Sale): At this point, the envelope pinned to the wall was opened. The intermediate step was revealed and the sale took place in the session for a certain number of consumers chosen at random from the room. The sale prices of each of the four wines were also drawn at random from a box of prices (the consumers did not know beforehand that the price distribution would be done in this way) and were binding on each consumer. Next, each consumer selected for the sale bought the wine that maximized his surplus (difference between the WTP declared at the intermediate step and the wine's sale price), assuming that at least one surplus is positive.[12]

Thus for each step in the evaluation process, consumers had to provide a (new) WTP for each of the four wines. At the first step we asked them for a simple hedonic score so that they would focus on the intrinsic qualities of the products by giving their general appreciation regardless of any economic consideration in purchasing these wines

[12] If all the surpluses are strictly negative or if the largest surplus is zero but with a WTP of zero, the consumer cannot buy any wine. Finally, if more than one wine gives the same maximum surplus, consumers may choose to buy the wine they want from these wines. In practice, the numbers that had been prepared as the prices in the box had a decimal to avoid this happening too often (and it did not in fact occur).

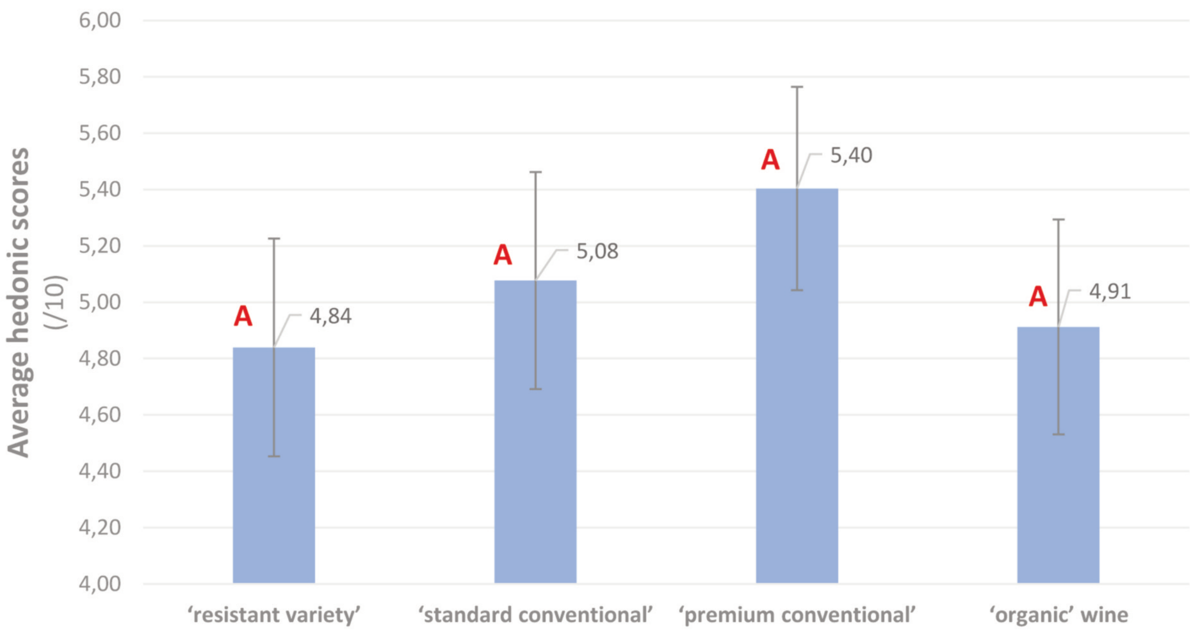

Figure 1. Average hedonic scores given in step 1 (95% confidence intervals)

(subsequently, we would of course check that the WTP given in step 1 was an increasing function of this hedonic score). The following steps only added information about each wine, regarding production methods and the results of the indicators on environmental and health performance.

We shall return in the final discussion to the relevance of testing this type of information when it is not subject to labeling regulations. We shall simply note at this stage that while the process we used of providing information in increasing amounts (and hence, not independently) is partly determined by operational considerations of the experiment, it nevertheless fully justifies research into the effect of providing information contextualized by a prior organoleptic evaluation and knowledge of the region of production and the vintage.[13]

Results and discussion

1. Consumer ranking and preferences

The following figures give an overview, based on the averages of the hedonic scores and willingness to pay, of the ranking of the wines by the consumers, taking into account the standard deviations in our population. Figure 1 shows the average hedonic scores awarded to the four wines in step 1.

Two products share the same letter (e.g. "A") if and only if they have not been valued significantly differently by all of the group (ANOVA).

The averages of the hedonic scores appear to show a preference for the two conventional wines, and especially for the "Premium" conventional wine. In contrast, overall, the wine from the resistant variety was not well perceived by consumers (it obtained the lowest average score, very similar to that of the organic wine), although it was not completely rejected. This wine is produced from a grape variety unknown to the consumers, and its specific organoleptic characteristics were surprising, but were not completely condemned at this stage of declaring preferences. At this stage, the hedonic scores given to the four wines were not significantly different (an analysis of variance gives a probability of error of rejection of the null hypothesis of equal averages of 0.1682). The differences in the appreciation of the four wines between consumers themselves were therefore too great for an objective discrimination to emerge between the wines.

Figure 2 shows the average WTPs given at this same step.

Two products share the same letter (e.g. "A") if and only if they have not been valued significantly differently by all of the group (ANOVA, post-hoc Tukey tests, threshold 3%).

Although evaluation of the wines by WTP gives a very similar average picture to that for the hedonic scores, we observe that it is more discriminating. This time, the differences become significant in an analysis of variance, at a threshold lower than 5%

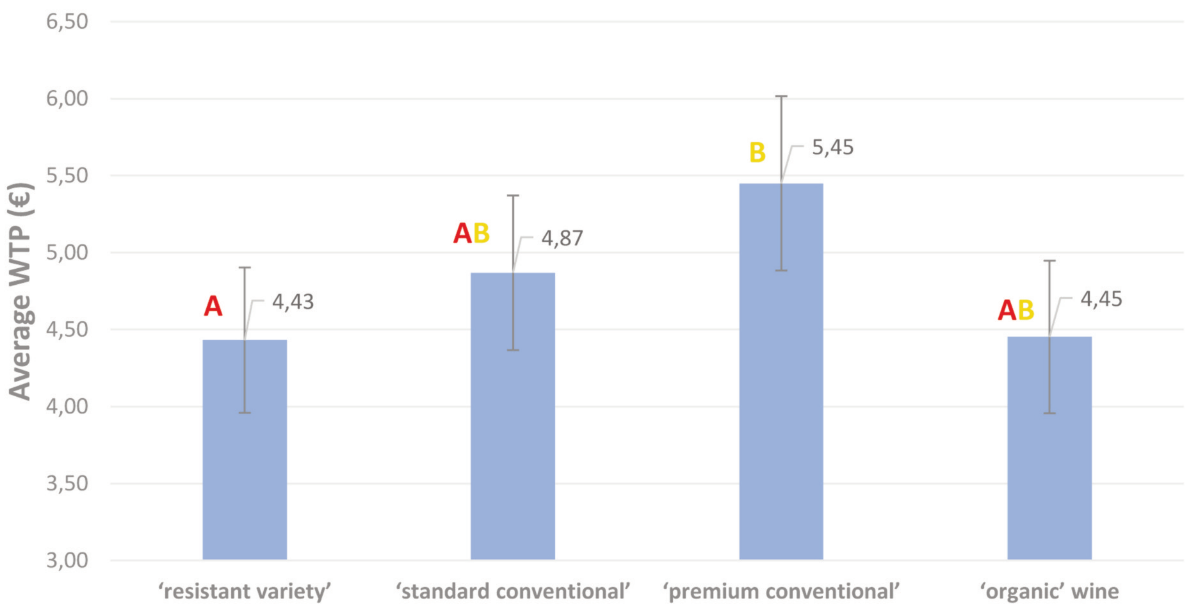

Figure 2. Average WTPs at step 1 (confidence intervals 95%)

(p_0 = 0.0185). If we compare the wines two by two in a post-hoc analysis of variance test (Tukey, 1949), we see that the premium wine has a significantly better evaluation than the wine from the resistant variety from a threshold of 3% (whereas at this same threshold, the other two wines did not differ significantly one from the other). The hedonic scores and the willingness to pay approaches can therefore be seen to complement each other. With the economic incentive of the sale at the end of the experiment, the consumers indicated their preferences more strongly than with the hedonic scores.

To conclude step 1, we see that the comparison of the selected wines seems to be fairly relevant for the consumers, in that they did not reject any of them for their organoleptic qualities. These consumers were nevertheless sufficiently discerning to recognize a certain superiority in the premium conventional wine, but this result was mainly seen through the incentivizing technique of revealing willingness to pay.

After this organoleptic step 1, we provided consumers with environmental and health information. Figure 3 shows the change in average WTP step by step.

At step 2, information on TFI completely reverses the average preferences of the group of consumers, putting the organic wine and the wine from a resistant variety in the top places, whereas they were ranked 3rd and 4th at step 1. These two best performing wines in this field (TFI=2) improved their WTP considerably compared with the 'standard conventional' and 'premium conventional' wines (with TFIs of 12.7 and 16.9 respectively). Not only does the information on TFIs have a negative effect (to be expected) on the conventional wines, but it also leads to a gain in WTP for the high-performance wines. It is interesting to note that there is a certain symmetry in these valuations and devaluations, which can be seen in Figure 3: the two high-performing wines are re-evaluated by the same amount of around 70 to 75 centimes while the two less successful wines are both devalued by the same amount of €1.15.

Step 3 and knowledge about production methods do not make very much difference. Knowledge of organic certification revalued the average WTP for the wine concerned by only 35 centimes (significant increase by a paired Student's t-test on this wine between the two steps, with a probability lower than 0.0001), which is the same order of absolute magnitude for the evaluation of the organic quality of wines as that obtained by Raineau (2018).

At this stage it can therefore be said that environmental performance, measured by the TFI, was the determining step for fully understanding the hierarchy of the wines. Organoleptic quality has not been forgotten (we can see this from the parallel

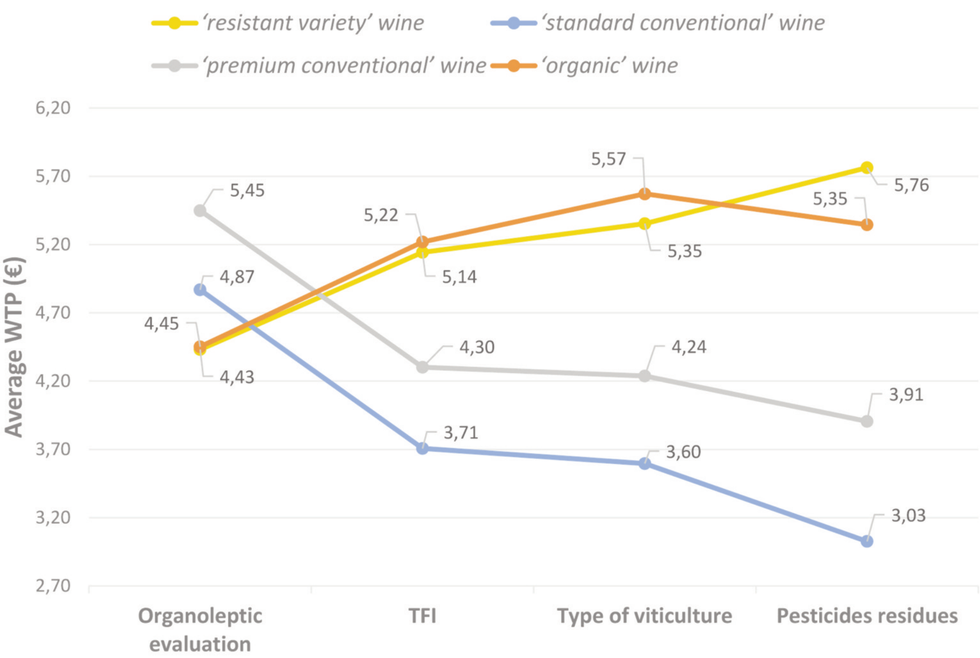

Figure 3. Average WTP per wine and evaluation step

change in the average WTP for the conventional wines). Consumers have nevertheless had no hesitation in changing their evaluations with this information on the use of pesticides at plot level. The question now is to know the exact reasons. Is it for purely altruistic reasons of collective awareness or is it out of a private interest in anticipating food safety? To answer this fully, it would have been necessary, for example, to conduct a survey at this stage of the experiment (i.e. after step 2), however, this would have extended and compromised our experiment. We therefore preferred to limit our study to additional information on the presence or absence of pesticide residues in the wines and to measure the consequences. The effect of step 4 is to reduce the WTP of the conventional wines a little more, as they are diverging further from the organic wine and the resistant variety wine, and to reverse the order of preference between these last two wines. The copper residues caused a slight drop in the average WTP for the organic wine between steps 3 and 4 (significant with a probability of 0.0008 by a paired Student's t-test).

To test the robustness of the change in these preferences, we performed a new analysis of WTP variance, this time with two factors: the wine and the step. Unlike the beginning of the section where analyses of variance (on WTP and hedonic scores) covered step 1 only, here we take into account the overall uniformity of the evaluations (WTP) produced by the consumers over the four steps of the experiment. The statistical results for this analysis of variance are shown in Table 2.

The results show that the wine-consumer crossed factor is a significant element (p<0.0001) in the WTPs given in the course of the experiment. Thus there is indeed a crossed role for wine and experimental step in the heterogeneity of the economic assessments given for the wines. Therefore we can now carry out a post-hoc comparison test on pairs of WTP from the different wine-step crossings (once again using the Tukey test) and evaluate the significance of their differences. These results are summarized in Figure 4. Here, we see the changes in average WTP for each of the four wines throughout the experiment with the letters (A, B, C, D, E and F) added, indicating the significance of the differences between the sixteen wine-step interactions: two wine-step interactions share the same letter if, and only if, they have not been valued significantly differently by all of the group (with a probability of less than 10%). To make the graph easier to read, circles have been drawn at each step to group together wines with a statistically identical evaluation.

Figure 4 shows the gradual separation of the four wines into two groups: conventional wines on the one hand and "environmental" wines on the other (organic and resistant variety). In step 1, there was no significant difference in the way the four wines were evaluated (they have the letters A and B in common on the graph).[14] At step 2, the standard conventional wine (SD) becomes significantly less valued than the two high environmental performance wines (SD and BIO no longer have a letter in common on the graph)

[13] The duration fixed to complete our experimental market in the laboratory was around ninety minutes. Longer than this (which would be needed for an experiment with independent information) and the experiment would be more expensive (additional compensation for consumers) and in particular, it would lose in effectiveness, because participants would lose concentration. However, the increasing information enables us to better contextualize, in terms of perceived quality, the changes made to WTPs after environmental and health information was provided (see the contributions in the literature cited in the introduction to this section).

[14] Note that the analysis of variance of WTP for this step alone showed, on the contrary, a significantly different evaluation of the wines. Here, the analysis considers the heterogeneity of WTP for the entire experiment and relativizes the differences between WTP in step 1 and their increase over the following steps.

Table 2. Two-way ANOVA (WTP*Step) on the wines in steps 1 to 4

Number of obs = 2,608 R-squared = 0.0440
Root MSE = 3.67694 Adj R-squared = 0.0385

Source	Partial SS	df	MS	F	Prob>F
Model	1612.8592	15	107.52395	7.95	0.0000
Vin	831.62566	3	277.20855	20.50	0.0000
étape	30.7385	3	10.246167	0.76	0.5177
Vin#étape	750.49503	9	83.388337	6.17	0.0000
Residual	35043.642	2,592	13.519924		
Total	36656.501	2,607	14.060798		

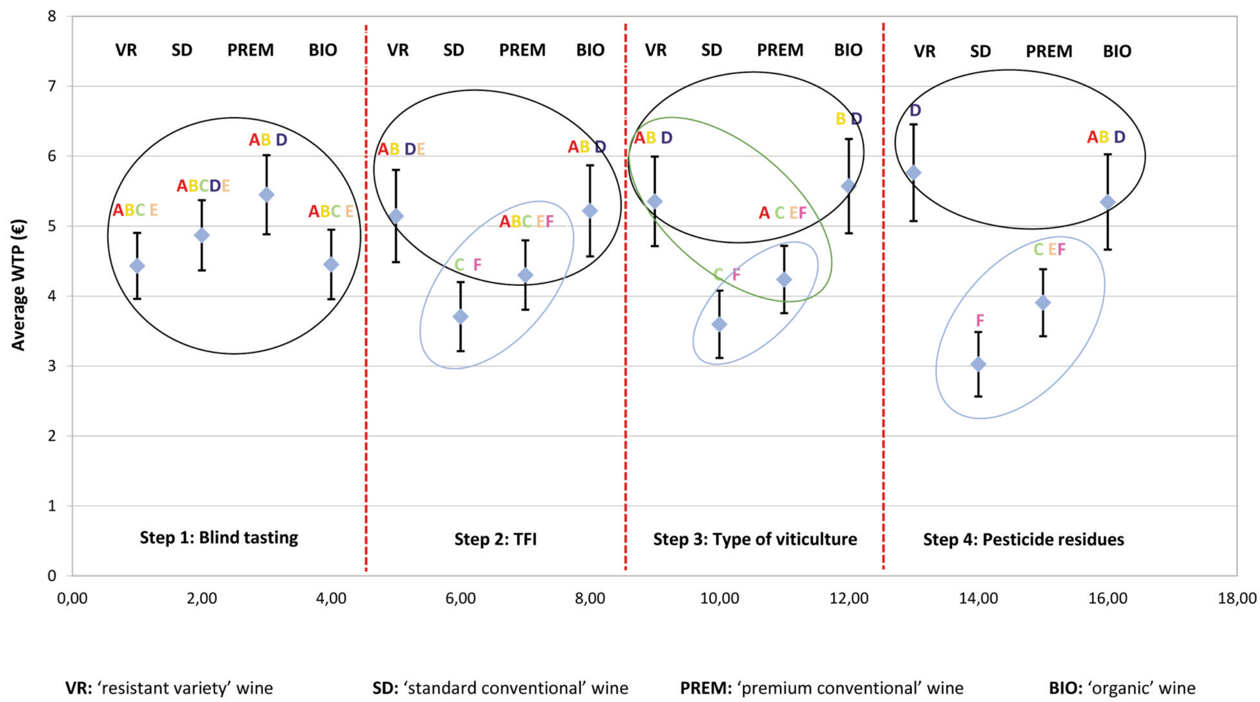

Figure 4. Discriminating wines using the Tukey test (significance threshold of 10%)

but remains similar to the premium conventional wine (PREM). At step 3, the wines vary a little more with the appearance of a significant difference between the organic wine and the premium wine. Step 4 completes the differentiation of the wines into two distinct groups.

The letters A, B, C, D, E, F seen on the graph can also be viewed horizontally, this time observing the changes in each wine, taken individually, through the four steps. Although no wine shows a complete break from one step to another, where the evaluation at step n is significantly different from the evaluation of the same wine at step n-1, we note that as the letters change there is a gradual change in each wine regarding its initial position. In particular, we see that it is only from step 4 that the evaluations of three of the wines become significantly different from the original evaluations: the wine from the resistant variety, whose evaluation increases significantly from the beginning to the end of the experiment (letters ABCE in step 1 to D in step 4), and the two conventional wines, whose evaluations decrease significantly (letters ABCDE to F for the standard wine and ABD to CEF for the premium wine). The organic wine is the only one to be evaluated in a similar way throughout the experiment by the consumers (it retains letter B from start to finish).

Figure 3 shows that the inversion of the hierarchy between the "conventional" wines and the wines with a strong environmental performance happened from the first step where information was provided. However, we see here that the series of steps and the successive provision of information on the environmental, then the health performances of the wines, reinforces this inversion of the hierarchies so that at the end of the experiment it is fully significant.

One last point that it is important to highlight concerns the relative dispersion of the tastes of our consumers and the search for factors to account for this dispersion. Individually, we obtain a fairly high level of heterogeneity of reactions after the environmental and health information is given. Some consumers did not value the former but did value the latter, indicating a greater consideration for private issues. For others, valorization was not symmetrical across the wines and was made according to their initial appreciation: the same TFI of 2 for the 'resistant variety' and the 'organic' wines could lead, for example to a much greater increase in WTP for the one wine out of these two that was preferred in the blind tasting. Finally, the winegrowing method is not always neutral in the preferences. For a number of consumers, the 'resistant variety' wine experienced a sharp fall in WTP at the step where they learned that it came from a non-traditional grape variety. This behavior marks a certain opposition to abandoning traditional varieties. We could perhaps have expected such a general trend in our overall results. However, we observe, on the contrary, that combined with perfect information on production methods and measurement of the environmental and health performances of the products, the resistant variety wine was not negatively stigmatized. To further investigate the heterogeneity results at individual consumer level, we studied the impact of socioeconomic variables in the willingness to pay for each evaluation step. Analyses of variance (two-way ANOVA), with a paired comparison using Duncan's test ($p<0.05$) show that the sex, age and income variables have no significant impact in constructing WTP during the different steps. Consumers appear to be influenced only by intrinsic characteristics and characteristics linked with the environmental and health aspects that are unveiled at each step.

2. Analysis of surpluses and market shares

Measurement of WTPs is often used by economists to measure consumer preferences for several products that could be offered to them on a market. As we have seen, this parameter gives credibility to the declarations made by those questioned, using experimental economics techniques. Often, it can also reveal preferences that were not perceptible when using simple declarative hedonic scores. However, preferences shown for a product do not necessarily mean that a person will prefer it to others in terms of their economic decision (many people prefer a Romanée-Conti wine, but few actually buy it!). For this reason, it can be important to calculate consumer surpluses, taking product sale prices into account (provided in Table 1). The precise definition of the surplus is the difference between the maximum the consumer is prepared to pay for a good (willingness to pay) and the amount actually paid (the sale price of the good in question). We consider that a consumer buys the product that gives him the maximum surplus, provided that this amount is positive. For each consumer, we therefore calculated this surplus and defined the wine potentially bought at each step in our experiment.[15] By counting the number of times a wine is bought, its market share can be calculated for the step under consideration (percentage of the total number of sales).[16]

Figure 5 presents these results in graph form. During step 1 with the hedonic appreciation, the standard conventional wine was overwhelmingly the most popular (73% of market share). We also note that the premium conventional wine represented only 8% of market share, whereas it had, on average, the highest sensory score (5.4/10) and the highest WTP (€5.45). The 'organic' and 'resistant variety' wines were given very similar hedonic scores (around 4.8/10 for the hedonic score and €4.40 for WTP) yet their market shares were fairly different (4% for the organic wine and 15% for the resistant variety wine). In step 2, consumers learned the TFI levels. As we have seen, this information had a strong impact on WTPs. As a result, market shares from step 1 were considerably modified. The resistant variety wine obtained 48% of market share, becoming the most purchased wine, and the organic wine quadrupled its percentage, reaching 16%. Interestingly, while the 'standard conventional' wine collapsed in terms of market share (falling from 73% to only 29%), the same was not the case for the 'premium conventional' wine, which was not particularly penalized by consumers, despite its relatively high TFI for the presence of residues detected and its high price (market share only dropped from 8% to 7%). It is therefore possible that in this case, the organoleptic quality acted as a restoring force.

Step 3, where production methods were provided, had only a limited impact on the change in the distribution of market shares (and hence our comments on WTP still hold good when studying surpluses) with the exception of the organic production method which gained 7% over the previous step. As was expected, this gain in market share will nevertheless be lost as soon as the consumer learns of the presence of copper residues in the wine. Step 4, with its health information, largely benefitted the resistant variety wine which, having been presented as the only wine with no pesticide residues, reached 60% of market share! Market share dropped off for the 'standard conventional' wine (-18%) and the 'organic' wine (-6%) while the 'premium conventional' wine stagnated at around the same values, about 5% of market share.[17] We can thus see here a contextualization effect of market share loss according to the organoleptic quality of the

[15] In the event of equal surpluses, we considered that the consumer bought the wine he liked best (i.e. highest WTP).

[16] Of course, the sale prices that were available at the time of the experiment, and which are given in Table 1 could be modified, in order to test the sensitivity of our results in the vicinity of the prices given.

[17] This result is further confirmed if we analyze consumer loyalty from step 1 to step 4 of the experiment. In fact, 28% of consumers who preferred the premium conventional wine to all the other wines continued to prefer this wine despite the environmental and health information (compared with 13% for the standard conventional wine).

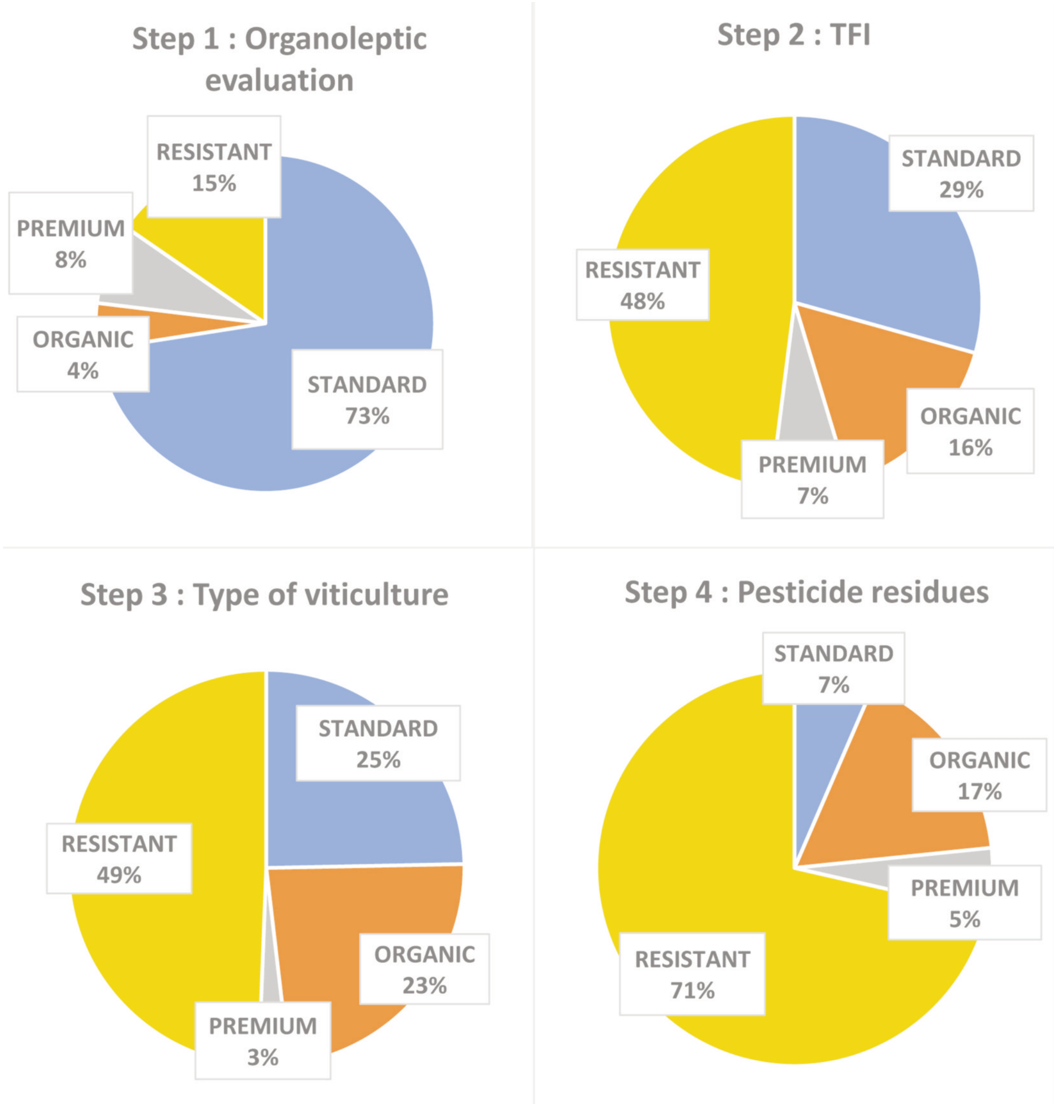

Figure 5. Market shares (%) for the 4 wines for each step

product, showing incidentally the need to integrate sensory dimensions into the valorization analyses of environmental and health certifications.

We can see that as the consumer received more and more information, the resistant variety wine gained market share and was ultimately the top seller in step 4. The premium conventional wine, which was preferred for its sensory qualities, remained in the 'market niche' position from the beginning to the end of the experiment. Nevertheless, unlike the standard conventional wine, its market share will not be eroded by the arrival of wines that are more respectful of the environment. If we extrapolate to the real market, we can indeed think that wines from resistant varieties will compete above all with entry level wines, rather than premium wines as it is still difficult to imagine a total substitution of the traditional varieties. If we maintain our results, assuming that the sale prices that we have are a good reflection of production costs, our results tend to show that with total transparency in the environmental and health performances of wines:

- More than half of market share is likely to be taken up by wines from resistant varieties which could gradually replace standard conventional wines;

- Organic wines will probably have a production margin provided that they control the use of copper and production cost overruns;

- Premium conventional wines are likely to retain their minority role in consumption due to their sale price, but they should retain their market share due to their organoleptic quality;

- Standard conventional wines will probably be replaced gradually by wines from resistant varieties.

This first research project on consumer acceptance of wines from resistant varieties has shown up a very strong responsiveness to environmental and health performances. Information on the TFI had a strong impact on willingness to pay as consumers valued ‘organic’ wines and those from ‘resistant varieties’. The two conventional wines, which were preferred at the blind sensory evaluation, moved down into second place. The information on residues accentuated the split by classifying the wines into three significantly different categories in terms of willingness to pay: in first position were wines from ‘resistant varieties’ and ‘organic’ wines, next came the ‘premium conventional’ wine and finally, in last place, the ‘standard conventional’ wine. From the analysis of surpluses we were able to refine this analysis by reconnecting the study of willingness to pay with market prices.

Conclusion

Our market study, based both on the disclosure of willingness to pay and the trade-offs in terms of economic surplus, enabled us to verify the growing importance of environmental and health issues for wine consumers. The resistant varieties that represent a radical innovation to meet these challenges have been relatively well valorized in the framework of our experimental market, which consisted of low-end wines from the Languedoc region. This innovation achieved similar performances to organically certified wines in terms of willingness to pay, and even proved to be much more successful in terms of market share, if production costs allow for sale prices similar to conventional wines.

Nevertheless, considerable attention must be given to the organoleptic quality of the wine produced as a result of these innovations. It is clear from our experiment and in line with the arguments of a certain number of authors that it played an important part in our evaluations of the overall valorization of the wines by the consumers and in our evaluations of the premium related to environmental information. On the one hand because it is difficult to consider that there could be an absolute ‘premium’ associated with information on the reduction of pesticides or on certified production methods (we see that this premium is mostly relative, and dependent on other characteristics of the wine in question); on the other hand, because a wine’s high organoleptic quality may have less significant consequences for market share losses linked with pesticide use. In this respect, this trade-off between quality/health and environmental performance could be the subject of further studies with other types of wines, for example at higher quality level and prices. In the same way, it could be useful to reinforce our results on the acceptance of the production method used for resistant varieties by referring to other vineyards which make use of iconic and virtually exclusive varieties for their Designations of Origin (e.g. Cabernet Sauvignon and Merlot in the Bordeaux region, Pinot Noir and Chardonnay in Burgundy and Champagne, Sangiovese in Tuscany, Tempranillo in Rioja, Touriga Nacional in the Dão and Douro regions, etc.).

Another important point that this study highlights concerns information on the environmental and health characteristics of the products available to the consumer when making an evaluation. In real life, this information is partly given by the wine label. However, for questions relating to a reduction in the use of pesticides, there are only general certifications on the market that relate to production methods, whether public or private, (‘Organic’ wines, ‘Integrated production’, ‘Sustainably farmed grapes’, ‘Pesticide residue free’, etc.). These certifications do not exactly match the indicators that we have used and passed on to the consumers. Of course, these indicators have the effect of putting a great deal of emphasis on the wines’ environmental and health performances. Consequently, our results should rather be interpreted as sounding the alarm on changes in consumption trends, in a country like France where society is currently seeing considerable focus on the use of pesticides in winegrowing, and the resulting consequences. It could be useful to carry out further analyses to determine the real contribution made by certifications, private standards and claims informing consumers about these objective indicators of the real use of pesticides at vineyard level and the presence of residues in wines.

From a methodological point of view, our evaluation of consumers’ willingness to pay using experimental economics methods enables us to dispense with the declarative types of study that do not involve consumers sufficiently. By using incentives to reveal willingness to pay, significant differences in evaluation can be highlighted which do not appear by simply looking at the declared hedonic scores, and hence are not binding. The experimental economics method thus complements the sensory analysis.

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