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▶ **To cite this version:**

Dominique Valentin, Wendy V. Parr, Dominique Peyron, Claire Grose, Jordi Ballester. Colour as a driver of Pinot noir wine quality judgments: An investigation involving French and New Zealand wine professionals. Food Quality and Preference, 2016, 48 (Part A), pp.251-261. 10.1016/j.foodqual.2015.10.003 . hal-01257191

HAL Id: hal-01257191
https://hal.science/hal-01257191

Submitted on 15 Jan 2016

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Food Quality and Preference 48 (2016) 251–261

Contents lists available at ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

Colour as a driver of Pinot noir wine quality judgments: An investigation involving French and New Zealand wine professionals

Dominique Valentin [a], Wendy V. Parr [b,*], Dominique Peyron [a], Claire Grose [c], Jordi Ballester [a]

[a] CSGA UMR5170 CNRS, University of Burgundy, INRA, France
[b] AGLS Faculty, Lincoln University, Christchurch, New Zealand
[c] Institute of Plant and Food Research, Marlborough, New Zealand

ARTICLE INFO

Article history:
Received 28 August 2015
Received in revised form 18 October 2015
Accepted 19 October 2015
Available online 28 October 2015

Keywords:
Colour
Quality
Pinot noir wine
Sensory
Wine professionals

ABSTRACT

Despite anecdotal reports suggesting an influence of perceived wine colour on wine professionals' judgments of wine intrinsic quality, there is a lack of empirical evidence on the phenomenon. The major aim of the present study was to investigate the importance of perceived colour as a driver of chemosensory judgments of Pinot noir wines including sensory evaluations of quality and typicality. Twenty-three French and 23 New Zealand (NZ) wine professionals judged Pinot noir wines from France and NZ on a range of attributes including perceived colour (hue, intensity, and brightness), varietal characteristics, and overall wine quality. The wines were evaluated in both standard clear glassware where colour could serve as a cue, and in opaque (black) glassware. Results demonstrated that colour was not a major factor in sensory assessment of the Pinot noir wines including in judgments of wine quality, although wine colour had several minor effects. On the other hand, the data show that perceived balance of a wine was the most important factor driving quality judgments of the wines for tasters of both cultures. The data are discussed in terms of the concept of perceived quality in wine as well as in terms of cultural differences in sensory evaluation of Pinot noir wines. Finally, an important methodological issue, namely usage of opaque (black) glassware as opposed to standard, clear glassware in wine sensory research, is discussed.
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1. Introduction

Intrinsic quality is an abstract but important attribute of foods and beverages that has until recently been little investigated in wine (Charters & Pettigrew, 2007; Lattey, Bramley, & Francis, 2010; Saenz-Navajas et al., 2015). Understanding the importance of perceived colour as a driver of wine professionals' judgments of intrinsic quality in Pinot noir wines was the major aim of the present study.

Pinot noir *Vitis vinifera* L. cv. Pinot noir produces table wines considered fine wines, commanding amongst the highest prices paid for bottled wine anywhere in the world. Well established as the most important red wine produced in Burgundy, France, Pinot noir has become over the last decade the most important red wine varietal in New Zealand (NZ) in terms of increased vine plantings, viticultural research output, consumer interest, and economic returns. A key aspect of Pinot noir wine is that as a result of phenolic composition, namely lower concentration of anthocyanins and tannins in Pinot noir grape berries (Mercurio, Dambergs, Cozzolino, Herderich, & Smith, 2010) relative to many other red wine grapes, Pinot noir wines tend to be lighter in colour than red table wines produced from varietals such as Cabernet Sauvignon and Syrah. Although there is a lack of published research, anecdotal evidence has implicated the lighter colour of Pinot noir wines as influencing both wine professionals' quality judgments and consumer acceptance (Mercurio et al., 2010).

Despite the lack of published research involving Pinot noir, several other red wine varietals have been investigated to determine associations between wine colour and chemo-sensory attributes. In studies involving Cabernet Sauvignon, Merlot, and Zinfandel, and trained panellists as participants, Dooley, Threlfall, Meullenet, and Howard (2012) and Fricke et al. (2014) have demonstrated positive associations between perceived colour depth and perceived wine flavour intensity. Dooley et al. (2012) also provide hedonic data from American wine consumers from which they argue that colour/appearance of the red wines was an important wine characteristic for the wine consumers. More specifically, their data show that overall liking of the wines correlated with ratings of liking of appearance which in turn correlated

* Corresponding author at: Department of Wine, Food & Molecular Biosciences, Faculty of AGLS, P.O. Box 85084, Lincoln University, Lincoln 7647, Christchurch, New Zealand.
E-mail address: wendy.parr@lincoln.ac.nz (W.V. Parr).

http://dx.doi.org/10.1016/j.foodqual.2015.10.003
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positively with physico-chemical measures including red wine colour density measured spectrophotometrically and total anthocyanin concentration. Further support for the importance of colour as a wine attribute for consumers comes from the interview data concerning wine intrinsic quality reported by Charters and Pettigrew (2007) which demonstrated that appearance, including colour, was a correlate of conceptualised wine quality for low- or medium-involvement wine consumers who associated wine appearance (e.g., "nice colour": p. 1002) with sensual pleasure.

In terms of wine professionals whose job description requires them to judge wine quality either within a winery or within the wider wine industry (e.g., as part of a judging panel at wine awards' competitions), there are few published data addressing how they go about it; that is, precisely how they assess wine overall quality. There are even less data published that directly link wine professionals' judgments of perceived colour of red wines with perceived wine quality. An exception is the work of Lattey et al. (2010) where the authors investigated winemakers' quality judgments and consumer acceptance of Australian Cabernet Sauvignon and Shiraz wines. Wine professionals judged the wines on a 20-point, wine-judging scale for overall quality, while trained panellists assessed the sensory attributes of the wines by a descriptive rating task. The data show that wines considered higher in overall quality were also judged higher in overall colour. Saenz-Navajas et al. (2015) also reported data on red wine intrinsic quality as judged by wine professionals, this study employing a selection of Spanish and French red wines none of which was Pinot noir. More importantly, the actual sensory characterisation of the wines was not performed by wine professionals but by trained panellists, with the wine professional participants' role limited to sorting the wines in terms of quality. As well, the study did not report data on perceived wine colour, nor colour's relationship with the quality categorisations of the wines by the wine professionals. Hence, the current study is novel in several ways, first with its within-subject design where wine professionals characterised the wines sensorially, including via colour judgments, as well as in terms of overall wine quality, and second by employment of Pinot noir as wine varietal.

It is well established that the appearance of a food or beverage influences the initial judgment made about the product including its safety, sensory characteristics and acceptability (Clydesdale, 1993; Spence, Levitan, Shankar, & Zampini, 2010). Appearance of a food product includes many contextual factors, the most frequently-researched being colour (e.g., Parr, White, & Heatherbell, 2003), packaging (e.g., Velasco et al., 2014), and serving ware such as glass type for serving a beverage (e.g., Wan, Zhou, Woods, & Spence, 2015). In the specific case of appearance and wine, colour and clarity serve as key factors in many formal judging situations where overall wine quality is assessed by wine professionals (e.g., at national and international wine awards shows), with colour and clarity explicitly referred to in several scoring methods such as the 20-point judging scale (Parr, Green, & White, 2006). A large body of research over the last 50 years, employing a range of methodologies and beverage types, has demonstrated that colour influences both qualitative and quantitative aspects of perceived aroma and taste (Kemp & Gilbert, 1997; Pangborn, Berg, & Hansen, 1963; Parr et al., 2003; Shankar, Levitan, & Spence, 2010; Stillman, 1993; Zellner, 2013; Zellner & Whitten, 1999). In her recent review, Zellner (2013) outlines research concerning multimodal perception of flavour that provides evidence that visual and olfactory senses, including retronasal olfaction where the flavour is experienced via the mouth, interact. The influence of colour on chemosensory judgments of beverages appears to be a particularly powerful biasing factor. For example, expertise in the domain of wine did not prevent colour-driven olfactory bias occurring when very experienced wine professionals evaluated a white wine artificially coloured red by odourless anthocyanin (Parr et al., 2003). More surprisingly, Stillman (1993) demonstrated that participants were significantly influenced by colour when judging flavour of artificially-coloured beverages, despite being advised in advance that colour of the to-be-tasted beverages may not be indicative of flavour (i.e., that colour and flavour may not be congruent).

One cognitive interpretation of appearance-driven influence on judgments of smell and taste involves the mediating mechanism of expectations (Deliza & MacFie, 1996; Engen, 1972; Parr et al., 2003; Spence et al., 2010). Expectations is the term employed for a hypothesised cognitive construct that is assumed generated on the basis of prior experience and knowledge. Knowledge about a colour's relevance to the product being assessed (e.g., a red tomato vs a green tomato) is assumed to drive a person's expectations regarding anticipated flavour (Shankar et al., 2010) of the product. In the case of wine, expectations generated by aspects of colour would conceivably include ideas about flavour and style of a white wine vs a red wine (Morrot, Brochet, & Dubourdieu, 2001), and anticipated sensory characteristics of mature wines, specific varietals, and so forth. An important point to note about colour-driven bias is that fundamental research on implicit learning and implicit memory suggests that colour-induced activation of expectations is not necessarily accompanied by a judge's conscious awareness of either the influencing stimulus or its effect on their judgments (Degel & Koster, 1999).

As mentioned above, expectations are assumed learned on the basis of prior experience with the stimuli of interest (Deliza & MacFie, 1996). Research concerning colour–flavour congruence with food and beverage products (for example, some colours appear to correspond or "go with" certain odours while others are less appropriate) has provided evidence in support of this (Velasco et al., 2015; Zellner, 2013). Further, it has been demonstrated that congruency between a product's flavour and appearance can be culture specific (Velasco et al., 2014), suggesting product familiarity to be a factor. France and NZ are countries with very different wine-production histories (Mouret, Lo Monaco, Urdapilleta, & Parr, 2013), with NZ often discriminated as a young wine producer to contrast it with countries such as France that have hundreds of years of wine-production history. It follows that wine professionals in NZ may have very different domain-specific, experiential histories (e.g., learning opportunities) in comparison with French wine professionals, this being reflected in their judgments to fine wines such as Pinot noir. In support of this notion, Mercurio et al. (2010) argue that in Australia, another relatively young wine-producing country, a relationship between red wine colour and wine perceived quality exists in the wine market, with deeper coloured wines graded more highly. Further, Dambergs (2012) reported data showing an association between depth of Pinot noir colour as measured by anthocyanin and tannin composition and awarding of medals at Australian wine shows, with darker wines receiving more gold medals. In the present experiment, our major aim was to determine the influence of colour as a driver of wine quality judgments by wine professionals in both France and New Zealand when judging Pinot noir wines from their own country and when judging wines from the other country. As well, we were interested in determining, as a function of participant culture, which attributes other than colour are important in judging overall quality of Pinot noir wines.

In terms of understanding how wine overall quality is assessed sensorially, it seems prudent to consider how perceived quality is related to wine attributes other than colour, including abstract wine concepts such as typicality and complexity, and to hedonic aspects such as liking. As with quality, the latter two concepts have been little investigated in wine professionals with liking almost universally considered by sensory researchers to be a hedonic

judgment to be made by wine consumers rather than wine professionals (e.g., Dooley et al., 2012). With respect to wine complexity, interview data reported by Charters and Pettigrew (2007) suggest a link between conceptualised wine quality and complexity. However the association remains unsubstantiated by empirical tasting data, with a recently-published study that investigated wine professionals' judgments of perceived complexity not collecting data concerning judgments of overall quality (Schlich, Medel, Urbano, & Parr, 2015). Receiving much more attention by researchers studying wine professionals' wine assessments is the notion of wine typicality, a concept usually operationalised by asking the tasters to judge wines in terms of the degree to which they are good examples of their varietal and/or geographical location (e.g., Ballester, Dacremont, Le Fur, & Etiévant, 2005; Parr, Valentin, Green, & Dacremont, 2010). In their study with experienced French tasters, Parr et al. (2010) reported wine typicality and wine liking to be closely correlated. More recently, typicality, liking and complexity were shown to be closely associated attributes in Sauvignon blanc wines (Parr, Ballester, Peyron, Grose, & Valentin, 2015) but unfortunately no data were collected concerning overall quality, leaving a gap in direct evidence of an association between wine liking, perceived typicality, complexity, and quality. The current study not only addresses this, but as well incorporates wine colour as a potentially related factor when the varietal Pinot noir is assessed.

A secondary but innovative aim of the project was to investigate the influence of glass colour (standard, clear glass vs opaque glass) on sensory evaluations of Pinot noir wines by wine professionals from France and NZ. Use of opaque tasting glasses has become standard practice in research over the last decade to eliminate the influence of wine colour when wines are assessed sensorially. Given that other aspects of glassware such as shape of a glass have been demonstrated to influence ratings of liking and familiarity of beverages including red wine (Wan et al., 2015), it is conceivable that opaque glassware may influence wine professionals' judgments. Most everyday wine tasting, including in professional contexts such as wine competitions or winery laboratories, is not undertaken in black glassware. Hence, in terms of congruency, opaque glassware is not congruent in terms of being statistically normal and thus has potential to influence the overall tasting environment by reducing ecological validity. In the present experiment we tested the influence of tasting glass colour by comparing tasters' responses when characterising Pinot noir wines served in clear glassware with their responses to the same wines served in opaque glassware.

To summarise, the present study involved sensory characterisation of Pinot noir wines from France and NZ by French and NZ wine professionals to determine the influence of colour as a driver of wine quality judgments. We determined as well the wine attributes other than colour that were important to quality judgments of Pinot noir wines for participants of each culture. Finally, since wines were assessed in both standard, clear glasses and in opaque (black) glassware we investigated the influence of glass colour on wine judgments. The following hypotheses were formed. First, we predicted a positive association between perceived intensity of wine colour and judgments of overall wine quality. Second, we predicted an interaction between perceived intensity of wine colour and participant culture, with NZ participants more likely than French participants to negate a wine as a function of lighter colour. Third, we predicted that wine attributes associated with Pinot noir's varietal profile such as red fruits, dark fruits and oak character (Campo, Ballester, Langlois, Dacremont, & Valentin, 2010; Tomasino, Harrison, Sedcole, & Frost, 2013) would be important in predicting perceived wine quality. Finally, we predicted an influence of glass colour on wine sensory judgments, with the assumption that the black glass could constitute an incongruent, contextual stimulus. The precise nature of this latter influence was not determined *a priori*.

2. Materials and methods

2.1. Participants

Twenty-three French wine professionals and 23 New Zealand (NZ) wine professionals participated in the sensory study. All participants were experienced with production and tasting of Pinot noir wine and were considered to be wine experts as defined by Parr, Heatherbell, and White (2002, p. 748). That is, they were known to be employed in Pinot noir wine production, their expertise exemplified in that the mean number of years of wine industry experience was 17 years (range: 6–32 years) for NZ participants and 18 years (range: 2–50 years) for French participants. NZ participants were primarily oenologists and winemakers ($N = 20$), two defined themselves as winery managers, and one participant was a viticulturist. French participants were oenologists ($N = 14$), oenology educators/researchers ($N = 2$), viticulturists ($N = 5$) and negotiants/wine retailers ($N = 2$) who were involved in Pinot noir production in Burgundy. Mean age of the participants was 40 years (age range: 29–54) for NZ and 44 years (age range: 24–72) for France. French participants comprised 26% female and 74% male, and NZ participants comprised 30% female and 70% male. Ten of the NZ participants and 22 of the French participants reported formal wine judging experience. Two French and two NZ participants reported that they were smokers. Participants were not subjected to any form of training prior to their participation in the current study. All participants had however attended one or more research tastings related to our prior experiments (e.g., Parr et al., 2015) and were familiar with the environmental controls (e.g., individual booths), the rating scales, and the wine attributes to-be-rated.

2.1.1. Wines

Twelve Pinot noir wines from the 2012 vintage, six from NZ and six from Burgundy, spanning a range in terms of colour depth/density as judged *a priori* by human vision, were employed in the study (see Table 1). Wine standard parameters were determined by WineScan™ FT2 (FOSS) and these data can be seen in Table 2. All wines were within a quality category, operationally defined by price (NZ$25–35; Euro 10–22.50). The Euro price range resulted in wines of AOC rating in France to be regional or village level. The NZ wines were air-freighted to France for the study, and the French wines were air freighted to NZ.

Table 1
Wines employed in the study (2012 vintage). Note that at the time the studies were conducted, 25 NZ dollars (NZD) ≃ 15.5 Euros (€). NZ = New Zealand.

Wine	Country of origin	Region	Alc (v/v)	Price
NZBE	NZ	Waipara, Canterbury	13.4	25 NZD
NZSL	NZ	Rapaura, Marlborough	13.4	27 NZD
NZBET	NZ	Southern Valleys, Marlborough	13.5	30 NZD
NZARC	NZ	Martinborough	13	32 NZD
NZMV	NZ	Central Otago	13.6	31 NZD
NZWE	NZ	Nelson	13.2	35 NZD
FRBHCN	France	AOC Bourgogne Hautes Côtes de Nuits	12.2	10.95 €
FRBCND	France	AOC Bourgogne "La Chapelle Notre Dame"	13	11.7 €
FRBLCB	France	AOC Bourgogne "Les Croix Blanches"	12.4	12 €
FRAC	France	AOC Aloxe-Corton	12.8	22.50 €
FRGC	France	AOC Gevrey-Chambertin	12.7	20 €
FRBG	France	AOC Beaune-Grèves	13.2	20 €

Table 2
Wine (2012 vintage) basic parameters as determined by WineScan™ FT2 (FOSS). VA = volatile acidity; Folin C index = a measure of wine total phenolics.

Wine	Reducing sugar (g/L)	pH	Total acidity (g/L)	Tartaric acid (g/L)	Malic acid (g/L)	Lactic acid (g/L)	Ethanol (v/v)	VA (g/L)	Folin C index
NZBE	0.6	3.6	5.2	2.6	−0.3	1.7	13.44	0.5	55.5
NZSL	0.6	3.5	5.4	2.1	−0.5	1.8	13.44	0.6	57.2
NZBET	1.0	3.6	4.9	1.9	−0.4	1.6	13.51	0.6	54.3
NZARC	0.4	3.6	4.9	2.0	−0.2	1.9	13.02	0.5	54
NZMV	−0.2	3.6	5.3	1.8	−0.1	1.9	13.56	0.5	50.5
NZWE	0.4	3.6	4.7	1.6	−0.3	1.9	13.2	0.5	55
FRBHCN	0.4	3.4	5.7	2.3	−0.4	2.1	12.19	0.7	55.7
FRBCND	−0.3	3.5	4.7	2.2	−0.3	1.5	12.89	0.4	47.8
FRBLCB	−0.5	3.4	5.0	1.8	−0.1	1.4	12.43	0.3	44.5
FRAC	−0.3	3.4	5.3	2.4	−0.2	1.7	12.84	0.6	44.8
FRGC	0.3	3.5	4.9	2.3	−0.4	1.4	12.68	0.4	50
FRBG	−0.1	3.4	5.1	2.2	−0.1	1.0	13.23	0.5	55.3

Table 3
Descriptors employed for rating in Conditions 1 and 2.

French descriptors	English descriptors	Scale anchors (in English)
Qualité globale	Overall quality	Poor–Good
Notes de réduction	Reductive notes	Absent–Intense
Intensité aromatique	Aromatic intensity	Weak–Strong
Fruits rouges	Red fruits	Weak–Strong
Fruits noirs	Black fruits	Weak–Strong
Fruits murs	Ripe fruit	Weak–Strong
Boisé	Oak	Weak–Strong
Acidité	Acidity	Weak–Strong
Amertume	Bitterness	Weak–Strong
Astringence	Astringency	Weak–Strong
Soyeux	Silkiness	Weak–Strong
Densité en bouche	Weight in mouth	Weak–Strong
Structure	Structure	Poor–Good
Longueur en bouche	Length in mouth	Poor–Good
Equilibre	Balance	Poor–Good
Typicité Pinot noir	Pinot noir typicality	Poor–Good

2.2. Experimental design

Two sensory studies were conducted, one at the sensory facilities of the IUVV, University of Burgundy, France in early June, 2014, and the second at the Marlborough Wine Research Centre in NZ in the 2nd half of July, 2014. The mixed-design experiment involved participant culture (France; NZ) as a between-subject factor, and wine (France; NZ) and chemo-sensory evaluation condition ($N = 2$: assessment in opaque glasses; assessment in clear glasses) as within-subject factors. Finally, participants judged the wines by visual colour assessment.

2.3. Procedure

The experiment in France and the experiment in NZ were conducted under virtually identical conditions. Two to seven people participated at any particular time. Participants were welcomed to the sensory facilities and seated in separate booths. The environment of the sensory facilities was controlled as advised for sensory experimentation (ASTM, 1986). Participants were provided with basic information about the study, following which they completed forms in keeping with ethical requirements of the respective institutions, either Lincoln University or the University of Burgundy. They were advised that they would taste and make judgments about twelve wines and that all wines were Pinot noir. They were not given any other information about the study.

The wines were served at ambient temperature. A new bottle of each wine was opened each day that the experiment was conducted and the wines were first checked for faults by two or three experienced wine professionals. The wine samples for each stage of the task comprised 30-ml, with a new sample poured for each of the two chemo-sensory evaluations and for the visual assessment. In Evaluation Condition 1, the wine samples were served in standardised tasting glasses (ISO, 1977) that were black (opaque), while in Evaluation Condition 2 the wines were served in standardised clear glasses. The wines were served in clear glasses for the visual assessment. The glasses were coded with 3-digit numbers and were covered with plastic Petri dishes. In order to limit carry over effects and memory biases, all wine samples were presented in a different order specific to each participant within each session according to a Williams Latin square arrangement generated by FIZZ software (Biosystemes, Courtenon, France). Water was available throughout each session.

Participants undertook all aspects of the procedure in the same order and on the same day in an overall session that lasted approximately 2 h. They were advised that they were to evaluate each wine in the order presented, and that all wine was to be expectorated (i.e., not swallowed). In Evaluation Conditions 1 and 2, which were separated by a brief temporal interval, each participant rated the wines on the sixteen descriptors reported in Table 3. Table 4 shows the descriptors employed in the visual assessment undertaken by each participant in the final task, namely the visual assessment. The descriptors employed in Evaluation Conditions 1 and 2 were rated in the order given in the table, with overall quality the first attribute to be rated in each evaluation condition. The 16 descriptors were selected as not only appropriate for sensory characterisation of Pinot noir wines (Tomasino et al., 2013), but as well to involve wine characters that could assist in differentiating wines of varying phenolic composition (e.g., ripe fruit; astringency; silkiness; structure). The attributes were scored on 10-point scales with each scale's anchors as described in Table 3.

2.4. Physico-chemical methods

At the time of the sensory experiment in NZ, wine samples were taken for physico-chemical analysis of standard wine parameters (Table 2). The wine parameters in Table 2 were determined by InfraRed spectrometry using Fourier Transformation (IRFT) with a Winescan™ FT2 (FOSS) that was calibrated with wine samples analysed in accordance with official OIV practices. Samples were analysed in duplicate and parameters were quantified using a high-input calibration file. Relative standard deviations were exclusively lower than 10%.

Table 4
Descriptors employed in the visual assessment.

French descriptors	English descriptors	Scale anchors (English)
Teinte de la couleur	Colour/hue	Tile/Orange–Violet
Intensité de la couleur	Intensity of colour	Light–Dark
Brillance	Brightness	Dull–Bright

2.5. Data analysis

2.5.1. Effect of perceived colour on quality judgments

A 3-way, mixed design ANOVA with participant culture (France; NZ) as a between-subject variable and evaluation condition (clear vs black tasting glasses) and wine origin (France; NZ) as within-subject variables was carried out on wine quality judgments.

2.5.2. Prediction of quality judgments by visual colour assessments

Six multiple regression analyses (three for each participant culture) were carried out with measures of perceived hue, colour intensity, and brightness as predictors of wine quality when the wines were evaluated in the clear glass condition. The first analysis for each participant culture was carried out on the entire set of wines. The two other analyses were carried out on French and NZ wines separately.

2.5.3. Effect of tasting glass (clear vs black) on chemosensory judgments

A 3-way, mixed design ANOVA with participant culture as a between-subject variable and evaluation condition (clear vs black glasses) and wines as within-subject variables was carried out on chemosensory descriptors.

2.5.4. Prediction of quality by chemosensory judgments

Four multiple regression analyses (two for each participant culture) were carried out with chemosensory descriptors as predictors of wine quality judgments in the clear and black glasses' evaluation conditions separately.

2.5.5. Wine quality and typicality mapping

Four principal components analyses (PCA) were carried out, one in each tasting condition for each country (French participants, clear glass condition; French participants, black glass condition; NZ participants, clear glass condition; and NZ participants, black glass condition). All chemosensory assessments (including quality and typicality) were entered in the analysis as active variables. Visual assessments and wine standard physico-chemical parameters were entered as supplementary variables.

3. Results

3.1. Effect of perceived colour on quality judgments

A significant main effect of evaluation condition, $F(1,44) = 7.20$, $p < 0.05$, was observed. On average, judgments of perceived quality were higher in the clear glass (*Mean* = 5.61) than in the black glass (*Mean* = 5.41) condition. However, the strength of this effect is low ($R^2 = 0.02$) compared to other effects in the model. Besides the main effect of evaluation condition we observed a significant main effect of participant culture, $F(1,44) = 4.12$, $p < 0.05$, with NZ participants giving higher quality scores on average than French participants (*Mean* = 5.77 vs 5.26 respectively, $R^2 = 0.13$) as well as a significant main effect of wine origin, $F(1,44) = 4.12$, $p < 0.05$, with higher quality scores to NZ wines than to French wines (*Mean* = 6.16 vs 4.96 respectively, $R^2 = 0.82$). This latter effect explains the largest part of the model and appears due primarily to two French wines (FRBHCN and FRBLCB) that were judged low in quality in both evaluation conditions by both participant cultures (Fig. 1). There were no significant interactions.

3.2. Prediction of quality judgments by visual colour assessments

Table 5 shows the results of the multiple regression analyses for French and NZ participants in the clear glass condition. For French participants, only the regression analysis carried out on NZ wines was significant, $F(3,134) = 6.41$, $p < 0.001$, $R^2 = 0.12$, with colour intensity the one significant predictor ($t = 2.46$, $p < 0.05$): the more intense (dark vs light) the perceived wine colour, the higher the quality of NZ wines was judged to be by French participants. For NZ participants, the regression analysis carried out on all wines was marginally significant, $F(3,272) = 2.59$, $p < 0.06$, $R^2 = 0.03$, with brightness the only significant predictor ($t = 2.15$, $p < 0.05$): the more brilliant/bright the wine (as opposed to dull), the higher the quality of both NZ and French wines was judged to be.

3.3. Effect of tasting glass (clear vs black) on chemosensory judgments

Table 6 shows the results of the ANOVA carried out on the chemosensory descriptors. A significant main effect of evaluation condition (clear vs black glasses) was observed for nine of the fifteen descriptors. Six wine attributes were judged more intense on average when the wines were evaluated in clear glasses relative to evaluations in black glasses: aromatic intensity, red fruits, silkiness, structure, balance, and typicality. On the other hand, for the other three descriptors, namely oak, bitterness, and astringency, the direction of the significant effect was reversed (Fig. 2, left panel).

A wine main effect was observed for all descriptors, as well as a main effect of participant culture for eight descriptors, with NZ participants giving higher scores than French participants to these attributes (Fig. 2, right panel). Finally, the ANOVAs revealed no significant interactions with the exception of a culture * evaluation condition interaction for bitterness, and a culture * wine interaction for oak and typicality. Regarding this last interaction, whereas NZ participants judged all NZ wines more typical than did the French participants, a significant difference was observed only for one

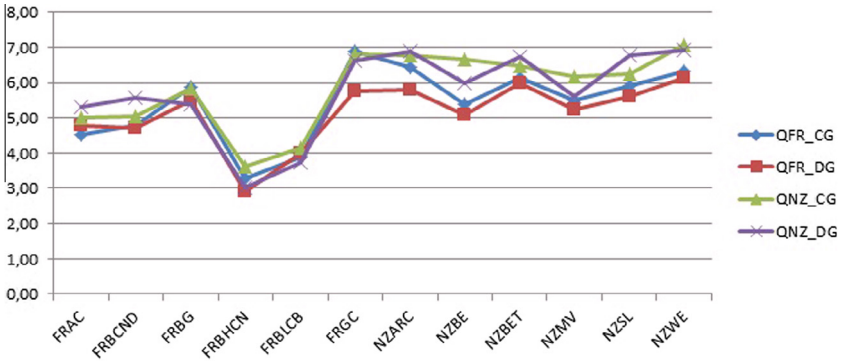


Fig. 1. Average quality scores given by French (QFR) and NZ (QNZ) participants in the clear (CG) and black (DG) glass conditions. The wine codes commencing with FR correspond to French wines and those commencing with NZ correspond to NZ wines.

Table 5
Multiple regression analyses of quality judgments by visual colour assessments by French (FR) and NZ participants in the clear glass condition for (i) all wines, (ii) French wines, and (iii) NZ wines (ns = not significant. Significant descriptors are in bold.).

Variable	*DF*	Parameter estimate	Standard error	*t* Value	*Pr* > |*t*|
FR participants, all wines, ns					
Intercept	1	4.61	0.76	6.05	<.0001
Hue	1	0.04	0.10	0.38	0.7055
Intensity	1	0.07	0.10	0.75	0.4514
Brightness	1	0.01	0.08	0.17	0.8638
FR participants, FR wines, ns					
Intercept	1	2.46	1.21	2.03	0.0440
Hue	1	0.30	0.16	1.86	0.0651
Intensity	1	−0.13	0.14	−0.99	0.3242
Brightness	1	0.17	0.12	1.34	0.1828
FR participants, NZ wines, F(3,134) = 6.41, p < 0.001, R^2 = 0.12					
Intercept	1	4.42	0.88	5.02	<.0001
Hue	1	0.07	0.13	0.53	0.5987
Intensity	**1**	**0.31**	**0.12**	**2.46**	**0.0152**
Brightness	1	−0.07	0.09	−0.78	0.4395
NZ participants, all wines, F(3,272) = 2.59, p < 0.06, R^2 = 0.03					
Intercept	1	5.32	0.51	10.36	<.0001
Hue	1	−0.12	0.06	−1.92	0.0555
Intensity	1	0.06	0.06	0.93	0.3522
Brightness	**1**	**0.12**	**0.05**	**2.15**	**0.0328**
NZ participants, FR wines, ns					
Intercept	1	3.96	0.75	5.22	<.0001
Hue	1	0.07	0.10	0.71	0.4780
Intensity	1	−0.06	0.10	−0.61	0.5401
Brightness	1	0.14	0.08	1.75	0.0830
NZ participants, NZ wines, ns					
Intercept	1	5.29	0.63	8.35	<.0001
Hue	1	−0.01	0.08	−0.24	0.8101
Intensity	1	0.07	0.08	0.92	0.3599
Brightness	1	0.14	0.06	2.20	0.0294

French wine, wine FRBCND (see Fig. 3). As no three-way interaction was observed this effect was not affected by the evaluation condition.

3.4. Prediction of quality by chemosensory judgments

All regression analyses were significant and explain about 70% of the variance (Table 7). For both cultures, the number of significant predictors was higher in the clear glass condition than in the black glass condition (6 vs 4 for French; 7 vs 5 for NZ). The only common significant predictor across the four combinations of the variables (2 cultures; 2 glass conditions) was wine balance; under all situations, the better balanced a wine was judged to be, the higher its perceived quality. Other important predictors of quality were fruity notes, albeit that the qualitative aspects of the fruity notes varied across evaluation conditions and cultures. For example, dark fruit was a significant predictor of quality when the wines were judged in clear glasses by French participants whereas red fruits were a positive predictor in the other conditions. Perceived oakiness was a positive predictor of quality for both cultures but only in the clear glass condition. Several other descriptors were significant in only one case out of the four possibilities. Finally, density in mouth (palate weight) and acidity were not significant predictors for this sample set of Pinot noir wines.

3.5. Wine quality and typicality mapping

Figs. 4 and 5 show the PCA plots of sensory data and wine standard physico-chemical parameters in the clear glass and black glass evaluation conditions for French (Fig. 4) and NZ (Fig. 5) participants. Visual attributes and physico-chemical variables were set as supplementary variables. For all PCAs, the first two components explained more than 80% of total variance. Pearson correlation coefficients showed high similarity between the first components in all conditions ($r > 0.90$) and to a lesser extent between the second components ($r > 0.60$). In all conditions, the first components were strongly correlated with quality and typicality judgments. Whereas French wines are spread out along this dimension, NZ wines tend to cluster on the higher quality and typicality side of the component. Both quality and typicality judgments were highly positively correlated with fruity descriptors, albeit that there were a few differences across conditions on the nature of the fruit. As well, quality and typicality were positively correlated with perceived structure and balance of the wines which appear correlated with several wine parameters, namely pH and concentrations of Folin C (an index providing a measure of wine total phenolics), residual sugar, and ethanol. Conversely, typicality and quality are negatively correlated with perceived bitterness, astringency and acidity, and with estimated wine total acidity. The second components are mostly driven by colour (hue and intensity) which appears to be independent of quality and typicality.

Besides these similarities, some differences appear in the four PCAs, these largely concerning perceived reductive characteristics. For French participants, reductive characters were positively correlated with visual attributes of intensity and hue in the clear glass

Table 6
Sensory descriptors' ANOVA results (Fischer *F*): Model = Subject (Culture) * Evaluation condition (clear vs black glasses) * wines.

Descriptor	Participants' culture	Wine	Evaluation condition	Culture * wine	Culture * Evaluation condition
Aroma_intensity	ns	11.08***	12.50**	ns	ns
Red fruits	16.48***	5.88***	12.27**	ns	ns
Black fruits	ns	11.13***	ns	ns	ns
Ripe fruit	ns	13.42***	ns	ns	ns
Oak	10.13**	19.77***	10.37**	1.86*	ns
Reductive notes	7.60**	6.90***	ns	ns	ns
Bitterness	ns	14.99***	4.84*	ns	4.67*
Acidity	ns	13.13***	ns	ns	ns
Astringency	5.40*	26.49***	3.86*	ns	ns
Silkiness	ns	25.52***	14.26***	ns	ns
Weight	ns	12.26***	ns	ns	ns
Structure	7.39**	16.32***	4.35*	ns	ns
Balance	6.78*	26.26***	8.66**	ns	ns
Length	9.51**	10.07**	ns	ns	ns
Typicality	10.86**	20.80***	14.54**	2.26*	ns

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

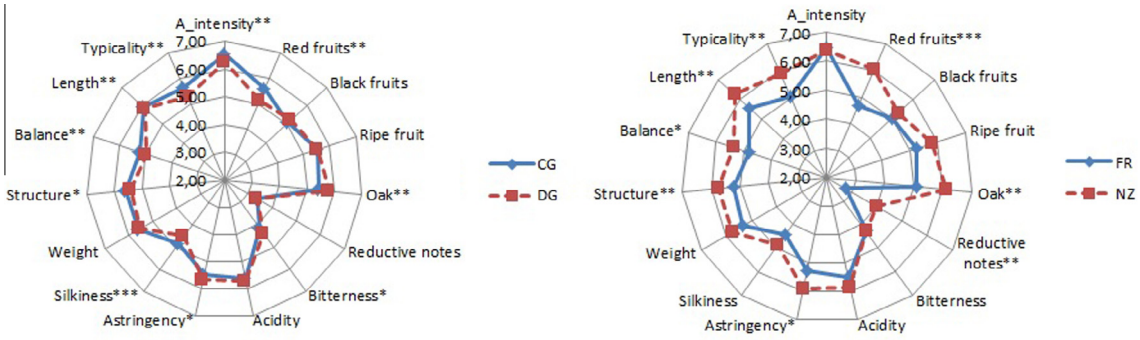


Fig. 2. Effect of evaluation (clear vs black glass) condition (left panel) and participant culture (right panel) on chemosensory descriptors. The stars represent significance level of the ANOVA main effects of evaluation condition and participant culture (*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$). A_intensity = aromatic intensity.

Table 7
Linear multiple regression analyses of quality judgments and chemosensory descriptors in the two evaluation conditions (clear vs black glasses) for the two groups of participants. Significant effects are in bold type.

Descriptor	Clear glasses FR		Black glasses FR		Clear glasses NZ		Black glasses NZ	
	t Value	*Pr* > |*t*|	*t* Value	*Pr* > |*t*|	*t* Value	*Pr* > |*t*|	*t* Value	*Pr* > |*t*|
Aroma_intensity	1.31	0.1901	1.18	0.2384	0.42	0.6731	**3.74**	**0.0002**
Red fruits	1.85	0.0657	**2.30**	**0.0224**	**3.16**	**0.0017**	**3.11**	**0.0021**
Black fruits	**2.26**	**0.0243**	0.32	0.7497	**2.72**	**0.0071**	**2.58**	**0.0106**
Ripe fruit	0.76	0.4469	**3.67**	**0.0003**	**2.23**	**0.0269**	0.89	0.3756
Oak	**3.04**	**0.0026**	1.74	0.0835	**3.68**	**0.0003**	1.15	0.2505
Reductive notes	0.4	0.6928	−1.87	0.0620	**−2.21**	**0.0279**	−1.42	0.1557
Bitterness	−1.11	0.2661	−0.44	0.6607	**−2.01**	**0.0457**	0.22	0.8290
Acidity	0.07	0.9413	0.47	0.6406	0.20	0.8386	−1.08	0.2803
Astringency	**−4.36**	**<.0001**	−0.65	0.5150	−0.22	0.8259	0.98	0.3267
Silkiness	**2.25**	**0.0255**	1.90	0.0581	0.41	0.6796	1.93	0.0542
Weight	−0.63	0.5319	−0.19	0.8491	1.35	0.1771	0.91	0.3655
Structure	1.08	0.2797	**3.09**	**0.0023**	0.62	0.5391	**3.29**	**0.0012**
Balance	**6.54**	**<.0001**	**8.86**	**<.0001**	**7.51**	**<.0001**	**4.38**	**<.0001**
Length	**2.3**	**0.022**	−1.56	0.1201	0.26	0.7923	1.39	0.1656
	$F = 59.72$, $p < .0001$, $R^2 = 0.76$		$F = 50.52$, $p < 0.0001$, $R^2 = 0.71$		$F = 45.57$, $p < 0.0001$, $R^2 = 0.72$		$F = 47.89$, $p < 0.0001$, $R^2 = 0.73$	

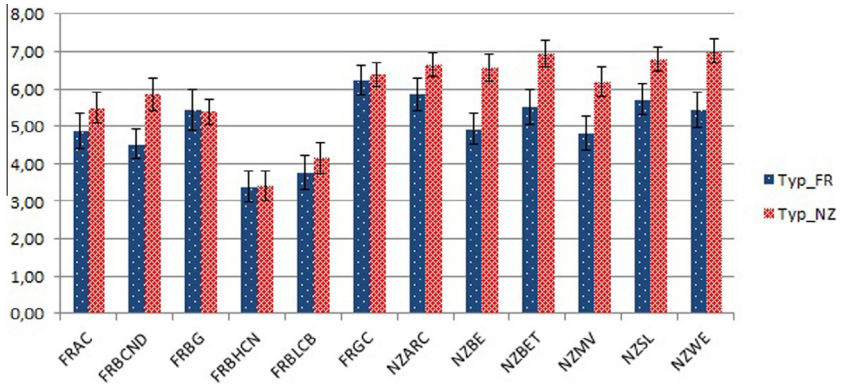


Fig. 3. Average typicality scores given by French (Typ_FR) and NZ (Typ_NZ) participants, averaged across evaluation conditions. The wine codes commencing with FR correspond to French wines and those commencing with NZ correspond to NZ wines. The error bars represent the standard error.

condition whereas they were negatively correlated with those variables and positively correlated with brightness in the black glass condition. This switch in the position of reductive notes seems to have its source in perception of two FR wines (FRBG and FRBHCN) which were perceived as having higher reductive characters in the clear condition than in the black glass condition. For NZ participants, reductive characters opposed hue and colour intensity in the black glass condition but not in the clear glass condition. Three wines, FRAC, FRBCND, and NZBE, tended to be perceived as having reductive characters when they were assessed in black glasses and as having red fruits when assessed in clear glasses.

4. Discussion

The major aim of the study was to investigate the statistical association between Pinot noir wine quality and perceived wine

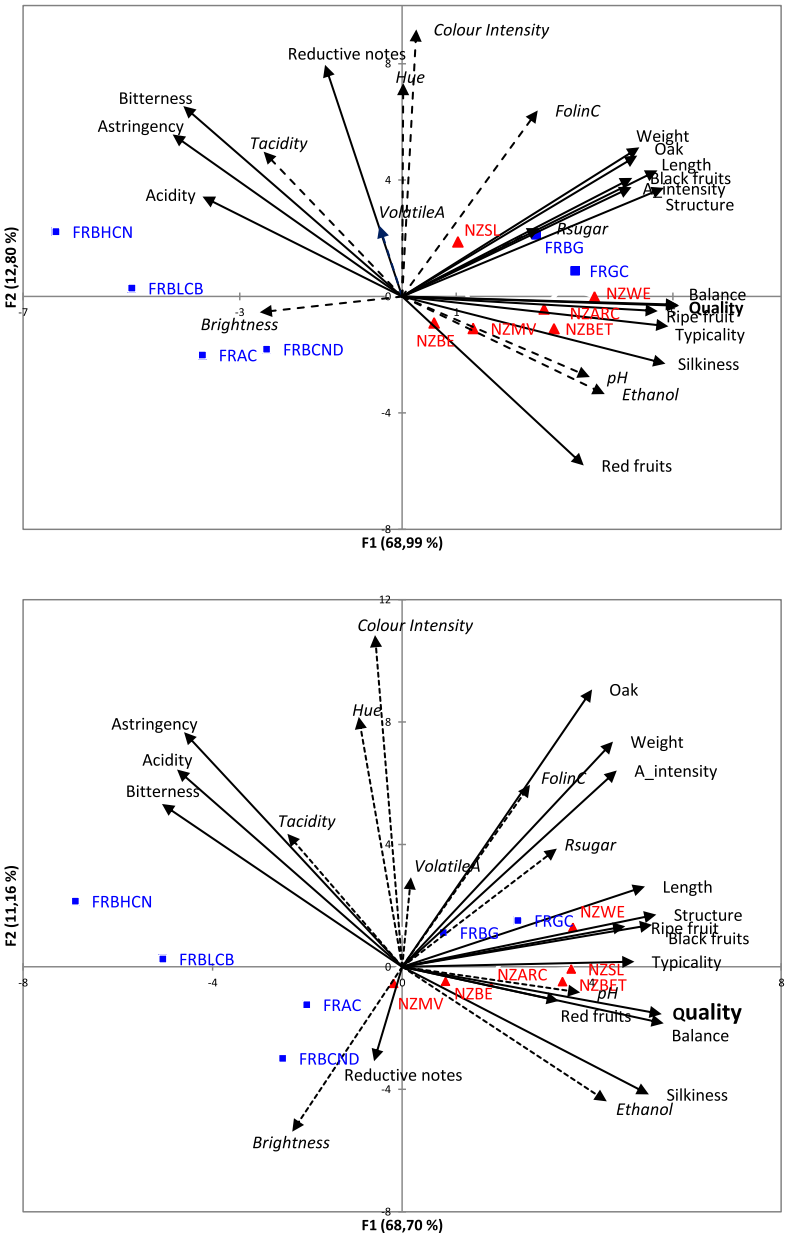


Fig. 4. PCA of sensory data and wine basic parameters in the clear glass (top panel) and black glass (bottom panel) evaluation condition for French participants. Dotted lines indicate supplementary variables (visual assessment and physico-chemical data).

colour as a function of the culture of the wine-professional participants (France; NZ). The most important outcome is demonstration that contrary to our first hypothesis, wine colour was not a major driver of perceived wine quality for tasters of either culture, albeit that there were several minor effects observed pertaining to wine colour. Instead, for both French and NZ wine professionals, the most important driver of perceived quality in the French and NZ Pinot noir wines was perceived wine balance. Supporting our third hypothesis, wine typicality, oakiness, structure, and varietal fruit attributes (red fruits; black fruits; ripe fruit) were identified as important to perceived quality, suggesting that the characters considered to give Pinot noir its varietal nature also enhanced a wine's perceived quality.

Both visually-assessed wine colour (hue: orange–violet; intensity: light–dark; and brightness: dull–bright) and type of wine-tasting glass (clear vs opaque) had effects on judgments of the Pinot noir wines, some of these effects more easily interpretable than others. In terms of our first two hypotheses, based largely on anecdotal evidence, the data are not in support of either. To the contrary, the one significant result involving wine colour intensity (light vs dark) showed that it was French rather than NZ participants who employed colour intensity as a driver of their quality judgments, with darker coloured, NZ wines considered of higher quality. Presumably, the NZ wines were relatively novel stimuli for French wine professionals, suggesting lack of familiarity a factor in the judgments. More easily interpretable in terms of cross-cultural effects is the result demonstrating brightness of a wine as a positive predictor of wine quality for NZ participants, but not for French participants. As a young, wine-producing country NZ wine producers tend toward use of technology in wine production with fining and filtering common practices, both aimed at enhancing wine clarity and perceived brightness. In contrast, more

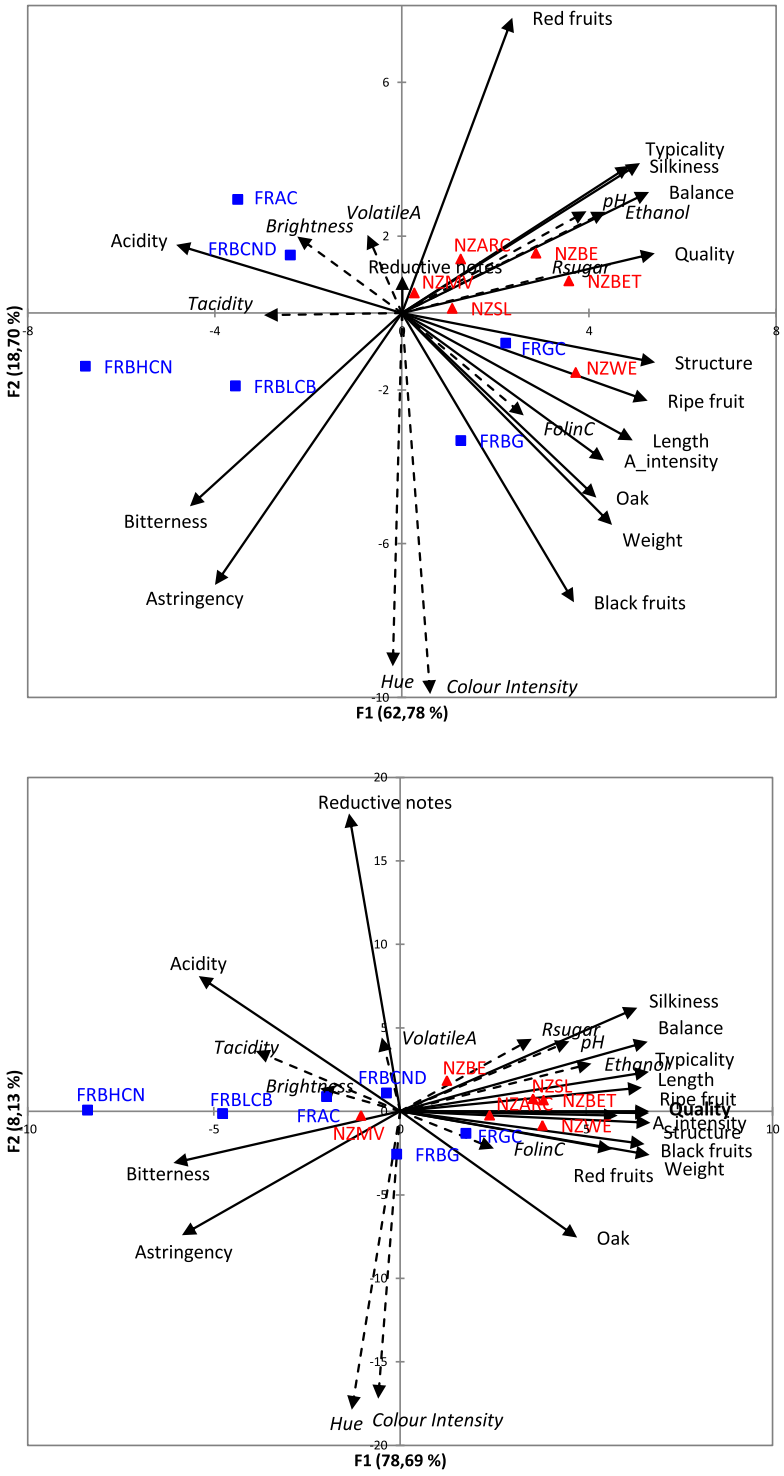


Fig. 5. PCA of sensory data and wine basic parameters in the clear glass (top panel) and black glass (bottom panel) evaluation condition for NZ participants. Dotted lines indicate supplementary variables (visual assessment and physico-chemical data).

traditional wine-production methods as employed by many Burgundian wine producers can result in production and sale of unfiltered Pinot noir wines where less emphasis is placed on clarity and brightness when a wine is assessed organoleptically. Hence, it is conceivable that differences in experiential history for the French and NZ wine professionals contributed to this cross-cultural difference in wine quality assessments (Mouret et al., 2013).

In terms of glass colour, several effects are worthy of discussion. First, although the effect was small wines were judged overall to be of higher quality when presented in clear glasses rather than in black glasses. In keeping with this, several wine attributes related to Pinot noir varietal typicality, namely fruitiness (red fruits; black fruits), silkiness, and typicality, were judged higher when the wines were in clear rather than black glassware. Taken together,

these results argue that the black glass context may have its own effect on wine tasting behaviour, albeit a subtle effect, muting or attenuating responding either at the decision-making stage (i.e., introducing bias) or in scale usage when rating (see Lawless & Heymann, 2010, for discussion on the latter). This black-glass effect conceivably has its source in the incongruent context generated for wine professionals who seldom judge wines in opaque glassware. Further studies specifically designed to investigate opaque vs clear glassware in wine-tasting research are clearly warranted given that many data collected within the black-glass context are generalised to broader tasting situations.

An important result demonstrated by the present study is that both French and NZ wine professionals drew on attributes other than colour to judge overall quality of a Pinot noir wine. In this respect, cultural similarities were more pronounced than cultural differences. Positively associated with the global and somewhat abstract notion of wine intrinsic quality were global wine characteristics of balance, structure, and perceived typicality, along with more concrete attributes related to Pinot noir varietal fruity notes (i.e., intensity of black fruits, red fruits, and ripe fruit) and oakiness. These results are broadly in keeping with those of Lattey et al. (2010) who reported that Cabernet Sauvignon and Shiraz wines considered by wine professionals to be higher in quality were rated by the trained panellists as higher in red berries, spice, woody, vanilla, fruit flavour, and persistence than wines judged lower in quality. In the present study, quality judgments were also negatively correlated with several attributes for participants of both cultures, these being perceived bitterness, astringency and acidity. These data show that the concept of quality as applied to Pinot noir wines appears a shared mental construct across wine professionals from France and New Zealand despite cultural differences in wine-production histories and attitudes toward wine (Mouret et al., 2013). A similar shared mental construct of wine quality was reported by Saenz-Navajas, Ballester, Pecher, Peyron, and Valentin (2013) for French and Spanish wine professionals evaluating Spanish Rioja and French Cote du Rhone red wines. In terms of the basic wine parameters estimated, Figs. 4 and 5 show that Folin C, one of several available measures of wine total phenolics, associated with oakiness, wine structure, length in mouth, and intensity of black fruits and ripe fruit, while perceived silkiness, balance, and quality associated with wine pH and ethanol concentration. As with perceived acidity, estimated wine total acidity opposed perceived quality in the Pinot noir wines. Overall, these data add to a growing literature aimed at understanding the nature of the abstract but often reported wine attribute *quality* (Saenz-Navajas et al., 2015).

5. Summary and conclusion

In summary, our main hypothesis predicting a positive relation between perceived quality and perceived colour of Pinot noir wines was minimally supported. On the other hand, the present study has provided novel data concerning the wine attributes that French and NZ wine professionals do associate with Pinot noir wine quality. Further, we have shown that both the salience and direction of influence of these attributes (i.e., whether positive or negative) is largely shared across the two cultures investigated. In terms of generalisation of these results it is prudent to comment that demonstration that wine professionals draw on attributes other than wine colour to judge overall quality of a Pinot noir wine does not eliminate the notion that consumer acceptance of such wines may be subject to colour bias. This is an issue of interest to wine producers and marketing professionals that lends itself to future empirical investigation. Finally, an important methodological issue, namely usage of opaque glassware in wine sensory research, has been identified as a topic worthy of serious future research endeavour.

Acknowledgments

The project was funded by a Trimble Agricultural Travel Fellowship awarded to Wendy Parr, and by the New Zealand Grape and Wine Research Programme, Plant and Food Research Institute of NZ, and NZ Wine Growers. We thank Abby Albright, MWRC, NZ for conduction of WineScan analyses, the study participants in Burgundy, France and in Marlborough, New Zealand, and the wine producers who provided their wines for the study.

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