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			X

Indicate (X) client(s) to whom this final report is submitted.
Replace any of these with other relevant clients if required.

FINAL REPORT
FOR 2011

PROGRAMME & PROJECT LEADER INFORMATION

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PROJECT INFORMATION

Project number	WW 08/30
Project title	The role of metals on the (in)stability/maturation rate/"houvermoe" of wines.
Project Keywords	Metals, shelf-life, white wine

Industry programme	**CFPA**	
	Deciduous	
	DFTS	
	Winetech	Production Technology
	Other	

Fruit kind(s)	Grapes (Wine)
Start date (dd/mm/yyyy)	01/04/2009
End date (dd/mm/yyyy)	31/03/2012

(Note: adjust footer – insert the project number no, researcher and research institution)

FINAL REPORT

(Completion of points 1-5 is compulsory)

1. Executive summary

Give an executive summary of the *total* project in no more than 250 words

The ultimate aim of the project is to investigate the role of (heavy)metals on the maturation rate and quality characteristics of white wines. The first part of this study investigates the role of metals on the maturation rate at different temperatures (i.e. 15°C, 25°C and 35°C) of white wine through the removal of metals against a control wine not subjected to this treatment. Dose-dependent studies performed initially indicated the amount of particular metal-chelating resin necessary to get optimal extraction of metals from Chenin blanc wine. Chenin blanc wine treated with optimal resin to remove metals, and control wines not subjected to this treatment were then stored at different temperatures and analysed sensorially and chemically at time zero (unmatured) and at 4, 7 and 16 months of bottle ageing. Data, subjected to univariate and multivariate statistical analysis, showed groupings according to treatment, storage temperature and time of bottle ageing. Discriminate analysis provided better separation of samples than principal component analysis. Correlations could be drawn between treatment, storage temperature and / or ageing, sensory descriptors and chemical data (including metals). Strong correlations between certain metals and positive / negative sensory descriptors and wine components, thus gave an indication of which metals could be important and determining regarding the quality of wine. Treated wines (metals concentration reduced) had significantly ($p \leq 0.05$) better colour, showed less oxidative character ($p \geq 0.05$), and formed less ($p \geq 0.05$) sediment than untreated or control Chenin blanc wines. Treated wines were less prone to turbidity and oxidative increases, and decreases in fruity character, persistence and overall quality under accelerated conditions at high storage temperatures. Despite the positive impact of metal removal on shelf-life descriptors such as colour, oxidation and sediment formation, the particular resin treatment, however, in addition to metal removal, also impacted on certain wine components.

2. Problem identification and objectives

State the problem being addressed and the ultimate aim of the project.

Although there is nothing wrong with the vinification process and the levels of heavy metals (iron and copper) are not higher than legally permitted, some South African white wines show premature aging effects after relatively short bottle aging. Could the faster maturation of white wine perhaps be attributed to the levels and type of metals that act as catalysts of oxidation? Metals in wine are known to act as catalysts in oxidation processes, form complexes with various wine constituents, lead to haze formation, clouding and precipitation, cause wine instability at high concentrations, and impact on the organoleptic properties of wine. The ultimate aim of the project is to investigate the role of (heavy) metals on the maturation rate and quality characteristics of white wines. Results can be used to implement strategies for wine quality improvement. A possible outflow of this study would be to make recommendations on the optimum degree of reduction of the metallic content of specific white wines in the context of achieving a significant control over its tendency to suffer deterioration.

3. Workplan (materials & methods)

List trial sites, treatments, experimental layout and statistical detail, sampling detail, cold storage and examination stages and parameters.

A few preliminary trials were first conducted in the process of ascertaining the efficacy of the chosen metal-chelating agents. These early investigations proved to be valuable regarding optimal conditions to be used in the actual experiment. The preliminary trials were:

- Trial 1: A simple comparative study to select a suitable analytical method of metal analyses;
- Trial 2: A study to determine the optimum dose of metal-chelating agent for effective metal removal from wine;
- Trial 3: A study to prove the differences in efficacy between unwashed and acid-washed resins in their metal-chelating abilities;
- Trial 4: An improved repetition of the first dose dependence study (Trial 2), but taking into account the results and information obtained from previous trials.

Chenin blanc wine treated with optimal resin to remove metals, and control wines not subjected to this treatment were stored at different temperatures and analysed sensorially and chemically at time zero (unmatured) and at 4, 7 and 16 months of bottle ageing. Data were subjected to univariate and multivariate statistical analysis.

Although not initially part of the proposed analyses of the main experiment's samples, wines were also analysed for total polyphenols and routine parameters.

4. Results and discussion

State results obtained and list any benefits to the industry. Include a short discussion if applicable to your results. This final discussion must cover ALL accumulated results from the start of the project, but please limit it to *essential* information.

Milestone	**Achievement**
3.1. Continuation of literature overview and popular publications.	3.1. *Objective completed 2011.* Popular publications in the March issue of 2010 and March, April and May 2011 issues of Wineland / incorporating Wynboer Tegnies.
3.2. Survey and identification of a cellar for collaboration and from which juice/tank/commercial wine sample(s) will be sourced.	3.2. *Objective completed 2009.*
3.3. Determination of optimal metal removal capacity of metal-chelating resin(s) and determination of the percentage removal.	*3.3. Objective completed 2009.*
3.4. Procurement/collection of wine.	*3.4. Objective completed 2009.*
3.5. Removal of metals with metal-chelating agents/resin.	*3.5. Objective completed 2009.*
3.6. Storage of samples for up to 16 months at 15℃, 25℃ and 35℃, and sensory and chemical evaluation at regular intervals.	*3.6. Objective completed.*
3.7. Evaluation of Wine & Spirits Board approved and rejected wines for metal content and collection of sensory and routine chemical results.	*3.7. Objective ongoing 20/11.* All rejected wines collected during 2010. Awaiting approved wines from the same producers / blocks if possible as part of the extension of this project in 2011.

Milestones 3.1- 3.2, 3.4, 3.7.

See above table.

Milestone 3.3. Determination of optimal metal removal capacity of metal-chelating resin(s) and determination of the percentage removal.

Selection of metal-chelating agents

Globally a small amount of work has been reported on metal-chelating agents/resins for the extraction of specific metals from wine, therefore an extensive amount of time was spent on researching, selecting and procuring suitable resins for this experiment. As a result of various factors, such as the limited literature available, the difficulty to find resins locally as local suppliers are not familiar with metal-chelating resins, and rather high resin prices, five different metal-chelating agents could ultimately be obtained, i.e. Divergan® HM, Lewatit® TP-207, Purolite® C100E, Purolite® C100S and potassium ferrocyanide.

These metal-chelating agents were selected based on the following:

- that Divergan® HM, being a commercially-available resin, has already been used on wine before (but for specific metals only) and carried FDA-approval;
- the two Purolite resins are also FDA-approved resins used in the food industry (not wine), but were recommended by the supplier;
- Lewatit® TP-207, being a known iminodiacetic chelating agent, is selective for the removal of heavy metals from weakly acidic solutions;
- and lastly, potassium ferrocyanide, a controversial fining agent which has already been used extensively in the wine industry, but under strict legal regulations due to its potential toxicity.

Most of these metal-chelating agents are not supplied on small-scale and, therefore, donations were secured from the suppliers, but for limited amounts only, allowing for their evaluation before making any decisions as to which was the most suitable resin(s) for the purpose of this study.

Preliminary investigations and optimisations

Before carrying out the main experiment a few preliminary studies first had to be completed so as to ascertain the efficacy of the selected metal-chelating agents and the envisaged treatments. The selectivity of the chelating resin(s) for metal removal from wine was demonstrated by comparing the metal concentrations of untreated (control) wine and treated wine.

Trial 1: Multi-metal vs. Single-metal Scan

The first of these trials was a comparison between the multi-metal and the single-metal ICP-OES analyses done by an external laboratory. The reason for this was that there were financial implications related to which method would be chosen (with the latter method being the more expensive one). Fortunately, these two methods of analyses showed similar results in the data produced – with slight variations in sensitivity between duplicates – but the overall trend proved to be the same for both types of analysis (Fig.1).

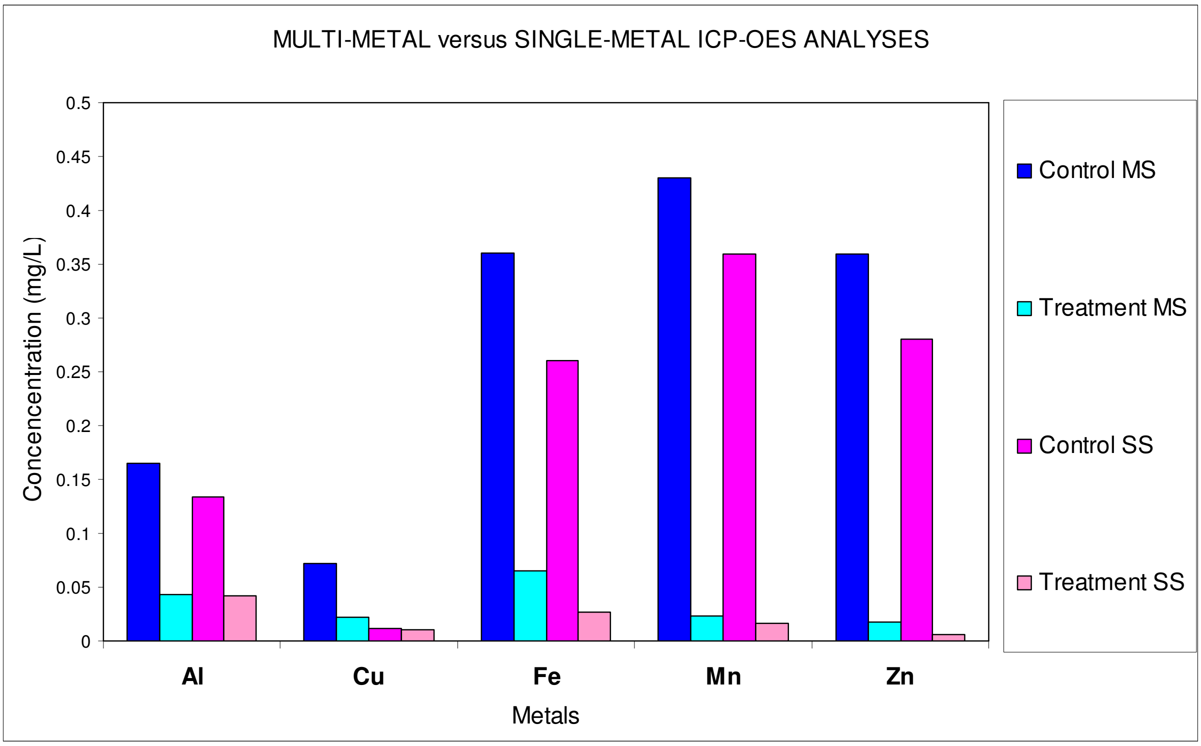


Fig. 1. Differences in concentrations of selected metals in control (untreated) and treated (treated with a metal-chelating resin) white wine samples during a comparative study of the ICP-OES multi- (blue bar graphs) and single-metal (pink bar graphs) methods of analyses.

In brief, the above trial simply entailed treating a 2009 Chenin blanc wine (obtained from Goudini Cellars) with an arbitrary amount of resin and left to extract overnight (overnight being used as the maximum time for effective metal extraction to occur). The following day the treated wine, together with a control sample, was sent to an external laboratory for metal analyses. The laboratory conducted Multi-element(metal) ICP-OES analysis, as well as Single-metal ICP-OES analysis on the treated and control (untreated) wine samples. The multi-metal scan (trial "MS") analysed a total of 45 metals in one run (*i.e.* Ag, Al, As, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ge, Hf, Hg, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, S, Re, Sb, Sn, Sc, Se, Si, Sr, Be, Te, Ta, Ti, Tl, V, Y, Zr, Zn and W), while the single-metal scan (trial "SS") was a more sensitive approach as it only analysed one metal at a time, but took longer and was thus the more expensive method. The 13 metals of interest, as initially layed out in the project proposal, were mainly focused on in these analyses and also for subsequent discussions.

Trial 2: Dose dependence study

The objective of the next study was to identify the ideal dose of each resin for the effective extraction of metals from wine. An initial dose, based on related literature, was used as a starting point for each resin/chelating agent with various increments calculated, resulting in four different doses of each resin/chelating agent being added to individual wine samples. Each wine sample (100mL) with its particular dose of resin/chelating agent was left to extract (stirred on magnetic stirrer-plates at a low RPM to avoid foaming) overnight, and then sent for analyses at an external laboratory. An example of the results is illustrated below (Fig. 2).

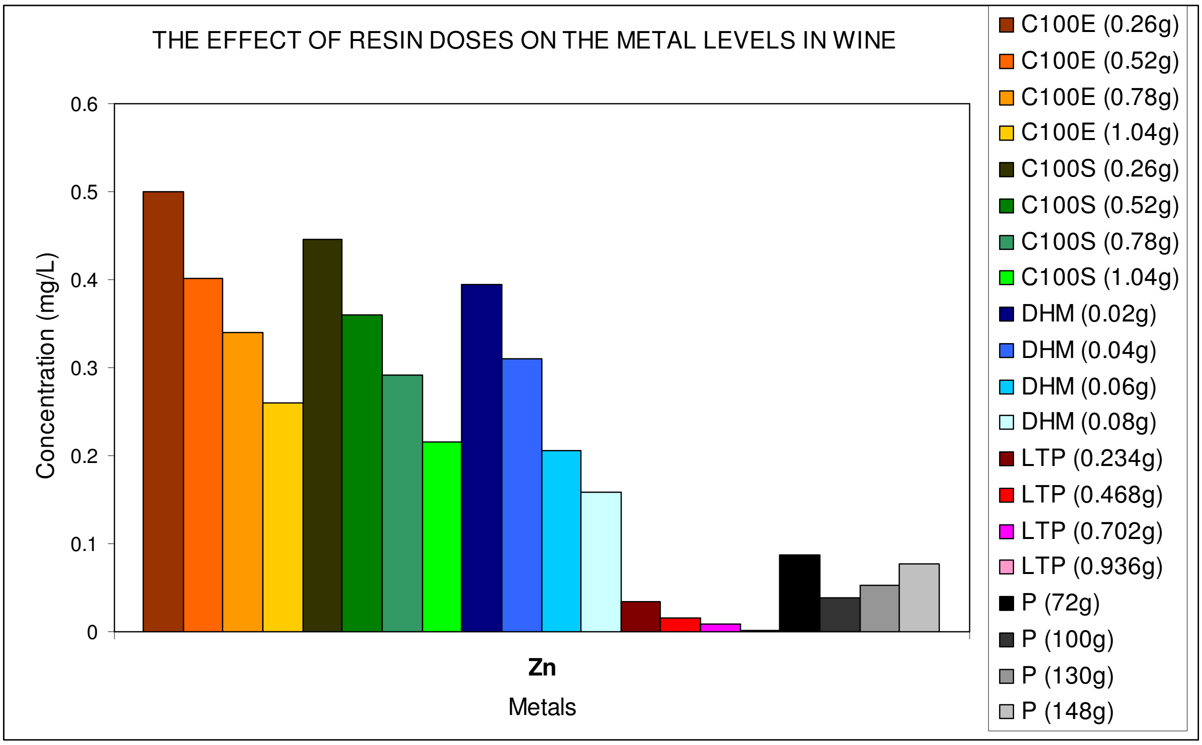


Fig. 2. Effect of increasing doses of various metal-chelating agents on the concentration levels of a selected metal, zinc (Zn), in Chenin blanc wine. The metal-chelating agents used were: C100E = Purolite® C100E; C100S = Purolite® C100S; DHM = Divergan® HM; LTP = Lewatit® TP-207; and P = potassium ferrocyanide.

Figure 2 clearly shows how the zinc levels decrease in the wine with every set of increasing doses of metal-chelating agents. Only the potassium ferrocyanide does not follow the aforementioned trend for zinc, as there is a slight increment in its levels as the resin dose increases. So, clearly in this case, 4 out of 5 chelating agents are effective in reducing the levels of zinc in wine.

However, for sodium (Na) there was an increment in its concentration levels as the doses were increased for the two Purolites and for Lewatit® TP-207. In contrast, the sodium levels remain consistently low and stable for the chelating agents, Divergan® HM and potassium ferrocyanide. It was later established that the increasing sodium levels in the former three resins were due to the fact that the resins were still in their sodium forms when it was used in the extractions, which is their stable forms, especially during storage and transportation. Thus, these resins first had to be activated before use by washing it with a strong acid to convert it to its hydrogen (H) form.

Trial 3: Unwashed vs. Washed resin

The previous trial resulted in this short study to confirm the differences between the unwashed and washed Na-form resins. After more literature searches and a communication with a foreign researcher it was advised to wash, rinse and dry the relevant resins (Purolite and Lewatit) before use. It was also pointed out that the Lewatit® TP-207 that was chosen, has its own set of problems and is therefore not a good candidate for metal extraction from wine. The Lewatit® TP-207, being macroporous, contained many impurities and therefore needs to undergo complex washing procedures to purify it before use in wine. It also contained strong ligands that, when released into the wine, could prevent metal extraction due to the complexation of the ligands and the metals. Based on this new information, it was decided not to use Lewatit® TP-207 in the main experiment.

The Lewatit® TP-207 and the remaining Na-form resins, the two Purolites, underwent astringent acid-washing, thorough rinsing and drying procedures before being used to extract metals from wine again. Samples of wine (100mL each) were then treated with a washed and an unwashed resin and the following results were obtained (Figs 3 and 4).

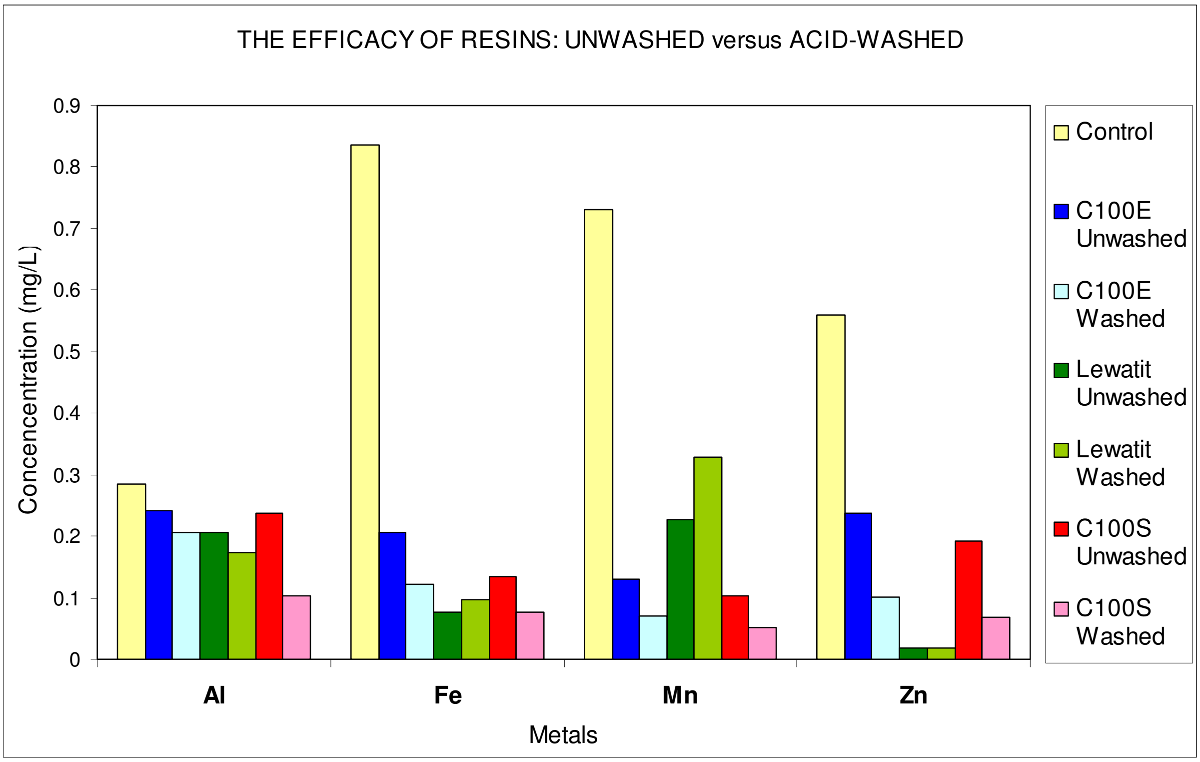


Fig. 3. Effect on the metal-chelating efficacy of acid-washed and unwashed Na-form resins on selected metals in Chenin blanc wine. The resins are: C100E = Purolite® C100E; Lewatit = Lewatit® TP-207; and C100S = Purolite® C100S.

Figure 3 thus proves how vital it is to acid-wash resins, normally stored and transported in a stable Na-form, before utilising them for metal extractions. Once activated, they tend to be more effective in their metal-chelating abilities. For most, except Lewatit® TP-207 for Fe and Mn, the washed resins showed a lower concentration level for the selected metals.

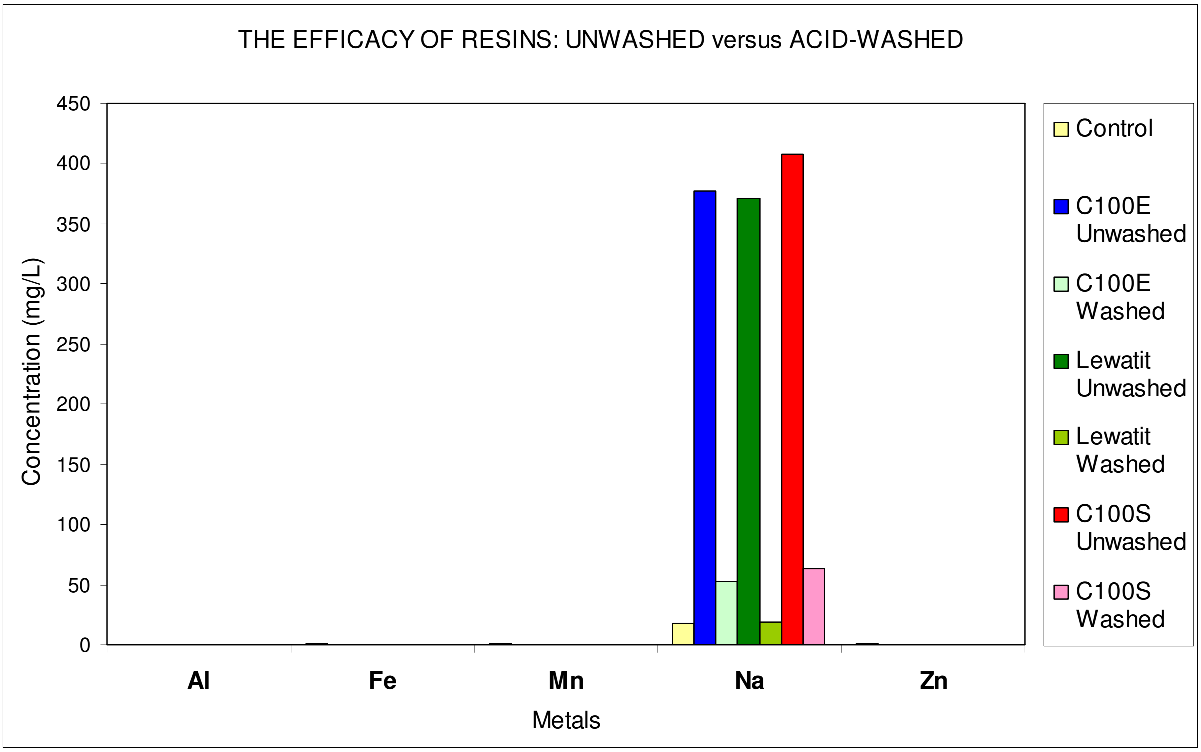


Fig. 4. Effect on the metal-chelating efficacy of acid-washed and unwashed Na-form resins on sodium (Na) levels in Chenin blanc wine. The resins are: C100E = Purolite® C100E; Lewatit = Lewatit® TP-207; and C100S = Purolite® C100S.

In figure 4 the concentration levels for Na all show a significant drop in the wines treated with the acid-washed resins. Therefore, this proves the necessity of washing these Na-form resins thoroughly before using them for metal extractions.

Trial 4: Improved Dose Dependence Study

At this point in the project it was decided to repeat the dose dependence study, but incorporating all the new information and findings regarding some of the metal-chelating agents into this new approach. However, for this improved study potassium ferrocyanide was excluded because of the uncertainty regarding its potential toxicity when used at increased levels in wine, as well as the fact that it proportionally increased the levels of iron (Fe) in the first dosage study (Trial 2).

Similar to the previous dose dependence study (Trial 2), different doses (but this time only three amounts were used, because the total amount of resins/agents were limited), as well as mixtures of the metal-chelating agents were added to individual 100mL samples of wine and allowed to extract overnight. The following day these samples, together with control samples, were sent to an external laboratory for metal analyses. The subsequent results proved that there was a significant improvement in the efficacy of the metal-chelating agents for extracting certain metals from white wine (Fig. 5).

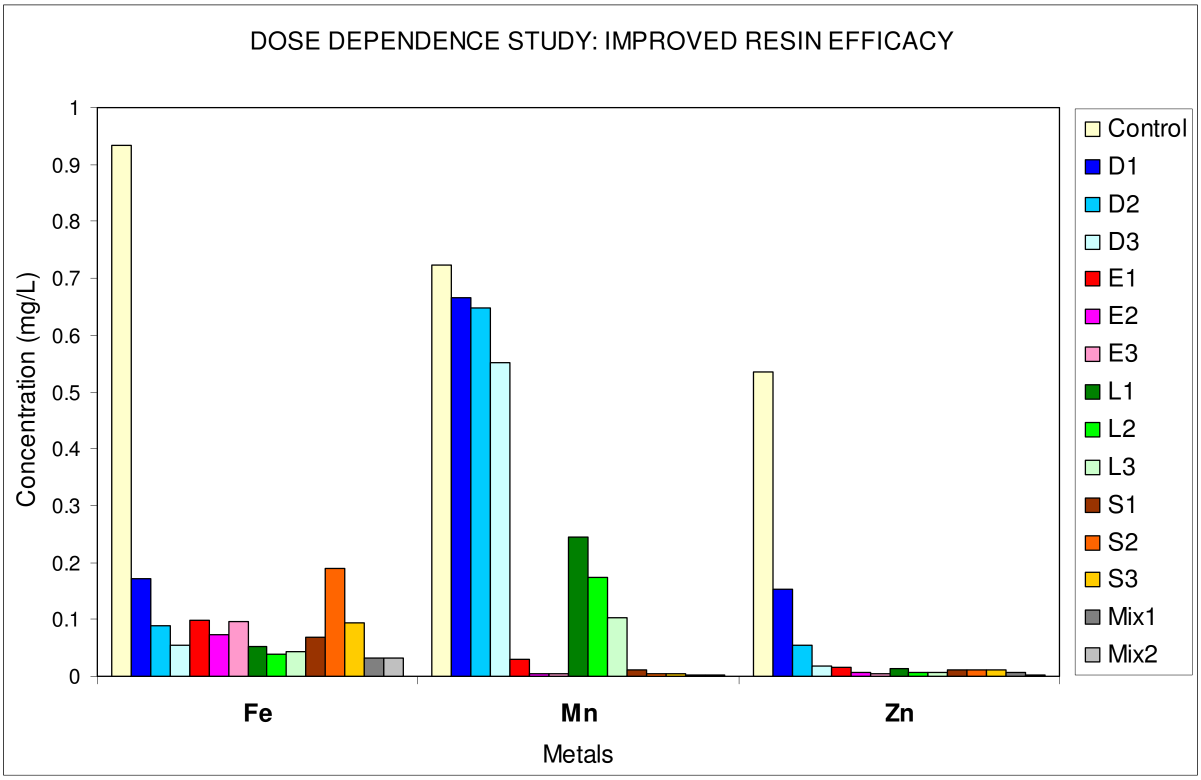


Fig. 5. Improved metal-chelating efficacy with increasing doses (numbers 1, 2 and/or 3 denote the various doses) of metal-chelating agents in white wine. The metal-chelating agents used are: D = Divergan® HM; E = Purolite® C100E; L = Lewatit® TP-207; S = Purolite® C100S; Mix = mixtures of certain metal-chelating agents.

A general trend of reduction in metal concentration levels can clearly be noted in the above illustration (Fig. 5). Most metals seem to react as expected, by decreasing in concentration with the increasing doses of metal-chelating agents. Significant reductions can be seen for those samples treated with a mixture of the resins/agents. The best results, however, are seen for the concentration levels of Zn. The metal-chelating agents were very effective in extracting zinc, because as the resin/agent doses were increased, the levels of Zn present in the wine dropped significantly, with an almost complete removal of Zn in the samples treated with the resin/agent mixtures.

It can thus be concluded that a high-dosage, mixture of activated (acid-washed, where applicable) metal-chelating agents will be the most effective choice in achieving an almost complete removal of metals from white wine.

Milestones 3.5 and 3.6. Removal of metals with metal-chelating agents/resins. Storage of samples for up to 15 months at 15℃, 25℃ and 35℃, and sensory and chemical evaluation at regular intervals.

During one of the preliminary trials it was already decided to exclude Lewatit® TP-207 from the main experiment based on the information about it containing large amounts of impurities and thus requiring extensive and time-consuming purification steps to be carried out. Another concern was that its ligands were able to form complexes with metals in wine, preventing effective metal extraction from the wine.

Unfortunately Divergan® HM also had to be excluded from being used in the main experiment. The fine, powdery nature of this effective chelating agent made it difficult to clarify the wines once treated. Attempts to centrifuge these turbid wine samples at a low speed did not completely clear the Divergan® HM suspension, and the uncertainty of the effects of centrifugation on the wine matrix prevented further attempts at centrifuging at higher speeds.

The main experiment was, therefore, continued with the only two remaining resins, Purolite® C100E and Purolite® C100S. After the acid-washing, rinsing and drying of these Na-form resins, thirty 800 mL wine samples were each treated with equally high (based on the results of Trial 4) doses of each resin and allowed to extract overnight, by gentle agitation on a horizontal shaker. The thirty control samples (untreated) were also subjected to the same overnight agitation.

Upon completion of the extraction process the control (untreated) and treated wines were bottled in 750mL bottles. Before storage, three of the treated, together with three control wines were sampled and sent to an external laboratory for metal analyses. These samples constituted the Zero (0) Month analyses. The bottles with the left-over Zero Month wines were treated with nitrogen (N_2) to prevent oxidation and stored at -6℃.

The remaining bottles of wine (treated and controls) of the main experiment were divided equally and stored at the Nietvoorbij Cellar at different temperatures: 15, 25 and 35℃.

After approximately four, seven and sixteen months in storage, three bottles each, of the treated and control wines, were removed from the respective storage temperatures, sampled and sent to an external laboratory for metal analyses. These samples constituted the Four, Seven and Sixteen (4, 7, 16) Month analyses. The bottles with the left-over Four Month wines were treated with nitrogen (N_2) to prevent oxidation and stored at -6℃.

The wines were first sensorially evaluated by a panel of judges from the ARC Infruitec-Nietvoorbij, and thereafter sent away to an external laboratory for routine (pH, VA, TA, malic acid, alcohol, glycerol, fructose, glucose, lactic acid), as well as total polyphenol analyses. Total polyphenol analyses were done on the Zero and Four (remaining wines that were stored at -6℃), and Seven and Sixteen Month samples.

Compared to untreated (contol) wines, resin-treated wines contained significantly ($p \leq 0.05$) lower concentrations of the following metalic elements, with percentage reduction indicated in brackets: Al (60%), B (5%), Ba (90%), Ca (99%), Cd (56%), Cu (87%), Fe (90%), Ge (41%), K (90%), La (85%), Mg (99.7%), Mn (99.3%), Mo (31%), P (2%), Pb (42%), Si (3%), Sr (99.3%), Sr (99.3%), Tl (72%), Zn (74%) and W (25%) (Table 1). Although activated, resin treatment of wines contributed to the wine's Na. Significant decreases in fructose, total phenols, pH, VA, and increases in TA, malic acid, glucose, EtOH and glycerol with treatment occurred (Table 1).

Treated wines (metals concentration reduced) had significantly ($p \leq 0.05$) better colour, showed less oxidative character ($p \geq 0.05$), and formed less ($p \geq 0.05$) sediment than untreated or control Chenin blanc wines (Table 2). Despite the positive impact of metal removal on shelf-life descriptors such as colour, oxidation and sediment formation, the resin treatment, however, had an impact on wines treated, with treated wines showing significantly less persistence, fruity aroma and lower overall quality (Table 2, Figs 6, 7, 9, 11). Differences between control and treated wine did, however, became less pronounced after 16 months of ageing and more so at high storage temperatures. Treated wines were also rated as more sulphurous, with higher VA, faulty acid balance, more astringent, and thinner in consistency, probably as direct result of the treatment with acid washed and deionised water rinsed activated resin. pH adjustments of treated wines during the last round of organoleptic evaluations, however, improved ($p \geq 0.05$) the overall quality of the wines (Table 3), indicating that in addition to the positive impact of metal removal on the shelf-life descriptors colour, oxidation and sedimentation, that pH adjustment of treated wines at the start of ageing would have yielded even more acceptable wines. pH adjustments, however, can contribute certain metals to the wine. pH adjustments at 16 months increased the levels of metals such as Ag ($p \leq 0.05$), Ba, Be, Bi, Ca ($p \leq 0.05$), Ge, Hf, K, La, Li, Mg, Mn, Mo, Na ($p \leq 0.05$), Ni, Pb, Rb, Sb ($p \leq 0.05$), Si ($p \leq 0.05$), Sr ($p \leq 0.05$), Ta, Te, Ti, Tl, W, Y, Zn, Zr in wines, although not all these metals contributed to their separation or grouping (Fig. 8). Separation between the treated (Trt), and treated and pH adjusted (TpH) wines were largely afforded by metal differences as opposed to other chemical components (Fig. 8).

Chenin blanc wines stored at higher temperatures, i.e. 35ºC, rated significantly higher for insufficient colour, the presence of sulphur off-odours, VA, faulty acid balance, oxidative character and other. Wines stored at higher temperatures also were significantly less fruity, with significantly less persistence, and showed the lowest overall quality (Table 2).

Storage time also affected the storage life of Chenin blanc wines, with wines stored for longer storage periods, i.e. 16 months, showing higher turbidity, significantly more sediment, significantly less sufficient colour, being significantly more sulphurous, significantly higher VA, significantly higher faulty acid balance rating, most oxidative character, higher astringency and significantly thinner consistency. Wines stored for longer storage periods were also significantly less fruity, showed the least persistence, and had the significantly lower overall quality (Table 2).

Turbidity generally decreased with time of storage, whereas sedimentation generally increased (Fig. 6). Untreated control wines stored at 35ºC experienced the largest increase in turbidity. Oxidative character increased with time of storage, being much more pronounced at 35ºC, and for control wines at this temperature. Faulty acid balance and thin consistency increased in control untreated wines with time of storage, whereas in treated wines from which metals were removed, these descriptors initially decreased with time of storage, after which it increased again with longer storage periods up to 16 months, being much more pronounced at 35ºC. Differences at 16 months between these descriptors were less pronounced than initially at zero months storage. Fruity aroma decreased with time of storage, being much more pronounced at 35ºC. Treated wines from which metals were removed did not experience decreases in persistence and overall quality observed in control untreated wines. Decreases in persistence and overall quality were more pronounced at 35ºC. Treated wines were thus less prone to turbidity and oxidative increases, and decreases in fruity character, persistence and overall quality under accelerated conditions at high storage temperatures. Observed increases in VA and sulphur compounds could be due to wine bacteriological activity.

Correlations between treatments, sensory descriptors and chemical parameters are given in Table 4. Negative sensory descriptors are always positively correlated to other negative sensory descriptors, and negatively correlated to positive sensory descriptors (Table 4). Sensory descriptors were also positively or negatively correlated to metals (Table 4). Turbidity was significantly and negatively correlated to B, Nb, P, S and glucose, and positively to S and Ti. Sedimentation was significantly and positively correlated to Ag, Al, As, B, Ba, Bi, Ca, Cd, Co, La, Mo, Na, Ni, Re, Sb, Sn Sc, Sr, Te, Ta, V, Zr, Zn, W and negatively to Se, total phenols, VA, malic acid, glucose, alcohol, glycerol. Insufficient colour was significantly correlated to Al, As, Cd, Co, Sn and Ti. Sulphur compounds was significantly and positively correlated to As, Bi, Cd, Co, Mo, Na, Ni, Re, Sb, Sn, Sc, V, Zr, W, total acid and glucose, and negatively to Fe, K, Mg, Mn, Se and Sr, total phenols, VA, pH, fructose and alcohol. VA was significantly and positively correlated to Ag, As, B, Bi, Cd, Co, Re, Sb, Sn, Sc, Te, V, Zr, W, total acid and glucose, and negatively to K, Mg, Se, Si, total phenols, pH and fructose. Faulty acid balance correlated significantly and positively with As, Bi, Cd, Co, Mo, Na, Sb, Sn, Sc, V, Zr, W, TA, glucose and glycerol, and negatively with Ba, Fe, K, Mg, Mn, Se, Sr, Tl, total phenols, pH, VA, fructose and alcohol. Oxidative character correlated significantly and positively with As, Bi, B, Bi, Cd, Co, Ge, Re, Sb, Sn, Te, Y, Zr and W, and negatively to Se and total phenols. Astringency is positively correlated to Cr, S, total acid, malic acid and glycerol, and negatively to Ba, Ca, K, Mg, Mn, Pb, Si, Sr, total phenols, pH and fructose. Thin consistency is significantly and positively correlated to As, Bi, Mo, Na, Sb, Sn, Te, V, Zr, W, total acid and glycerol, and negatively to Ba, Fe, K, Mg, Mn, Se, Sr, Tl, total phenols, VA, fructose and alcohol. The fruity aroma of Chenin blanc wines were significantly and positively correlated with Ba, Cu, Fe, K, Mg, Mn, Sr, Tl, Zn, total phenols, pH and fructose, and negatively with As, Bi, Co, Na, Sn, total acid and glycerol. Persistence is significantly and positively correlated to Ba, Cu, Fe, K, Mg, Mn, Sr, Tl, Zn, total phenols, pH, VA, fructose and alcohol, and negatively to Ag, As, Na, Sb, Sn, W, total acid and glycerol. Metals therefore impact on positive / negative sensory descriptors, and thus play a crucial role in the quality of wine. Not only the individual metals, but also their inter relation to one another are important. The sensory descriptors fruity aroma, persistence and overall quality were always positively and significantly related to total phenols, pH, VA, fructose and alcohol, and negatively and significantly to TA and glycerol, with just the opposite generally being true for the other descriptors (Table 4).

Groupings based on treatment and times of storage were evident (Figs 7-11). Evidently from figures 7-9 and 11, untreated wines stored for shorter storage periods and at lower temperatures gave fruitier aromas, persistence, better overall quality, and generally were associated with higher levels of Ba, Cu, Fe, K, Mg, Mn, Sr, Zn, fructose and total phenols. Wines with higher oxidative character, sedimentation and insufficient colour (i.e. untreated wines stored for longer periods of time at higher temperatures) generally were associated with higher concentrations of Ag, Al, B, As, Ca, Cd, Co, Hg, Hf, La, Mo, Ni, Re, Sn, Sb, Ta, Te, Ti, V, W, Y and Zr. Treated wines that suffered from higher sulphur off-odours, faulty acid balance, thinner consistency and astringency had higher levels of S and total acid (Figs 7-9, 11).

Table 1. Chenin blanc chemical parameters as influenced by different treatments.

Treatment	**N**	**Chemical compound**		
		Ag	Al	As
Control	24	0.012[a] (0.017)	0.523[a] (0.558)	0.003[a] (0.005)
Treated	24	0.016[a] (0.021)	0.210[b] (0.302)	0.003[a] (0.004)

		B	Ba	Bi
Control	24	3.447[a] (0.276)	0.063[a] (0.031)	1.076[a] (1.234)
Treated	24	3.273[b] (0.191)	0.006[b] (0.011)	1.124[a] (1.093)
		Ca	Cd	Co
Control	24	61.568[a] (6.929)	0.023[a] (0.042)	0.036[a] (0.087)
Treated	24	0.349[b] (0.419)	0.010[b] (0.019)	0.046[a] (0.102)
		Cr	Cu	Fe
Control	24	0.042[a] (0.055)	0.229[a] (0.411)	1.214[a] (0.884)
Treated	24	0.045[a] (0.045)	0.026[b] (0.058)	0.119[b] (0.152)
		Ge	Hf	Hg
Control	24	0.297[a] (0.399)	0.041[a] (0.075)	0.004[a] (0.014)
Treated	24	0.174[b] (0.231)	0.027[a] (0.041)	0.005[a] (0.015)
		K	La	Li
Control	24	492.848[a] (149.765)	0.028[a] (0.047)	0.001[a] (0.003)
Treated	24	47.272[b] (16.305)	0.004[b] (0.020)	0.000[a] (0.000)
		Mg	Mn	Mo
Control	24	65.048[a] (7.321)	1.133[a] (0.284)	0.611[a] (0.767)
Treated	24	0.204[b] (0.228)	0.008[b] (0.010)	0.419[b] (0.652)
		Na	Nb	Ni
Control	24	19.364[b] (8.223)	0.015[a] (0.023)	0.019[a] (0.049)
Treated	24	31.951[a] (9.104)	0.014[a] (0.019)	0.024[a] (0.082)
		P	Pb	Rb
Control	24	159.354[a] (10.945)	0.083[a] (0.079)	0.000[a] (0.000)
Treated	24	156.020[b] (9.289)	0.048[a] (0.044)	0.000[a] (0.000)
		S	Re	Sb
Control	24	639.926[b] (78.087)	0.049[a] (0.081)	0.303[a] (0.628)
Treated	24	779.167[a] (120.446)	0.053[a] (0.088)	0.199[a] (0.431)
		Sn	Sc	Se
Control	24	5.840[a] (5.253)	0.001[b] (0.004)	0.118[a] (0.168)
Treated	24	5.671[a] (4.966)	0.016[a] (0.044)	0.138[a] (0.180)
		Si	Sr	Be
Control	24	13.809[a] (8.809)	0.560[a] (0.249)	0.000017[a] (0.000082)
Treated	24	13.366[b] (8.525)	0.004[b] (0.004)	0.000[a] (0.000)
		Te	Ta	Ti
Control	24	0.320[a] (0.347)	0.096[a] (0.226)	0.005[a] (0.012)
Treated	24	0.194[a] (0.289)	0.029[a] (0.062)	0.003[a] (0.007)
		Tl	V	Y
Control	24	1.107[a] (2.082)	0.007[a] (0.015)	0.001[a] (0.003)
Treated	24	0.314[b] (0.694)	0.010[a] (0.023)	0.000[a] (0.001)
		Zr	Zn	W
Control	24	0.028[a] (0.029)	0.824[a] (0.253)	1.290[a] (2.318)
Treated	24	0.027[a] (0.038)	0.207[b] (0.137)	0.967[b] (1.727)
		TotPhenols	pH	VolatileAcid
Control	24	173.833[a] (41.550)	3.234[a] (0.036)	0.356[a] (0.062)
Treated	24	124.292[b] (18.320)	2.635[b] (0.050)	0.335[b] (0.059)
		TotalAcid	MalicAcid	LacticAcid
Control	24	6.640[b] (0.065)	4.011[b] (0.105)	0.300[a] (5.84E-17)
Treated	24	7.505[a] (0.032)	4.172[a] (0.096)	0.300[a] (5.84E-17)
		Glucose	Fructose	Alcohol
Control	24	0.305[b] (0.022)	0.682[a] (0.097)	12.826[b] (0.185)
Treated	24	0.335[a] (0.053)	0.300[b] (0.000)	12.918[a] (0.234)
		Glycerol		
Control	24	6.099[b] (0.345)		
Treated	24	7.703[a] (0.402)		

Temperature		Ag	Al	As
15ºC	16	0.019^{a} (0.026)	0.411^{a} (0.488)	0.002^{b} (0.003)
25ºC	16	0.012^{a} (0.016)	0.278^{a} (0.193)	0.003^{a} (0.005)
35ºC	16	0.011^{a} (0.012)	0.410^{a} (0.638)	0.004^{a} (0.005)
Temperature		B	Ba	Bi
15ºC	16	3.436^{a} (0.327)	0.034^{a} (0.038)	1.075^{a} (1.037)
25ºC	16	3.322^{b} (0.180)	0.035^{a} (0.038)	1.098^{a} (1.164)
35ºC	16	3.321^{b} (0.219)	0.034^{a} (0.037)	1.127^{a} (1.318)
Temperature		Ca	Cd	Co
15ºC	16	31.605^{a} (32.421)	0.015^{a} (0.032)	0.035^{a} (0.099)
25ºC	16	30.528^{a} (31.731)	0.014^{a} (0.023)	0.044^{a} (0.089)
35ºC	16	30.742^{a} (31.835)	0.021^{a} (0.042)	0.044^{a} (0.100)
Temperature		Cr	Cu	Fe
15ºC	16	0.035^{b} (0.033)	0.300^{a} (0.491)	1.049^{a} (1.253)
25ºC	16	0.040^{ab} (0.048)	0.045^{b} (0.058)	0.489^{b} (0.451)
35ºC	16	0.056^{a} (0.064)	0.037^{b} (0.069)	0.462^{b} (0.429)
Temperature		Ge	Hf	Hg
15ºC	16	0.184^{b} (0.238)	0.021^{a} (0.035)	0.007^{a} (0.018)
25ºC	16	0.196^{ab} (0.241)	0.044^{a} (0.088)	0.005^{a} (0.016)
35ºC	16	0.326^{a} (0.457)	0.037^{a} (0.044)	0.001^{a} (0.004)
Temperature		K	La	Li
15ºC	16	288.119^{a} (271.331)	0.006^{a} (0.010)	0.00^{a} (0.003)
25ºC	16	262.738^{b} (247.367)	0.021^{a} (0.046)	0.000^{a} (0.00000)
35ºC	16	259.324^{b} (241.436)	0.021^{a} (0.045)	0.000^{a} (0.00000)
Temperature		Mg	Mn	Mo
15ºC	16	34.539^{a} (35.905)	0.616^{a} (0.661)	0.563^{a} (0.653)
25ºC	16	31.679^{b} (32.795)	0.546^{b} (0.590)	0.498^{a} (0.739)
35ºC	16	31.659^{b} (32.794)	0.549^{b} (0.592)	0.483^{a} (0.781)
Temperature		Na	Nb	Ni
15ºC	16	26.152^{a} (10.279)	0.015^{ab} (0.014)	0.010^{a} (0.030)
25ºC	16	25.131^{a} (10.915)	0.021^{a} (0.030)	0.010^{a} (0.030)
35ºC	16	25.691^{a} (11.497)	0.009^{b} (0.014)	0.044^{a} (0.107)
Temperature		P	Pb	Rb
15ºC	16	159.238^{a} (10.365)	0.071^{a} (0.063)	0.000^{a} (0.000000)
25ºC	16	156.840^{b} (10.705)	0.067^{a} (0.072)	0.000^{a} (0.000000)
35ºC	16	156.983^{ab} (9.950)	0.059^{a} (0.066)	0.000^{a} (0.000000)
Temperature		S	Re	Sb
15ºC	16	693.796^{b} (136.926)	0.039^{a} (0.065)	0.303^{a} (0.646)
25ºC	16	737.991^{a} (123.293)	0.052^{a} (0.075)	0.181^{a} (0.429)
35ºC	16	696.853^{b} (108.882)	0.063^{a} (0.109)	0.270^{a} (0.537)
Temperature		Sn	Sc	Se
15ºC	16	4.920^{a} (5.224)	0.001^{b} (0.005)	0.111^{a} (0.154)
25ºC	16	6.267^{a} (4.834)	0.016^{a} (0.049)	0.143^{a} (0.191)
35ºC	16	6.079^{a} (5.326)	0.009^{ab} (0.027)	0.129^{a} (0.179)
Temperature		Si	Sr	Be
15ºC	16	13.811^{a} (9.118)	0.283^{a} (0.336)	0.000^{a} (0.000)
25ºC	16	13.372^{a} (8.542)	0.280^{a} (0.337)	0.000^{a} (0.000)
35ºC	16	13.578^{a} (8.623)	0.282^{a} (0.341)	0.000^{a} (0.000)
Temperature		Te	Ta	Ti
15ºC	16	0.200^{a} (0.351)	0.036^{a} (0.105)	0.006^{a} (0.011)
25ºC	16	0.307^{a} (0.336)	0.106^{a} (0.245)	0.001^{b} (0.001)
35ºC	16	0.264^{a} (0.289)	0.044^{a} (0.118)	0.005^{a} (0.012)
Temperature		Tl	V	Y

15ºC	16	0.944^{a} (2.204)	0.012^{a} (0.025)	0.000^{a} (0.00000)
25ºC	16	0.685^{a} (1.323)	0.007^{a} (0.016)	0.000^{a} (0.00000)
35ºC	16	0.503^{a} (1.085)	0.007^{a} (0.016)	0.001^{a} (0.004)
Temperature		Zr	Zn	W
15ºC	16	0.026^{a} (0.032)	0.588^{a} (0.469)	1.151^{a} (2.128)
25ºC	16	0.029^{a} (0.037)	0.470^{b} (0.346)	1.106^{a} (2.051)
35ºC	16	0.027^{a} (0.033)	0.488^{ab} (0.288)	1.128^{a} (2.040)
Temperature		TotPhenols	pH	VolatileAcid
15ºC	16	156.125^{a} (43.166)	2.929^{b} (0.313)	0.339^{b} (0.058)
25ºC	16	147.063^{b} (41.704)	2.940^{a} (0.315)	0.347^{a} (0.063)
35ºC	16	144.000^{b} (37.919)	2.935^{ab} (0.308)	0.351^{a} (0.065)
Temperature		TotalAcid	MalicAcid	LacticAcid
15ºC	16	7.090^{a} (0.451)	4.057^{b} (0.134)	0.300^{a} (3.95E-17)
25ºC	16	7.068^{b} (0.452)	4.101^{a} (0.130)	0.300^{a} (3.95E-17)
35ºC	16	7.060^{b} (0.447)	4.117^{a} (0.122)	0.300^{a} (3.95E-17)
Temperature		Glucose	Fructose	Alcohol
15ºC	16	0.333^{a} (0.061)	0.528^{a} (0.240)	12.873^{a} (0.232)
25ºC	16	0.317^{a} (0.036)	0.504^{a} (0.215)	12.864^{a} (0.214)
35ºC	16	0.310^{a} (0.025)	0.441^{b} (0.152)	12.879^{a} (0.208)
Temperature		Glycerol		
15ºC	16	6.909^{a} (0.936)		
25ºC	16	6.889^{a} (0.901)		
35ºC	16	6.904^{a} (0.894)		
Age		Ag	Al	As
4 months	18	0.0003^{c} (0.0012)	0.1694^{b} (0.093)	0.0002^{c} (0.0001)
7 months	18	0.027^{a} (0.017)	0.204^{b} (0.142)	0.002^{b}(0.0003)
16 months	12	0.014^{b} (0.022)	0.904^{a} (0.694)	0.010^{a} (0.0033)
Age		B	Ba	Bi
4 months	18	3.356^{b} (0.162)	0.020^{c} (0.021)	0.044^{c} (0.091)
7 months	18	3.170^{c} (0.099)	0.025^{b} (0.026)	1.078^{b} (0.597)
16 months	12	3.651^{a} (0.246)	0.068^{a} (0.049)	2.718^{a} (0.662)
Age		Ca	Cd	Co
4 months	18	29.687^{b} (30.361)	0.005^{b} (0.005)	0.001^{b} (0.002)
7 months	18	34.709^{a} (35.613)	0.000^{b} (0.000)	0.008^{b} (0.017)
16 months	12	27.239^{c} (27.637)	0.059^{a} (0.045)	0.152^{a} (0.140)
Age		Cr	Cu	Fe
4 months	18	0.021^{b} (0.005)	0.050^{a} (0.181)	0.452^{a} (0.704)
7 months	18	0.094^{a} (0.048)	0.177^{a} (0.391)	0.837^{a} (0.918)
16 months	12	0.003^{b} (0.011)	0.168^{a} (0.320)	0.733^{a} (0.891)
Age		Ge	Hf	Hg
4 months	18	0.118^{b} (0.116)	0.018^{b} (0.010)	0.002^{b} (0.005)
7 months	18	0.509^{a} (0.389)	0.063^{a} (0.089)	0.000^{b} (0.000)
16 months	12	0.000^{b} (0.000)	0.014^{b} (0.028)	0.014^{a} (0.027)
Age		K	La	Li
4 months	18	329.467^{a} (272.852)	0.007^{a} (0.008)	0.0001^{a} (0.0003)
7 months	18	172.029^{b} (145.204)	0.030^{a} (0.055)	0.0001^{a} (0.0005)
16 months	12	327.996^{a} (302.056)	0.008^{a} (0.029)	0.0010^{a} (0.004)
Age		Mg	Mn	Mo
4 months	18	33.500^{a} (34.568)	0.407^{c} (0.420)	0.334^{b} (0.443)
7 months	18	34.482^{a} (35.405)	0.629^{b} (0.644)	0.0000^{c} (0.0000)
16 months	12	28.531^{b} (29.831)	0.728^{a} (0.748)	1.558^{a} (0.430)
Age		Na	Nb	Ni
4 months	18	26.526^{b} (8.819)	0.004^{b} (0.004)	0.003^{b} (0.007)

7 months	18	17.076[c] (5.010)	0.032[a] (0.024)	0.0000[b] (0.0000)
16 months	12	37.228[a] (7.796)	0.005[b] (0.011)	0.082[a] (0.118)
Age	of	P	Pb	Rb
4 months	18	156.223[b] (4.468)	0.076[ab] (0.080)	0.000[a] (0.000)
7 months	18	168.179[a] (3.017)	0.040[b] (0.042)	0.000[a] (0.000)
16 months	12	144.146[c] (3.798)	0.088[a] (0.063)	0.000[a] (0.000)
Age		S	Re	Sb
4 months	18	623.625[c] (67.706)	0.000[b] (0.000)	0.000[b] (0.000)
7 months	18	790.651[a] (108.372)	0.082[a] (0.083)	0.000[b] (0.000)
16 months	12	716.773[b] (126.874)	0.082[a] (0.111)	1.005[a] (0.631)
Age	of	Sn	Sc	Se
4 months	18	0.598[c] (0.321)	0.00009[b] (0.00040)	0.326[a] (0.125)
7 months	18	6.711[b] (2.155)	0.00107[b] (0.00431)	0.01490[b] (0.0025)
16 months	12	12.058[a] (3.687)	0.032[a] (0.060)	0.00082[b] (0.00046)
Age	of	Si	Sr	Be
4 months	18	23.767[a] (1.182)	0.169[c] (0.172)	0.000[a] (0.000)
7 months	18	4.329[c] (0.121)	0.260[b] (0.266)	0.000[a] (0.000)
16 months	12	12.204[b] (0.554)	0.483[a] (0.496)	0.00003[a] (0.00012)
Age		Te	Ta	Ti
4 months	18	0.138[b] (0.080)	0.014[b] (0.025)	0.001[b] (0.001)
7 months	18	0.212[b] (0.246)	0.047[ab] (0.074)	0.001[b] (0.002)
16 months	12	0.504[a] (0.497)	0.157[a] (0.311)	0.013[a] (0.016)
Age		Tl	V	Y
4 months	18	0.078[b] (0.143)	0.00025[b] (0.001)	0.000[a] (0.000)
7 months	18	1.817[a] (2.205)	0.00007[b] (0.000)	0.00103[a] (0.0035)
16 months	12	0.000[b] (0.000)	0.034[a] (0.025)	0.000[a] (0.000)
Age		Zr	Zn	W
4 months	18	0.003[c] (0.002)	0.394[b] (0.274)	0.022[b] (0.030)
7 months	18	0.023[b] (0.022)	0.502[b] (0.398)	0.000[b] (0.000)
16 months	12	0.071[a] (0.030)	0.717[a] (0.399)	4.482[a] (1.110)
Age		TotPhenols	pH	VolatileAcid
4 months	18	182.667[a] (41.268)	2.912[b] (0.308)	0.366[b] (0.012)
7 months	18	122.889[c] (19.363)	2.910[b] (0.317)	0.392[a] (0.017)
16 months	12	137.917[b] (25.946)	3.005[a] (0.299)	0.246[c] (0.012)
Age		TotalAcid	MalicAcid	LacticAcid
4 months	18	7.021[b] (0.467)	4.096[b] (0.103)	0.300[a] (4.20E-17)
7 months	18	7.099[a] (0.446)	4.179[a] (0.080)	0.300[a] (4.20E-17)
16 months	12	7.110[a] (0.420)	3.953[c] (0.105)	0.300[a] (3.04E-17)
Age		Glucose	Fructose	Alcohol
4 months	18	0.300[b] (0.000)	0.498[ab] (0.216)	12.936[b] (0.062)
7 months	18	0.333[a] (0.047)	0.471[b] (0.187)	13.038[a] (0.067)
16 months	12	0.330[a] (0.060)	0.511[a] (0.227)	12.528[c] (0.038)
Age		Glycerol		
4 months	18	7.033[b] (0.818)		
7 months	18	7.177[a] (0.869)		
16 months	12	6.288[c] (0.793)		

Table 2. Chenin blanc sensory descriptive as influenced by individual treatments.

Treatment	**N**	**Sensory descriptive**		
		Turbidity	**Sedimentation**	**Insufficient colour**
Control	24	1.27[a] (0.27)	1.32[a] (0.30)	1.77[a] (0.84)
Treated	24	1.27[a] (0.21)	1.26[a] (0.33)	1.56[b] (0.26)
		Sulphur compounds	**Volatile acidity**	**Faulty acid balance**
Control	24	1.50[b] (0.44)	1.51[b] (0.48)	1.86[b] (0.61)

Treated	24	2.26^{a} (0.66)	1.98^{a} (0.57)	2.95^{a} (0.54)
		Oxidative character	**Astringency**	**Thin consistency**
Control	24	1.98^{a} (1.14)	1.38^{b} (0.27)	1.79^{b} (0.46)
Treated	24	1.86^{a} (0.58)	1.72^{a} (0.24)	2.45^{a} (0.42)
		Other	**Fruity aroma (%)**	**Persistence (%)**
Control	24	1.48^{a} (0.67)	51.21^{a} (13.48)	48.26^{a} (10.64)
Treated	24	1.76^{a} (0.68)	35.97^{b} (5.39)	36.13^{b} (3.19)
		Overall quality (%)		
Control	24	47.01^{a} (13.25)		
Treated	24	30.35^{b} (4.74)		
Temperature		**Turbidity**	**Sedimentation**	**Insufficient colour**
15ºC	16	1.23^{a} (0.21)	1.28^{a} (0.33)	1.47^{b} (0.25)
25ºC	16	1.21^{a} (0.19)	1.32^{a} (0.34)	1.42^{b} (0.31)
35ºC	16	1.35^{a} (0.29)	1.27^{a} (0.28)	2.11^{a} (0.86)
		Sulphur compounds	**Volatile acidity**	**Faulty acid balance**
15ºC	16	1.52^{c} (0.51)	1.70^{b} (0.65)	2.29^{b} (0.85)
25ºC	16	1.71^{b} (0.45)	1.58^{b} (0.46)	2.29^{b} (0.79)
35ºC	16	2.40^{a} (0.72)	1.96^{a} (0.57)	2.64^{a} (0.73)
		Oxidative character	**Astringency**	**Thin consistency**
15ºC	16	1.36^{b} (0.38)	1.53^{a} (0.31)	2.04^{a} (0.67)
25ºC	16	1.51^{b} (0.34)	1.48^{a} (0.32)	2.05^{a} (0.56)
35ºC	16	2.89^{a} (0.85)	1.62^{a} (0.27)	2.27^{a} (0.39)
		Other	**Fruity aroma (%)**	**Persistence (%)**
15ºC	16	1.44^{b} (0.53)	49.32^{a} (12.64)	45.73^{a} (11.26)
25ºC	16	1.38^{b} (0.45)	47.43^{a} (10.99)	43.54^{a} (10)
35ºC	16	2.04^{a} (0.83)	34.01^{b} (8.93)	37.32^{b} (6.28)
		Overall quality (%)		
15ºC	16	44.69^{a} (13.02)		
25ºC	16	42.22^{a} (12.22)		
35ºC	16	29.14^{b} (7.62)		
Age		**Turbidity**	**Sedimentation**	**Insufficient colour**
4 months	18	1.25^{a} (0.25)	1.03^{c} (0.13)	1.60^{b} (0.24)
7 months	18	1.23^{a} (0.18)	1.28^{b} (0.21)	1.59^{b} (0.69)
16 months	12	1.35^{a} (0.30)	1.69^{a} (0.19)	1.89^{a} (0.87)
		Sulphur compounds	**Volatile acidity**	**Faulty acid balance**
4 months	18	1.60^{c} (0.59)	1.24^{c} (0.21)	2.08^{b} (0.77)
7 months	18	1.84^{b} (0.58)	1.95^{b} (0.54)	2.28^{b} (0.70)
16 months	12	2.37^{a} (0.71)	2.20^{a} (0.42)	3.08^{a} (0.57)
		Oxidative character	**Astringency**	**Thin consistency**
4 months	18	1.49^{c} (0.55)	1.40^{b} (0.35)	1.97^{b} (0.52)
7 months	18	2.08^{b} (1.04)	1.63^{a} (0.25)	2.10^{b} (0.55)
16 months	12	2.33^{a} (0.87)	1.63^{a} (0.24)	2.38^{a} (0.54)
		Other	**Fruity aroma**	**Persistence**
4 months	18	1.41^{b} (0.50)	46.06^{a} (9.74)	43.11^{a} (9.16)
7 months	18	1.54^{b} (0.71)	43.52^{ab} (15.50)	42.96^{a} (12.16)
16 months	12	2.05^{a} (0.75)	39.98^{b} (12.32)	39.68^{a} (7.16)
		Overall quality		
4 months	18	40.17^{a} (11.21)		

7 months	18	39.78[a] (15.47)
16 months	12	34.80[b] (11.45)

Table 3. Chenin blanc sensory descriptive as influenced by individual treatments, including pH adjusted wines.

Treatment	N	Sensory descriptive		
		Turbidity	**Sedimentation**	**Insufficient colour**
Control	6	1.36[a] (0.37)	1.64[a] (0.12)	2.02[a] (1.26)
Treated+pH	6	1.26[a] (0.17)	1.60[a] (0.28)	1.67[a] (0.35)
Treated	6	1.33[a] (0.23)	1.74[a] (0.25)	1.76[a] (0.22)
		Sulphur compounds	**Volatile acidity**	**Faulty acid balance**
Control	6	1.93[c] (0.48)	1.93[b] (0.43)	2.60[c] (0.33)
Treated+pH	6	2.43[b] (0.39)	1.76[b] (0.35)	3.07[b] (0.44)
Treated	6	2.81[a] (0.63)	2.48[a] (0.12)	3.57[a] (0.16)
		Oxidative character	**Astringency**	**Thin consistency**
Control	6	2.33[a] (1.17)	1.52[ab] (0.23)	2.07[b] (0.55)
Treated+pH	6	2.07[a] (0.41)	1.43[b] (0.20)	3.07[a] (0.46)
Treated	6	2.33[a] (0.53)	1.74[a] (0.21)	2.69[a] (0.33)
		Other	**Fruity aroma**	**Persistence**
Control	6	1.67[b] (0.56)	46.90[a] (14.14)	41.55[a] (9.39)
Treated+pH	6	2.00[ab] (0.39)	36.90[b] (5.09)	29.88[b] (5.58)
Treated	6	2.44[a] (0.74)	33.05[b] (4.36)	37.81[a] (4.02)
		Overall quality		
Control	6	41.38[a] (12.90)		
Treated+pH	6	29.27[b] (4.25)		
Treated	6	28.21[b] (4.25)		

Table 4. Correlation matrix (Pearson (n)) for Chenin blanc wine sensory descriptors and chemical parameters.

Variables	Turbidity	Sedimentation	Insufficient colour	Sulphur compounds	Volatile acidity	Faulty acid balance	Oxidative character
Turbidity	**1**	0.123	**0.474**	0.130	0.100	0.182	0.239
Sedimentation	0.123	**1**	0.172	**0.409**	**0.552**	**0.398**	**0.405**
Insufficient colour	**0.474**	0.172	**1**	0.203	**0.278**	0.229	**0.636**
Sulphur compounds	0.130	**0.409**	0.203	**1**	**0.690**	**0.702**	**0.553**
Volatile acidity	0.100	**0.552**	**0.278**	**0.690**	**1**	**0.666**	**0.569**
Faulty acid balance	0.182	**0.398**	0.229	**0.702**	**0.666**	**1**	**0.353**
Oxidative character	0.239	**0.405**	**0.636**	**0.553**	**0.569**	**0.353**	**1**
Astringency	0.184	0.108	0.082	**0.386**	**0.522**	**0.581**	0.235
Thin consistency	0.118	**0.299**	**0.305**	**0.563**	**0.502**	**0.791**	**0.296**
Other	0.159	**0.392**	**0.336**	**0.555**	**0.455**	**0.482**	**0.637**
Fruity aroma	-0.230	-0.197	**-0.483**	**-0.731**	**-0.611**	**-0.760**	**-0.625**
Persistence	-0.235	-0.196	**-0.386**	**-0.605**	**-0.479**	**-0.774**	**-0.416**
Overall quality	-0.235	-0.165	**-0.444**	**-0.732**	**-0.546**	**-0.794**	**-0.551**
Ag	0.042	**0.370**	-0.138	0.219	**0.265**	0.247	0.075
Al	0.052	**0.439**	**0.262**	0.121	0.155	0.135	0.243
As	0.121	**0.760**	**0.256**	**0.523**	**0.489**	**0.476**	**0.403**
B	**-0.358**	**0.387**	-0.043	0.227	**0.255**	0.149	**0.312**
Ba	0.050	**0.413**	0.235	-0.207	-0.030	**-0.257**	0.233
Bi	-0.034	**0.680**	0.142	**0.517**	**0.521**	**0.431**	**0.374**
Ca	-0.043	**0.318**	0.036	0.091	-0.092	0.025	0.106
Cd	0.157	**0.538**	**0.291**	**0.261**	**0.276**	**0.263**	**0.284**
Co	0.189	**0.588**	**0.391**	**0.323**	**0.452**	**0.362**	**0.331**
Cr	0.155	-0.143	0.020	-0.044	-0.035	0.122	-0.098
Cu	-0.123	0.129	-0.208	-0.215	-0.029	-0.195	-0.111
Fe	-0.070	0.118	-0.066	**-0.392**	-0.140	**-0.407**	-0.022
Ge	-0.087	-0.105	0.246	-0.097	0.163	-0.104	**0.358**
Hf	-0.033	0.126	-0.052	0.108	0.112	0.179	0.098
Hg	0.030	0.251	-0.046	0.009	0.096	0.104	-0.093
K	0.073	-0.079	0.089	**-0.563**	**-0.435**	**-0.698**	-0.093
La	0.053	**0.283**	0.139	0.113	0.053	0.012	0.184
Li	-0.149	0.199	-0.144	-0.051	0.036	0.055	-0.081

Mg	0.023	-0.067	0.088	**-0.627**	**-0.425**	**-0.776**	-0.016
Mn	-0.031	0.176	0.162	**-0.457**	-0.197	**-0.530**	0.155
Mo	0.096	**0.634**	0.081	**0.360**	0.248	**0.349**	0.221
Na	0.152	**0.287**	0.018	**0.476**	0.162	**0.612**	-0.020
Nb	**-0.322**	-0.035	-0.220	-0.083	0.108	-0.199	-0.069
Ni	0.123	**0.278**	-0.009	**0.331**	0.204	0.232	0.179
P	**-0.409**	0.051	-0.127	0.004	0.180	-0.109	0.230
Pb	0.147	0.096	-0.076	-0.058	-0.141	-0.145	-0.148
S	**0.284**	-0.211	0.043	-0.029	-0.007	0.181	-0.243
Re	0.064	**0.360**	0.186	**0.288**	**0.382**	0.157	**0.309**
Sb	0.018	**0.574**	0.229	**0.386**	**0.328**	**0.425**	**0.255**
Sn	0.035	**0.699**	**0.286**	**0.464**	**0.629**	**0.440**	**0.500**
Sc	0.107	**0.360**	0.004	**0.355**	**0.339**	**0.291**	0.142
Se	0.191	**-0.622**	-0.048	**-0.411**	**-0.631**	**-0.320**	**-0.409**
Si	-0.144	-0.193	-0.047	-0.075	**-0.363**	-0.091	-0.113
Sr	0.020	**0.375**	0.223	**-0.256**	-0.119	**-0.320**	0.223
Te	0.050	**0.404**	0.228	0.169	**0.270**	0.219	**0.289**
Ta	-0.070	**0.257**	-0.094	0.131	0.018	0.054	0.091
Ti	**0.267**	0.189	**0.384**	0.082	0.072	0.205	0.121
Tl	-0.131	-0.010	-0.094	-0.245	-0.142	**-0.330**	0.008
V	0.055	**0.616**	0.205	**0.390**	**0.382**	**0.373**	0.231
Y	0.143	0.179	0.220	0.152	0.073	0.026	**0.292**
Zr	-0.021	**0.718**	-0.053	**0.459**	**0.446**	**0.421**	**0.296**
Zn	-0.108	**0.437**	0.029	-0.171	-0.007	-0.241	0.219
W	0.087	**0.724**	0.159	**0.431**	**0.388**	**0.461**	**0.297**
Total phenols	0.034	**-0.390**	-0.084	**-0.627**	**-0.656**	**-0.677**	**-0.378**
pH	-0.009	0.247	0.148	**-0.400**	**-0.317**	**-0.555**	0.123
Volatile acid	-0.087	**-0.611**	-0.120	**-0.461**	**-0.370**	**-0.550**	-0.143
Total acid	0.008	-0.168	-0.115	**0.370**	**0.385**	**0.531**	-0.074
Malic acid	-0.053	**-0.457**	-0.166	0.053	0.105	0.006	-0.087
Glucose	**-0.291**	**0.287**	-0.166	**0.304**	**0.454**	**0.262**	-0.009
Fructose	0.012	-0.001	-0.021	**-0.619**	**-0.460**	**-0.729**	-0.141
Alcohol	0.025	**-0.547**	-0.120	**-0.297**	-0.158	**-0.364**	-0.151
Glycerol	-0.030	**-0.400**	-0.188	0.251	0.203	**0.393**	-0.177

Variables	**Astringency**	**Thin consistency**	**Other**	**Fruity aroma**	**Persistence**	**Overall quality**	**Ag**
Turbidity	0.184	0.118	0.159	-0.230	-0.235	-0.235	0.042
Sedimentation	0.108	**0.299**	**0.392**	-0.197	-0.196	-0.165	**0.370**
Insufficient colour	0.082	**0.305**	**0.336**	**-0.483**	**-0.386**	**-0.444**	-0.138
Sulphur compounds	**0.386**	**0.563**	**0.555**	**-0.731**	**-0.605**	**-0.732**	0.219
Volatile acidity	**0.522**	**0.502**	**0.455**	**-0.611**	**-0.479**	**-0.546**	**0.265**
Faulty acid balance	**0.581**	**0.791**	**0.482**	**-0.760**	**-0.774**	**-0.794**	0.247
Oxidative character	0.235	**0.296**	**0.637**	**-0.625**	**-0.416**	**-0.551**	0.075
Astringency	**1**	**0.304**	**0.323**	**-0.505**	**-0.462**	**-0.491**	0.130
Thin consistency	**0.304**	**1**	**0.367**	**-0.705**	**-0.812**	**-0.770**	0.220
Other	**0.323**	**0.367**	**1**	**-0.554**	**-0.381**	**-0.511**	0.074
Fruity aroma	**-0.505**	**-0.705**	**-0.554**	**1**	**0.879**	**0.967**	-0.125
Persistence	**-0.462**	**-0.812**	**-0.381**	**0.879**	**1**	**0.931**	**-0.286**
Overall quality	**-0.491**	**-0.770**	**-0.511**	**0.967**	**0.931**	**1**	-0.153
Ag	0.130	0.220	0.074	-0.125	**-0.286**	-0.153	**1**
Al	-0.120	0.076	0.131	0.061	0.023	0.026	-0.081
As	0.040	**0.370**	**0.375**	**-0.288**	**-0.291**	**-0.284**	0.253
B	-0.100	0.113	**0.343**	-0.151	-0.087	-0.091	0.005
Ba	**-0.300**	**-0.286**	0.030	**0.357**	**0.320**	**0.381**	-0.060
Bi	0.100	**0.345**	**0.405**	**-0.272**	-0.239	-0.245	**0.268**
Ca	**-0.307**	0.245	0.142	0.017	-0.136	-0.012	**0.501**
Cd	-0.049	0.196	0.160	-0.118	-0.163	-0.126	0.111
Co	0.069	0.250	0.188	**-0.256**	-0.204	-0.225	0.112
Cr	**0.289**	0.018	-0.118	-0.046	-0.140	-0.119	**0.262**
Cu	0.075	-0.200	0.015	**0.374**	**0.385**	**0.391**	-0.048
Fe	-0.128	**-0.379**	-0.050	**0.495**	**0.516**	**0.537**	-0.107
Ge	0.084	-0.054	0.077	-0.124	0.006	-0.064	0.051
Hf	-0.007	0.253	0.119	-0.071	-0.157	-0.083	0.233
Hg	0.168	0.012	0.167	0.061	0.051	0.032	-0.103
K	**-0.531**	**-0.631**	**-0.290**	**0.634**	**0.631**	**0.672**	**-0.297**
La	-0.093	0.165	0.188	-0.096	-0.153	-0.083	**0.319**
Li	0.103	0.093	0.099	0.181	0.018	0.138	0.044
Mg	**-0.513**	**-0.684**	-0.250	**0.678**	**0.725**	**0.738**	-0.247
Mn	**-0.334**	**-0.515**	-0.116	**0.515**	**0.549**	**0.570**	-0.181

Mo	-0.100	**0.266**	**0.320**	-0.141	-0.191	-0.151	**0.294**
Na	0.242	**0.569**	**0.288**	**-0.365**	**-0.525**	**-0.461**	**0.324**
Nb	0.018	-0.141	-0.146	0.159	0.228	0.215	-0.001
Ni	-0.042	0.177	0.206	-0.147	-0.225	-0.184	**0.569**
P	-0.042	-0.091	0.126	-0.047	0.076	0.042	-0.083
Pb	**-0.414**	-0.051	-0.036	0.229	0.168	0.193	0.250
S	**0.296**	0.213	-0.220	-0.078	-0.161	-0.152	0.038
Re	0.187	0.180	0.238	-0.211	-0.086	-0.147	0.195
Sb	0.035	**0.445**	**0.361**	-0.206	**-0.313**	-0.227	0.243
Sn	0.113	**0.383**	**0.367**	**-0.343**	**-0.295**	**-0.289**	0.234
Sc	0.214	0.131	**0.312**	-0.188	-0.070	-0.203	-0.067
Se	-0.098	**-0.349**	**-0.336**	0.240	0.161	0.176	**-0.254**
Si	**-0.312**	-0.063	0.032	0.014	-0.008	-0.010	**-0.263**
Sr	**-0.358**	**-0.276**	-0.011	**0.378**	**0.309**	**0.401**	0.042
Te	0.167	**0.263**	**0.344**	-0.145	-0.198	-0.143	-0.018
Ta	-0.134	-0.015	0.054	0.024	-0.038	-0.004	**0.273**
Ti	-0.103	0.254	0.014	-0.096	-0.117	-0.144	-0.110
Tl	-0.019	**-0.282**	0.025	**0.272**	**0.302**	**0.301**	0.076
V	-0.001	**0.327**	**0.282**	-0.175	-0.175	-0.193	0.086
Y	0.033	0.209	**0.388**	-0.219	-0.191	-0.193	-0.056
Zr	0.187	**0.302**	**0.416**	-0.169	-0.155	-0.171	**0.286**
Zn	-0.247	-0.227	0.164	**0.342**	**0.335**	**0.393**	0.132
W	0.005	**0.364**	**0.381**	-0.211	**-0.270**	-0.222	**0.333**
Total phenols	**-0.557**	**-0.571**	**-0.350**	**0.624**	**0.603**	**0.626**	**-0.348**
pH	**-0.571**	**-0.414**	-0.066	**0.531**	**0.498**	**0.570**	0.043
Volatile acid	-0.133	**-0.398**	**-0.355**	0.242	**0.299**	**0.276**	-0.122
Total acid	**0.607**	**0.307**	0.080	**-0.475**	**-0.397**	**-0.495**	-0.144
Malic acid	**0.393**	-0.087	-0.123	-0.184	-0.048	-0.167	-0.233
Glucose	0.228	0.184	-0.007	-0.172	-0.171	-0.123	0.148
Fructose	**-0.544**	**-0.670**	**-0.308**	**0.724**	**0.726**	**0.774**	-0.237
Alcohol	0.133	**-0.433**	**-0.281**	0.128	**0.287**	0.160	**-0.385**
Glycerol	**0.512**	**0.312**	-0.039	**-0.438**	**-0.407**	**-0.466**	-0.055

Variables **Al** **As** **B** **Ba** **Bi** **Ca** **Cd** **Co** **Cr** **Cu** **Fe** **Ge**

Turbidity	0.052	0.121	**-0.358**	0.050	-0.034	-0.043	0.157	0.189	0.155	-0.123	-0.070	-0.087
Sedimentation	**0.439**	**0.760**	**0.387**	**0.413**	**0.680**	**0.318**	**0.538**	**0.588**	-0.143	0.129	0.118	-0.105
Insufficient colour	**0.262**	**0.256**	-0.043	0.235	0.142	0.036	**0.291**	**0.391**	0.020	-0.208	-0.066	0.246
Sulphur compounds	0.121	**0.523**	0.227	-0.207	**0.517**	0.091	**0.261**	**0.323**	-0.044	-0.215	**-0.392**	-0.097
Volatile acidity	0.155	**0.489**	**0.255**	-0.030	**0.521**	-0.092	**0.276**	**0.452**	-0.035	-0.029	-0.140	0.163
Faulty acid balance	0.135	**0.476**	0.149	**-0.257**	**0.431**	0.025	**0.263**	**0.362**	0.122	-0.195	**-0.407**	-0.104
Oxidative character	0.243	**0.403**	**0.312**	0.233	**0.374**	0.106	**0.284**	**0.331**	-0.098	-0.111	-0.022	**0.358**
Astringency	-0.120	0.040	-0.100	**-0.300**	0.100	**-0.307**	-0.049	0.069	**0.289**	0.075	-0.128	0.084
Thin consistency	0.076	**0.370**	0.113	**-0.286**	**0.345**	0.245	0.196	0.250	0.018	-0.200	**-0.379**	-0.054
Other	0.131	**0.375**	**0.343**	0.030	**0.405**	0.142	0.160	0.188	-0.118	0.015	-0.050	0.077
Fruity aroma	0.061	**-0.288**	-0.151	**0.357**	**-0.272**	0.017	-0.118	**-0.256**	-0.046	**0.374**	**0.495**	-0.124
Persistence	0.023	**-0.291**	-0.087	**0.320**	-0.239	-0.136	-0.163	-0.204	-0.140	**0.385**	**0.516**	0.006
Overall quality	0.026	**-0.284**	-0.091	**0.381**	-0.245	-0.012	-0.126	-0.225	-0.119	**0.391**	**0.537**	-0.064
Ag	-0.081	0.253	0.005	-0.060	**0.268**	**0.501**	0.111	0.112	**0.262**	-0.048	-0.107	0.051
Al	**1**	**0.638**	**0.287**	**0.622**	**0.497**	0.149	**0.784**	**0.447**	-0.042	0.123	0.212	-0.191
As	**0.638**	**1**	**0.344**	**0.453**	**0.869**	**0.379**	**0.747**	**0.674**	-0.145	-0.067	-0.087	**-0.321**
B	**0.287**	**0.344**	**1**	**0.298**	**0.388**	0.171	**0.264**	0.190	**-0.406**	0.217	**0.275**	0.012
Ba	**0.622**	**0.453**	**0.298**	**1**	**0.394**	0.195	**0.522**	**0.324**	-0.155	**0.342**	**0.591**	-0.038
Bi	**0.497**	**0.869**	**0.388**	**0.394**	**1**	**0.441**	**0.526**	**0.520**	-0.159	0.065	0.018	-0.183
Ca	0.149	**0.379**	0.171	0.195	**0.441**	**1**	0.148	-0.018	-0.118	0.044	0.034	-0.132
Cd	**0.784**	**0.747**	**0.264**	**0.522**	**0.526**	0.148	**1**	**0.539**	-0.112	-0.094	-0.039	**-0.317**
Co	**0.447**	**0.674**	0.190	**0.324**	**0.520**	-0.018	**0.539**	**1**	-0.088	-0.086	-0.085	-0.233
Cr	-0.042	-0.145	**-0.406**	-0.155	-0.159	-0.118	-0.112	-0.088	**1**	-0.051	-0.064	0.123
Cu	0.123	-0.067	0.217	**0.342**	0.065	0.044	-0.094	-0.086	-0.051	**1**	**0.893**	-0.052
Fe	0.212	-0.087	**0.275**	**0.591**	0.018	0.034	-0.039	-0.085	-0.064	**0.893**	**1**	0.137
Ge	-0.191	**-0.321**	0.012	-0.038	-0.183	-0.132	**-0.317**	-0.233	0.123	-0.052	0.137	**1**
Hf	0.096	0.100	0.078	-0.007	0.116	**0.352**	0.208	-0.078	-0.009	-0.047	-0.070	-0.018
Hg	0.123	0.062	-0.092	0.142	0.131	-0.121	0.042	0.194	0.115	0.251	0.156	-0.172
K	**0.294**	-0.063	-0.035	**0.731**	-0.155	-0.017	0.208	0.004	-0.114	**0.261**	**0.534**	-0.073
La	-0.117	0.253	0.085	0.047	0.239	**0.564**	-0.149	0.058	-0.052	-0.006	0.009	0.109
Li	0.133	-0.007	0.213	**0.331**	0.127	0.148	-0.029	-0.088	-0.045	**0.591**	**0.522**	-0.132
Mg	0.193	-0.186	-0.035	**0.671**	-0.215	0.004	0.021	-0.104	-0.104	**0.365**	**0.662**	0.223
Mn	**0.419**	0.062	0.248	**0.859**	0.045	0.004	0.243	0.057	-0.102	**0.483**	**0.777**	0.248
Mo	**0.565**	**0.817**	**0.398**	**0.450**	**0.670**	**0.437**	**0.704**	**0.523**	-0.167	0.054	0.055	**-0.456**
Na	0.155	**0.500**	-0.083	-0.156	**0.397**	**0.414**	**0.291**	**0.256**	0.043	-0.120	**-0.370**	**-0.550**

Nb	-0.110	-0.220	0.115	-0.060	-0.012	-0.170	**-0.257**	-0.098	-0.011	0.185	0.235	**0.355**
Ni	0.176	**0.398**	0.111	0.106	**0.356**	**0.448**	0.136	**0.276**	-0.056	-0.016	-0.082	-0.172
P	-0.035	-0.146	**0.787**	0.036	-0.016	-0.118	-0.136	-0.108	**-0.307**	0.225	**0.328**	**0.407**
Pb	0.242	0.189	-0.061	0.177	0.088	0.237	**0.312**	0.026	0.173	-0.032	0.026	-0.191
S	-0.200	-0.197	**-0.849**	**-0.324**	-0.201	-0.239	-0.185	-0.072	**0.469**	-0.166	**-0.268**	-0.005
Re	0.099	**0.300**	0.154	0.124	**0.367**	0.075	0.250	**0.489**	-0.059	0.092	0.074	-0.008
Sb	**0.528**	**0.751**	**0.332**	**0.418**	**0.716**	**0.597**	**0.600**	**0.426**	-0.137	0.069	0.011	**-0.366**
Sn	**0.504**	**0.812**	**0.402**	**0.426**	**0.836**	**0.261**	**0.557**	**0.536**	-0.146	-0.021	0.014	0.036
Sc	0.099	**0.379**	0.103	-0.048	**0.313**	-0.122	0.184	0.253	-0.058	0.029	-0.097	-0.157
Se	**-0.312**	**-0.536**	**-0.598**	**-0.281**	**-0.662**	-0.244	**-0.296**	**-0.302**	**0.284**	-0.237	**-0.257**	-0.214
Si	-0.001	-0.086	**0.506**	-0.007	-0.239	-0.003	0.067	-0.028	-0.249	-0.074	-0.047	**-0.337**
Sr	**0.591**	**0.401**	**0.277**	**0.952**	**0.374**	**0.384**	**0.495**	0.184	-0.145	**0.325**	**0.583**	0.037
Te	0.184	**0.333**	0.214	**0.384**	**0.332**	0.254	0.225	0.181	-0.091	0.206	0.188	-0.083
Ta	**0.301**	**0.348**	0.189	**0.343**	**0.460**	**0.396**	0.078	0.164	-0.071	0.052	0.093	-0.154
Ti	**0.629**	**0.402**	-0.070	**0.280**	**0.363**	0.142	**0.484**	**0.358**	-0.029	-0.078	-0.052	-0.233
Tl	-0.067	-0.164	0.068	0.090	0.025	-0.020	-0.203	-0.132	-0.022	0.131	**0.276**	**0.483**
V	**0.572**	**0.714**	0.253	**0.311**	**0.621**	0.227	**0.422**	**0.778**	-0.101	0.052	-0.017	**-0.308**
Y	-0.087	0.136	0.049	-0.021	0.124	**0.285**	-0.106	-0.086	0.004	-0.035	-0.015	0.153
Zr	**0.422**	**0.702**	**0.321**	**0.303**	**0.728**	**0.408**	**0.559**	**0.367**	-0.126	**0.260**	0.115	**-0.267**
Zn	**0.438**	**0.317**	**0.441**	**0.784**	**0.330**	**0.387**	**0.350**	0.090	-0.187	**0.609**	**0.742**	0.026
W	**0.616**	**0.915**	**0.367**	**0.510**	**0.814**	**0.465**	**0.776**	**0.539**	-0.154	0.022	-0.015	**-0.412**
Total phenols	-0.013	**-0.369**	-0.232	**0.278**	**-0.468**	-0.055	-0.075	-0.235	-0.056	0.085	0.238	-0.190
pH	**0.383**	0.214	0.164	**0.802**	0.186	**0.507**	**0.274**	0.042	-0.173	**0.298**	**0.560**	0.054
Volatile acid	**-0.560**	**-0.847**	-0.251	**-0.329**	**-0.734**	-0.238	**-0.677**	**-0.577**	0.086	-0.018	0.111	**0.575**
Total acid	**-0.255**	-0.153	-0.107	**-0.626**	-0.146	**-0.696**	-0.175	0.067	0.163	-0.215	**-0.429**	-0.018
Malic acid	**-0.517**	**-0.611**	-0.231	**-0.636**	**-0.521**	**-0.715**	**-0.530**	**-0.287**	0.170	-0.124	-0.221	**0.335**
Glucose	0.032	0.213	0.127	-0.195	**0.316**	-0.063	0.095	0.216	-0.035	-0.119	-0.196	0.010
Fructose	**0.277**	-0.059	0.031	**0.745**	-0.070	0.101	0.110	-0.061	-0.128	**0.391**	**0.666**	0.018
Alcohol	**-0.420**	**-0.730**	**-0.271**	**-0.328**	**-0.666**	**-0.749**	**-0.521**	**-0.332**	0.125	-0.022	0.047	**0.401**
Glycerol	**-0.525**	**-0.433**	-0.241	**-0.868**	**-0.359**	**-0.509**	**-0.445**	-0.221	0.191	**-0.284**	**-0.516**	0.084

Variables	**Hf**	**Hg**	**K**	**La**	**Li**	**Mg**	**Mn**	**Mo**	**Na**	**Nb**	**Ni**	**P**
Turbidity	-0.033	0.030	0.073	0.053	-0.149	0.023	-0.031	0.096	0.152	**-0.322**	0.123	**-0.409**
Sedimentation	0.126	0.251	-0.079	**0.283**	0.199	-0.067	0.176	**0.634**	**0.287**	-0.035	**0.278**	0.051

Insufficient colour	-0.052	-0.046	0.089	0.139	-0.144	0.088	0.162	0.081	0.018	-0.220	-0.009	-0.127
Sulphur compounds	0.108	0.009	**-0.563**	0.113	-0.051	**-0.627**	**-0.457**	**0.360**	**0.476**	-0.083	**0.331**	0.004
Volatile acidity	0.112	0.096	**-0.435**	0.053	0.036	**-0.425**	-0.197	0.248	0.162	0.108	0.204	0.180
Faulty acid balance	0.179	0.104	**-0.698**	0.012	0.055	**-0.776**	**-0.530**	**0.349**	**0.612**	-0.199	0.232	-0.109
Oxidative character	0.098	-0.093	-0.093	0.184	-0.081	-0.016	0.155	0.221	-0.020	-0.069	0.179	0.230
Astringency	-0.007	0.168	**-0.531**	-0.093	0.103	**-0.513**	**-0.334**	-0.100	0.242	0.018	-0.042	-0.042
Thin consistency	0.253	0.012	**-0.631**	0.165	0.093	**-0.684**	**-0.515**	**0.266**	**0.569**	-0.141	0.177	-0.091
Other	0.119	0.167	**-0.290**	0.188	0.099	-0.250	-0.116	**0.320**	**0.288**	-0.146	0.206	0.126
Fruity aroma	-0.071	0.061	**0.634**	-0.096	0.181	**0.678**	**0.515**	-0.141	**-0.365**	0.159	-0.147	-0.047
Persistence	-0.157	0.051	**0.631**	-0.153	0.018	**0.725**	**0.549**	-0.191	**-0.525**	0.228	-0.225	0.076
Overall quality	-0.083	0.032	**0.672**	-0.083	0.138	**0.738**	**0.570**	-0.151	**-0.461**	0.215	-0.184	0.042
Ag	0.233	-0.103	**-0.297**	**0.319**	0.044	-0.247	-0.181	**0.294**	**0.324**	-0.001	**0.569**	-0.083
Al	0.096	0.123	**0.294**	-0.117	0.133	0.193	**0.419**	**0.565**	0.155	-0.110	0.176	-0.035
As	0.100	0.062	-0.063	0.253	-0.007	-0.186	0.062	**0.817**	**0.500**	-0.220	**0.398**	-0.146
B	0.078	-0.092	-0.035	0.085	0.213	-0.035	0.248	**0.398**	-0.083	0.115	0.111	**0.787**
Ba	-0.007	0.142	**0.731**	0.047	**0.331**	**0.671**	**0.859**	**0.450**	-0.156	-0.060	0.106	0.036
Bi	0.116	0.131	-0.155	0.239	0.127	-0.215	0.045	**0.670**	**0.397**	-0.012	**0.356**	-0.016
Ca	**0.352**	-0.121	-0.017	**0.564**	0.148	0.004	0.004	**0.437**	**0.414**	-0.170	**0.448**	-0.118
Cd	0.208	0.042	0.208	-0.149	-0.029	0.021	0.243	**0.704**	**0.291**	**-0.257**	0.136	-0.136
Co	-0.078	0.194	0.004	0.058	-0.088	-0.104	0.057	**0.523**	**0.256**	-0.098	**0.276**	-0.108
Cr	-0.009	0.115	-0.114	-0.052	-0.045	-0.104	-0.102	-0.167	0.043	-0.011	-0.056	**-0.307**
Cu	-0.047	0.251	**0.261**	-0.006	**0.591**	**0.365**	**0.483**	0.054	-0.120	0.185	-0.016	0.225
Fe	-0.070	0.156	**0.534**	0.009	**0.522**	**0.662**	**0.777**	0.055	**-0.370**	0.235	-0.082	**0.328**
Ge	-0.018	-0.172	-0.073	0.109	-0.132	0.223	0.248	**-0.456**	**-0.550**	**0.355**	-0.172	**0.407**
Hf	**1**	-0.124	-0.143	-0.115	-0.086	-0.066	-0.050	0.197	0.155	0.088	0.162	0.045
Hg	-0.124	**1**	0.110	-0.111	**0.509**	0.059	0.032	0.081	0.218	-0.022	0.035	-0.254
K	-0.143	0.110	**1**	-0.101	0.172	**0.903**	**0.775**	0.111	**-0.401**	-0.142	-0.117	-0.091
La	-0.115	-0.111	-0.101	**1**	0.030	-0.009	-0.005	0.102	0.194	-0.059	**0.399**	-0.024
Li	-0.086	**0.509**	0.172	0.030	**1**	0.133	0.241	0.117	0.156	0.056	0.026	0.039
Mg	-0.066	0.059	**0.903**	-0.009	0.133	**1**	**0.865**	-0.080	**-0.577**	0.090	-0.155	0.080
Mn	-0.050	0.032	**0.775**	-0.005	0.241	**0.865**	**1**	0.077	**-0.543**	0.162	-0.107	**0.271**
Mo	0.197	0.081	0.111	0.102	0.117	-0.080	0.077	**1**	**0.567**	**-0.345**	**0.365**	-0.150
Na	0.155	0.218	**-0.401**	0.194	0.156	**-0.577**	**-0.543**	**0.567**	**1**	**-0.447**	**0.395**	**-0.541**
Nb	0.088	-0.022	-0.142	-0.059	0.056	0.090	0.162	**-0.345**	**-0.447**	**1**	-0.142	**0.450**
Ni	0.162	0.035	-0.117	**0.399**	0.026	-0.155	-0.107	**0.365**	**0.395**	-0.142	**1**	-0.121

P	0.045	-0.254	-0.091	-0.024	0.039	0.080	**0.271**	-0.150	**-0.541**	**0.450**	-0.121	**1**
Pb	0.067	0.073	**0.272**	-0.010	-0.063	0.176	0.075	**0.376**	0.180	**-0.256**	0.252	-0.241
S	-0.034	0.196	-0.214	-0.127	-0.086	-0.221	**-0.326**	**-0.292**	0.187	0.006	-0.131	**-0.693**
Re	0.164	0.034	-0.144	0.034	-0.084	-0.073	0.071	0.177	-0.012	**0.327**	0.040	0.149
Sb	**0.257**	0.079	-0.041	**0.327**	**0.276**	-0.181	0.027	**0.719**	**0.606**	-0.252	**0.323**	-0.176
Sn	0.189	-0.060	-0.144	0.228	0.001	-0.143	0.151	**0.550**	0.194	0.104	0.232	0.125
Sc	-0.033	**0.445**	-0.196	-0.043	-0.037	-0.190	-0.169	**0.256**	0.189	-0.135	0.150	-0.058
Se	-0.183	0.047	0.240	-0.195	-0.147	0.127	-0.196	**-0.375**	0.025	**-0.343**	-0.180	**-0.509**
Si	-0.096	-0.066	0.176	-0.084	0.020	-0.011	-0.034	0.199	0.083	**-0.378**	0.005	**0.266**
Sr	0.086	0.029	**0.691**	0.167	**0.291**	**0.677**	**0.857**	**0.397**	-0.161	-0.022	0.119	0.058
Te	**0.423**	**0.267**	0.073	0.210	**0.333**	0.053	0.191	**0.314**	0.230	-0.077	0.107	-0.031
Ta	-0.100	0.040	0.086	0.169	0.161	-0.003	0.130	**0.372**	0.191	-0.019	**0.498**	-0.037
Ti	-0.129	0.048	0.079	-0.155	-0.038	-0.051	0.080	**0.299**	0.218	-0.189	-0.013	**-0.304**
Tl	0.002	-0.134	-0.006	0.135	-0.070	**0.266**	**0.317**	**-0.301**	**-0.446**	**0.370**	-0.108	**0.357**
V	-0.145	**0.328**	-0.056	**0.292**	0.163	-0.157	-0.006	**0.563**	**0.446**	-0.107	**0.409**	-0.146
Y	-0.050	-0.071	-0.091	**0.724**	-0.042	-0.023	-0.004	-0.034	0.042	-0.071	-0.016	0.021
Zr	**0.463**	**0.312**	-0.134	0.069	0.225	-0.156	0.041	**0.698**	**0.472**	-0.092	**0.300**	-0.063
Zn	**0.285**	0.132	**0.555**	0.182	**0.397**	**0.615**	**0.779**	**0.435**	-0.132	0.034	0.243	0.236
W	0.181	0.135	0.010	0.150	0.173	-0.162	0.085	**0.877**	**0.582**	**-0.306**	**0.381**	-0.198
Total phenols	-0.082	0.113	**0.802**	-0.156	0.059	**0.687**	**0.369**	-0.085	**-0.262**	**-0.283**	-0.155	-0.245
pH	0.121	0.005	**0.783**	**0.264**	0.199	**0.828**	**0.797**	**0.301**	-0.235	-0.062	0.124	0.011
Volatile acid	-0.039	**-0.320**	0.074	-0.049	-0.226	**0.307**	0.118	**-0.818**	**-0.704**	**0.381**	**-0.284**	**0.340**
Total acid	-0.214	0.073	**-0.660**	**-0.374**	-0.157	**-0.704**	**-0.610**	**-0.276**	0.116	0.120	-0.189	0.047
Malic acid	-0.190	-0.087	**-0.419**	**-0.323**	-0.253	**-0.286**	**-0.331**	**-0.752**	**-0.425**	**0.366**	**-0.334**	**0.267**
Glucose	-0.059	0.066	**-0.298**	-0.015	0.014	**-0.336**	**-0.258**	0.101	0.066	**0.283**	-0.041	0.129
Fructose	-0.077	0.048	**0.921**	0.006	0.193	**0.931**	**0.850**	0.081	**-0.475**	0.044	-0.106	0.025
Alcohol	**-0.340**	-0.110	0.031	**-0.364**	**-0.291**	0.145	0.044	**-0.751**	**-0.659**	**0.337**	**-0.444**	**0.261**
Glycerol	-0.094	-0.088	**-0.742**	**-0.262**	-0.227	**-0.725**	**-0.752**	**-0.511**	0.058	0.158	-0.201	0.057

Variables	**Pb**	**S**	**Re**	**Sb**	**Sn**	**Sc**	**Se**	**Si**	**Sr**	**Te**	**Ta**	**Ti**
Turbidity	0.147	**0.284**	0.064	0.018	0.035	0.107	0.191	-0.144	0.020	0.050	-0.070	**0.267**
Sedimentation	0.096	-0.211	**0.360**	**0.574**	**0.699**	**0.360**	**-0.622**	-0.193	**0.375**	**0.404**	**0.257**	0.189
Insufficient colour	-0.076	0.043	0.186	0.229	**0.286**	0.004	-0.048	-0.047	0.223	0.228	-0.094	**0.384**
Sulphur compounds	-0.058	-0.029	**0.288**	**0.386**	**0.464**	**0.355**	**-0.411**	-0.075	**-0.256**	0.169	0.131	0.082

Volatile acidity	-0.141	-0.007	**0.382**	**0.328**	**0.629**	**0.339**	**-0.631**	**-0.363**	-0.119	**0.270**	0.018	0.072
Faulty acid balance	-0.145	0.181	0.157	**0.425**	**0.440**	**0.291**	**-0.320**	-0.091	**-0.320**	0.219	0.054	0.205
Oxidative character	-0.148	-0.243	**0.309**	**0.255**	**0.500**	0.142	**-0.409**	-0.113	0.223	**0.289**	0.091	0.121
Astringency	**-0.414**	**0.296**	0.187	0.035	0.113	0.214	-0.098	**-0.312**	**-0.358**	0.167	-0.134	-0.103
Thin consistency	-0.051	0.213	0.180	**0.445**	**0.383**	0.131	**-0.349**	-0.063	**-0.276**	**0.263**	-0.015	0.254
Other	-0.036	-0.220	0.238	**0.361**	**0.367**	**0.312**	**-0.336**	0.032	-0.011	**0.344**	0.054	0.014
Fruity aroma	0.229	-0.078	-0.211	-0.206	**-0.343**	-0.188	0.240	0.014	**0.378**	-0.145	0.024	-0.096
Persistence	0.168	-0.161	-0.086	**-0.313**	**-0.295**	-0.070	0.161	-0.008	**0.309**	-0.198	-0.038	-0.117
Overall quality	0.193	-0.152	-0.147	-0.227	**-0.289**	-0.203	0.176	-0.010	**0.401**	-0.143	-0.004	-0.144
Ag	0.250	0.038	0.195	0.243	0.234	-0.067	**-0.254**	**-0.263**	0.042	-0.018	**0.273**	-0.110
Al	0.242	-0.200	0.099	**0.528**	**0.504**	0.099	**-0.312**	-0.001	**0.591**	0.184	**0.301**	**0.629**
As	0.189	-0.197	**0.300**	**0.751**	**0.812**	**0.379**	**-0.536**	-0.086	**0.401**	**0.333**	**0.348**	**0.402**
B	-0.061	**-0.849**	0.154	**0.332**	**0.402**	0.103	**-0.598**	**0.506**	**0.277**	0.214	0.189	-0.070
Ba	0.177	**-0.324**	0.124	**0.418**	**0.426**	-0.048	**-0.281**	-0.007	**0.952**	**0.384**	**0.343**	**0.280**
Bi	0.088	-0.201	**0.367**	**0.716**	**0.836**	**0.313**	**-0.662**	-0.239	**0.374**	**0.332**	**0.460**	**0.363**
Ca	0.237	-0.239	0.075	**0.597**	**0.261**	-0.122	-0.244	-0.003	**0.384**	0.254	**0.396**	0.142
Cd	**0.312**	-0.185	0.250	**0.600**	**0.557**	0.184	**-0.296**	0.067	**0.495**	0.225	0.078	**0.484**
Co	0.026	-0.072	**0.489**	**0.426**	**0.536**	0.253	**-0.302**	-0.028	0.184	0.181	0.164	**0.358**
Cr	0.173	**0.469**	-0.059	-0.137	-0.146	-0.058	**0.284**	-0.249	-0.145	-0.091	-0.071	-0.029
Cu	-0.032	-0.166	0.092	0.069	-0.021	0.029	-0.237	-0.074	**0.325**	0.206	0.052	-0.078
Fe	0.026	**-0.268**	0.074	0.011	0.014	-0.097	**-0.257**	-0.047	**0.583**	0.188	0.093	-0.052
Ge	-0.191	-0.005	-0.008	**-0.366**	0.036	-0.157	-0.214	**-0.337**	0.037	-0.083	-0.154	-0.233
Hf	0.067	-0.034	0.164	**0.257**	0.189	-0.033	-0.183	-0.096	0.086	**0.423**	-0.100	-0.129
Hg	0.073	0.196	0.034	0.079	-0.060	**0.445**	0.047	-0.066	0.029	**0.267**	0.040	0.048
K	**0.272**	-0.214	-0.144	-0.041	-0.144	-0.196	0.240	0.176	**0.691**	0.073	0.086	0.079
La	-0.010	-0.127	0.034	**0.327**	0.228	-0.043	-0.195	-0.084	0.167	0.210	0.169	-0.155
Li	-0.063	-0.086	-0.084	**0.276**	0.001	-0.037	-0.147	0.020	**0.291**	**0.333**	0.161	-0.038
Mg	0.176	-0.221	-0.073	-0.181	-0.143	-0.190	0.127	-0.011	**0.677**	0.053	-0.003	-0.051
Mn	0.075	**-0.326**	0.071	0.027	0.151	-0.169	-0.196	-0.034	**0.857**	0.191	0.130	0.080
Mo	**0.376**	**-0.292**	0.177	**0.719**	**0.550**	**0.256**	**-0.375**	0.199	**0.397**	**0.314**	**0.372**	**0.299**
Na	0.180	0.187	-0.012	**0.606**	0.194	0.189	0.025	0.083	-0.161	0.230	0.191	0.218
Nb	**-0.256**	0.006	**0.327**	-0.252	0.104	-0.135	**-0.343**	**-0.378**	-0.022	-0.077	-0.019	-0.189
Ni	0.252	-0.131	0.040	**0.323**	0.232	0.150	-0.180	0.005	0.119	0.107	**0.498**	-0.013
P	-0.241	**-0.693**	0.149	-0.176	0.125	-0.058	**-0.509**	**0.266**	0.058	-0.031	-0.037	**-0.304**
Pb	**1**	-0.014	-0.167	0.152	-0.014	0.064	0.001	0.129	0.191	-0.156	0.120	0.134

S	-0.014	**1**	-0.062	-0.192	-0.158	-0.049	**0.301**	**-0.586**	**-0.340**	-0.096	-0.153	0.215
Re	-0.167	-0.062	**1**	**0.311**	**0.401**	0.168	**-0.413**	**-0.276**	0.104	**0.262**	0.021	0.097
Sb	0.152	-0.192	**0.311**	**1**	**0.646**	0.107	**-0.423**	0.011	**0.427**	**0.589**	0.244	**0.379**
Sn	-0.014	-0.158	**0.401**	**0.646**	**1**	0.207	**-0.729**	**-0.325**	**0.388**	**0.432**	**0.275**	**0.355**
Sc	0.064	-0.049	0.168	0.107	0.207	**1**	-0.182	-0.020	-0.192	0.239	-0.089	-0.105
Se	0.001	**0.301**	**-0.413**	**-0.423**	**-0.729**	-0.182	**1**	**0.269**	**-0.291**	**-0.276**	-0.246	-0.147
Si	0.129	**-0.586**	**-0.276**	0.011	**-0.325**	-0.020	**0.269**	**1**	-0.051	-0.050	-0.035	-0.112
Sr	0.191	**-0.340**	0.104	**0.427**	**0.388**	-0.192	**-0.291**	-0.051	**1**	**0.340**	**0.369**	**0.276**
Te	-0.156	-0.096	**0.262**	**0.589**	**0.432**	0.239	**-0.276**	-0.050	**0.340**	**1**	0.039	-0.047
Ta	0.120	-0.153	0.021	0.244	**0.275**	-0.089	-0.246	-0.035	**0.369**	0.039	**1**	**0.277**
Ti	0.134	0.215	0.097	**0.379**	**0.355**	-0.105	-0.147	-0.112	**0.276**	-0.047	**0.277**	**1**
Tl	-0.093	-0.069	0.110	-0.218	0.071	-0.097	-0.244	**-0.324**	0.165	-0.108	-0.107	-0.169
V	0.088	-0.101	**0.295**	**0.616**	**0.536**	0.233	**-0.348**	-0.001	0.207	0.247	**0.322**	**0.444**
Y	-0.145	-0.042	-0.008	0.187	0.156	-0.047	-0.145	-0.091	0.085	**0.287**	-0.056	-0.088
Zr	0.175	-0.174	**0.347**	**0.646**	**0.566**	**0.480**	**-0.519**	-0.143	**0.290**	**0.510**	0.194	0.090
Zn	0.185	**-0.442**	0.132	**0.385**	**0.319**	-0.022	**-0.392**	0.038	**0.813**	**0.457**	**0.260**	-0.019
W	**0.279**	-0.206	0.243	**0.852**	**0.737**	**0.264**	**-0.471**	0.013	**0.470**	**0.408**	**0.353**	**0.430**
Total phenols	**0.331**	-0.067	**-0.381**	-0.215	**-0.511**	-0.197	**0.596**	**0.385**	0.246	-0.066	-0.127	-0.063
pH	**0.285**	**-0.368**	0.031	**0.286**	0.164	-0.167	-0.106	0.028	**0.873**	**0.257**	0.253	0.115
Volatile acid	-0.220	0.071	-0.123	**-0.770**	**-0.583**	**-0.415**	**0.277**	-0.102	-0.213	**-0.371**	-0.251	**-0.395**
Total acid	**-0.315**	**0.346**	0.009	**-0.312**	-0.075	0.227	0.041	-0.067	**-0.757**	-0.232	**-0.260**	-0.073
Malic acid	**-0.381**	**0.279**	-0.028	**-0.739**	**-0.392**	0.048	0.186	-0.165	**-0.679**	**-0.377**	**-0.387**	**-0.352**
Glucose	-0.240	0.038	0.179	0.093	0.221	0.000	**-0.325**	-0.228	-0.196	-0.148	0.144	-0.040
Fructose	0.177	**-0.256**	-0.061	-0.024	-0.061	-0.197	0.091	0.043	**0.750**	0.112	0.167	0.051
Alcohol	**-0.260**	0.183	-0.076	**-0.830**	**-0.512**	-0.167	**0.310**	-0.083	**-0.369**	**-0.438**	**-0.288**	-0.233
Glycerol	**-0.326**	**0.390**	-0.079	**-0.458**	**-0.314**	0.030	0.175	-0.078	**-0.893**	**-0.340**	**-0.307**	-0.210

Variables	**V**	**Y**	**Zr**	**Zn**	**W**	**Total phenols**	**pH**	**Volatile acid**	**Total acid**	**Malic acid**	**Glucose**
Turbidity	0.055	0.143	-0.021	-0.108	0.087	0.034	-0.009	-0.087	0.008	-0.053	**-0.291**
Sedimentation	**0.616**	0.179	**0.718**	**0.437**	**0.724**	**-0.390**	0.247	**-0.611**	-0.168	**-0.457**	**0.287**
Insufficient colour	0.205	0.220	-0.053	0.029	0.159	-0.084	0.148	-0.120	-0.115	-0.166	-0.166
Sulphur compounds	**0.390**	0.152	**0.459**	-0.171	**0.431**	**-0.627**	**-0.400**	**-0.461**	**0.370**	0.053	**0.304**
Volatile acidity	**0.382**	0.073	**0.446**	-0.007	**0.388**	**-0.656**	**-0.317**	**-0.370**	**0.385**	0.105	**0.454**
Faulty acid balance	**0.373**	0.026	**0.421**	-0.241	**0.461**	**-0.677**	**-0.555**	**-0.550**	**0.531**	0.006	**0.262**

Oxidative character	0.231	**0.292**	**0.296**	0.219	**0.297**	**-0.378**	0.123	-0.143	-0.074	-0.087	-0.009
Astringency	-0.001	0.033	0.187	-0.247	0.005	**-0.557**	**-0.571**	-0.133	**0.607**	**0.393**	0.228
Thin consistency	**0.327**	0.209	**0.302**	-0.227	**0.364**	**-0.571**	**-0.414**	**-0.398**	**0.307**	-0.087	0.184
Other	**0.282**	**0.388**	**0.416**	0.164	**0.381**	**-0.350**	-0.066	**-0.355**	0.080	-0.123	-0.007
Fruity aroma	-0.175	-0.219	-0.169	**0.342**	-0.211	**0.624**	**0.531**	0.242	**-0.475**	-0.184	-0.172
Persistence	-0.175	-0.191	-0.155	**0.335**	**-0.270**	**0.603**	**0.498**	**0.299**	**-0.397**	-0.048	-0.171
Overall quality	-0.193	-0.193	-0.171	**0.393**	-0.222	**0.626**	**0.570**	**0.276**	**-0.495**	-0.167	-0.123
Ag	0.086	-0.056	**0.286**	0.132	**0.333**	**-0.348**	0.043	-0.122	-0.144	-0.233	0.148
Al	**0.572**	-0.087	**0.422**	**0.438**	**0.616**	-0.013	**0.383**	**-0.560**	**-0.255**	**-0.517**	0.032
As	**0.714**	0.136	**0.702**	**0.317**	**0.915**	**-0.369**	0.214	**-0.847**	-0.153	**-0.611**	0.213
B	0.253	0.049	**0.321**	**0.441**	**0.367**	-0.232	0.164	-0.251	-0.107	-0.231	0.127
Ba	**0.311**	-0.021	**0.303**	**0.784**	**0.510**	**0.278**	**0.802**	**-0.329**	**-0.626**	**-0.636**	-0.195
Bi	**0.621**	0.124	**0.728**	**0.330**	**0.814**	**-0.468**	0.186	**-0.734**	-0.146	**-0.521**	**0.316**
Ca	0.227	**0.285**	**0.408**	**0.387**	**0.465**	-0.055	**0.507**	-0.238	**-0.696**	**-0.715**	-0.063
Cd	**0.422**	-0.106	**0.559**	**0.350**	**0.776**	-0.075	**0.274**	**-0.677**	-0.175	**-0.530**	0.095
Co	**0.778**	-0.086	**0.367**	0.090	**0.539**	-0.235	0.042	**-0.577**	0.067	**-0.287**	0.216
Cr	-0.101	0.004	-0.126	-0.187	-0.154	-0.056	-0.173	0.086	0.163	0.170	-0.035
Cu	0.052	-0.035	**0.260**	**0.609**	0.022	0.085	**0.298**	-0.018	-0.215	-0.124	-0.119
Fe	-0.017	-0.015	0.115	**0.742**	-0.015	0.238	**0.560**	0.111	**-0.429**	-0.221	-0.196
Ge	**-0.308**	0.153	**-0.267**	0.026	**-0.412**	-0.190	0.054	**0.575**	-0.018	**0.335**	0.010
Hf	-0.145	-0.050	**0.463**	**0.285**	0.181	-0.082	0.121	-0.039	-0.214	-0.190	-0.059
Hg	**0.328**	-0.071	**0.312**	0.132	0.135	0.113	0.005	**-0.320**	0.073	-0.087	0.066
K	-0.056	-0.091	-0.134	**0.555**	0.010	**0.802**	**0.783**	0.074	**-0.660**	**-0.419**	**-0.298**
La	**0.292**	**0.724**	0.069	0.182	0.150	-0.156	**0.264**	-0.049	**-0.374**	**-0.323**	-0.015
Li	0.163	-0.042	0.225	**0.397**	0.173	0.059	0.199	-0.226	-0.157	-0.253	0.014
Mg	-0.157	-0.023	-0.156	**0.615**	-0.162	**0.687**	**0.828**	**0.307**	**-0.704**	**-0.286**	**-0.336**
Mn	-0.006	-0.004	0.041	**0.779**	0.085	**0.369**	**0.797**	0.118	**-0.610**	**-0.331**	**-0.258**
Mo	**0.563**	-0.034	**0.698**	**0.435**	**0.877**	-0.085	**0.301**	**-0.818**	**-0.276**	**-0.752**	0.101
Na	**0.446**	0.042	**0.472**	-0.132	**0.582**	**-0.262**	-0.235	**-0.704**	0.116	**-0.425**	0.066
Nb	-0.107	-0.071	-0.092	0.034	**-0.306**	**-0.283**	-0.062	**0.381**	0.120	**0.366**	**0.283**
Ni	**0.409**	-0.016	**0.300**	0.243	**0.381**	-0.155	0.124	**-0.284**	-0.189	**-0.334**	-0.041
P	-0.146	0.021	-0.063	0.236	-0.198	-0.245	0.011	**0.340**	0.047	**0.267**	0.129
Pb	0.088	-0.145	0.175	0.185	**0.279**	**0.331**	**0.285**	-0.220	**-0.315**	**-0.381**	-0.240
S	-0.101	-0.042	-0.174	**-0.442**	-0.206	-0.067	**-0.368**	0.071	**0.346**	**0.279**	0.038
Re	**0.295**	-0.008	**0.347**	0.132	0.243	**-0.381**	0.031	-0.123	0.009	-0.028	0.179

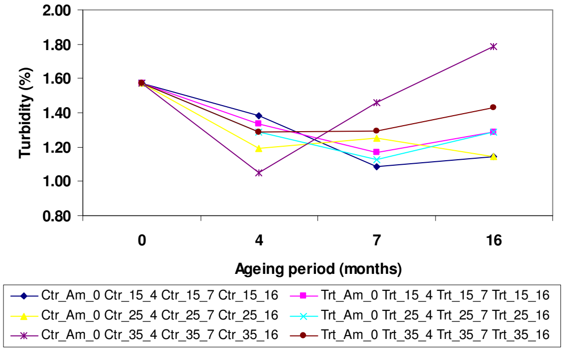
Sb	**0.616**	0.187	**0.646**	**0.385**	**0.852**	-0.215	**0.286**	**-0.770**	**-0.312**	**-0.739**	0.093
Sn	**0.536**	0.156	**0.566**	**0.319**	**0.737**	**-0.511**	0.164	**-0.583**	-0.075	**-0.392**	0.221
Sc	0.233	-0.047	**0.480**	-0.022	**0.264**	-0.197	-0.167	**-0.415**	0.227	0.048	0.000
Se	**-0.348**	-0.145	**-0.519**	**-0.392**	**-0.471**	**0.596**	-0.106	**0.277**	0.041	0.186	**-0.325**
Si	-0.001	-0.091	-0.143	0.038	0.013	**0.385**	0.028	-0.102	-0.067	-0.165	-0.228
Sr	0.207	0.085	**0.290**	**0.813**	**0.470**	0.246	**0.873**	-0.213	**-0.757**	**-0.679**	-0.196
Te	0.247	**0.287**	**0.510**	**0.457**	**0.408**	-0.066	**0.257**	**-0.371**	-0.232	**-0.377**	-0.148
Ta	**0.322**	-0.056	0.194	**0.260**	**0.353**	-0.127	0.253	-0.251	**-0.260**	**-0.387**	0.144
Ti	**0.444**	-0.088	0.090	-0.019	**0.430**	-0.063	0.115	**-0.395**	-0.073	**-0.352**	-0.040
Tl	-0.194	0.130	-0.096	0.149	-0.249	-0.141	0.174	**0.374**	-0.122	0.198	-0.052
V	**1**	0.132	**0.433**	0.160	**0.620**	-0.221	0.101	**-0.692**	-0.043	**-0.463**	0.244
Y	0.132	**1**	0.010	0.086	0.028	-0.136	0.120	0.015	-0.190	-0.111	0.059
Zr	**0.433**	0.010	**1**	**0.492**	**0.744**	**-0.320**	0.189	**-0.680**	-0.172	**-0.481**	0.152
Zn	0.160	0.086	**0.492**	**1**	**0.426**	0.224	**0.794**	-0.204	**-0.696**	**-0.606**	-0.161
W	**0.620**	0.028	**0.744**	**0.426**	**1**	-0.239	**0.279**	**-0.895**	-0.236	**-0.737**	0.110
Total phenols	-0.221	-0.136	**-0.320**	0.224	-0.239	**1**	**0.511**	0.198	**-0.496**	**-0.256**	**-0.393**
pH	0.101	0.120	0.189	**0.794**	**0.279**	**0.511**	**1**	-0.029	**-0.952**	**-0.699**	**-0.288**
Volatile acid	**-0.692**	0.015	**-0.680**	-0.204	**-0.895**	0.198	-0.029	**1**	-0.024	**0.593**	-0.182
Total acid	-0.043	-0.190	-0.172	**-0.696**	-0.236	**-0.496**	**-0.952**	-0.024	**1**	**0.724**	**0.302**
Malic acid	**-0.463**	-0.111	**-0.481**	**-0.606**	**-0.737**	**-0.256**	**-0.699**	**0.593**	**0.724**	**1**	0.109
Glucose	0.244	0.059	0.152	-0.161	0.110	**-0.393**	**-0.288**	-0.182	**0.302**	0.109	**1**
Fructose	-0.067	-0.031	-0.071	**0.654**	-0.005	**0.686**	**0.853**	0.144	**-0.734**	**-0.429**	**-0.273**
Alcohol	**-0.497**	-0.131	**-0.655**	**-0.413**	**-0.814**	0.096	**-0.362**	**0.736**	**0.441**	**0.812**	-0.062
Glycerol	**-0.299**	-0.103	**-0.345**	**-0.809**	**-0.493**	**-0.438**	**-0.961**	**0.283**	**0.887**	**0.813**	**0.256**

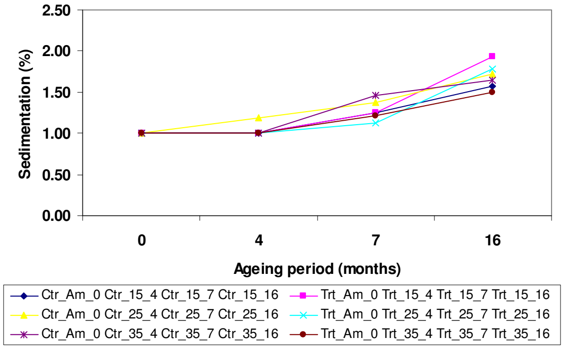
Variables	**Fructose**	**Alcohol**	**Glycerol**
Turbidity	0.012	0.025	-0.030
Sedimentation	-0.001	**-0.547**	**-0.400**
Insufficient colour	-0.021	-0.120	-0.188
Sulphur compounds	**-0.619**	**-0.297**	0.251
Volatile acidity	**-0.460**	-0.158	0.203
Faulty acid balance	**-0.729**	**-0.364**	**0.393**
Oxidative character	-0.141	-0.151	-0.177
Astringency	**-0.544**	0.133	**0.512**

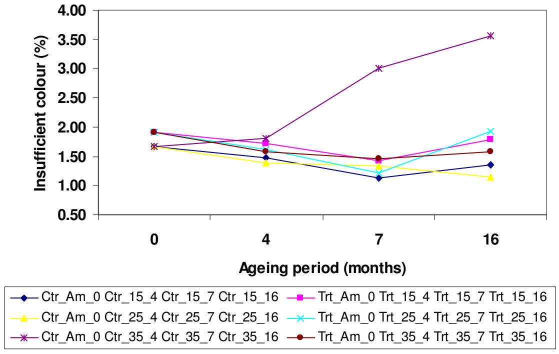
Thin consistency	**-0.670**	**-0.433**	**0.312**
Other	**-0.308**	**-0.281**	-0.039
Fruity aroma	**0.724**	0.128	**-0.438**
Persistence	**0.726**	**0.287**	**-0.407**
Overall quality	**0.774**	0.160	**-0.466**
Ag	-0.237	**-0.385**	-0.055
Al	**0.277**	**-0.420**	**-0.525**
As	-0.059	**-0.730**	**-0.433**
B	0.031	**-0.271**	-0.241
Ba	**0.745**	**-0.328**	**-0.868**
Bi	-0.070	**-0.666**	**-0.359**
Ca	0.101	**-0.749**	**-0.509**
Cd	0.110	**-0.521**	**-0.445**
Co	-0.061	**-0.332**	-0.221
Cr	-0.128	0.125	0.191
Cu	**0.391**	-0.022	**-0.284**
Fe	**0.666**	0.047	**-0.516**
Ge	0.018	**0.401**	0.084
Hf	-0.077	**-0.340**	-0.094
Hg	0.048	-0.110	-0.088
K	**0.921**	0.031	**-0.742**
La	0.006	**-0.364**	**-0.262**
Li	0.193	**-0.291**	-0.227
Mg	**0.931**	0.145	**-0.725**
Mn	**0.850**	0.044	**-0.752**
Mo	0.081	**-0.751**	**-0.511**
Na	**-0.475**	**-0.659**	0.058
Nb	0.044	**0.337**	0.158
Ni	-0.106	**-0.444**	-0.201
P	0.025	**0.261**	0.057
Pb	0.177	**-0.260**	**-0.326**
S	**-0.256**	0.183	**0.390**
Re	-0.061	-0.076	-0.079
Sb	-0.024	**-0.830**	**-0.458**
Sn	-0.061	**-0.512**	**-0.314**

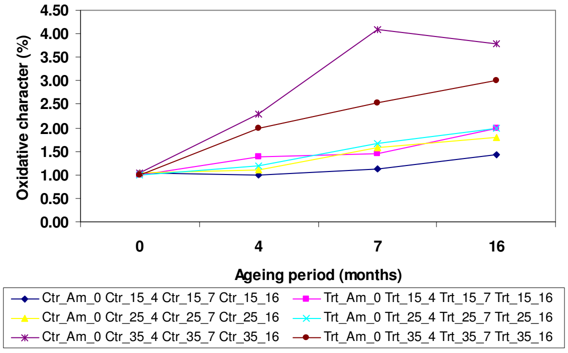
Sc	-0.197	-0.167	0.030
Se	0.091	**0.310**	0.175
Si	0.043	-0.083	-0.078
Sr	**0.750**	**-0.369**	**-0.893**
Te	0.112	**-0.438**	**-0.340**
Ta	0.167	**-0.288**	**-0.307**
Ti	0.051	-0.233	-0.210
Tl	0.171	0.230	-0.075
V	-0.067	**-0.497**	**-0.299**
Y	-0.031	-0.131	-0.103
Zr	-0.071	**-0.655**	**-0.345**
Zn	**0.654**	**-0.413**	**-0.809**
W	-0.005	**-0.814**	**-0.493**
Total phenols	**0.686**	0.096	**-0.438**
pH	**0.853**	**-0.362**	**-0.961**
Volatile acid	0.144	**0.736**	**0.283**
Total acid	**-0.734**	**0.441**	**0.887**
Malic acid	**-0.429**	**0.812**	**0.813**
Glucose	**-0.273**	-0.062	**0.256**
Fructose	**1**	0.006	**-0.790**
Alcohol	0.006	**1**	**0.505**
Glycerol	**-0.790**	**0.505**	**1**

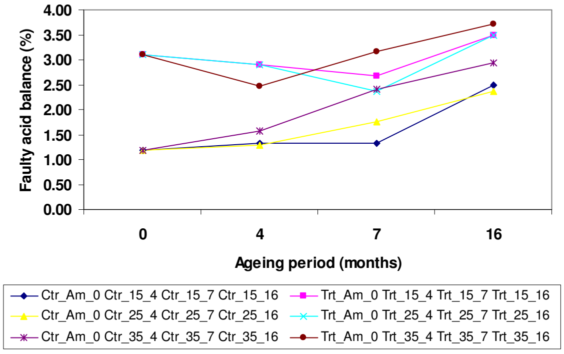
Values in bold are different from 0 with a significance level alpha=0.05

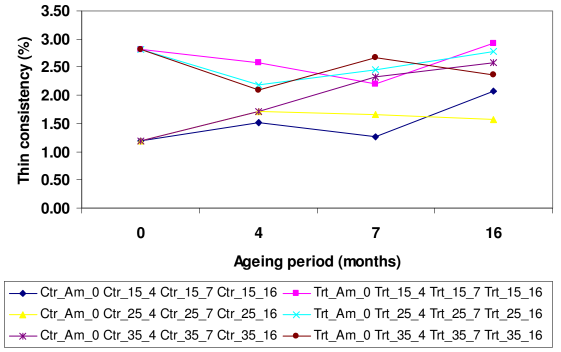

Turbidity (%)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0
4
7
16
Ageing period (months)
Ctr_Am_0 Ctr_15_4 Ctr_15_7 Ctr_15_16
Trt_Am_0 Trt_15_4 Trt_15_7 Trt_15_16
Ctr_Am_0 Ctr_25_4 Ctr_25_7 Ctr_25_16
Trt_Am_0 Trt_25_4 Trt_25_7 Trt_25_16
Ctr_Am_0 Ctr_35_4 Ctr_35_7 Ctr_35_16
Trt_Am_0 Trt_35_4 Trt_35_7 Trt_35_16

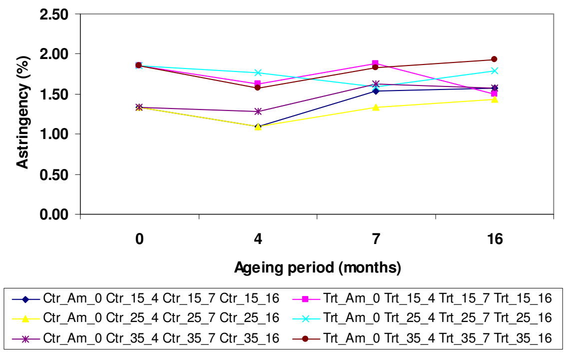

Sedimentation (%)
2.50
2.00
1.50
1.00
0.50
0.00
0
4
7
16
Ageing period (months)
Ctr_Am_0 Ctr_15_4 Ctr_15_7 Ctr_15_16
Trt_Am_0 Trt_15_4 Trt_15_7 Trt_15_16
Ctr_Am_0 Ctr_25_4 Ctr_25_7 Ctr_25_16
Trt_Am_0 Trt_25_4 Trt_25_7 Trt_25_16
Ctr_Am_0 Ctr_35_4 Ctr_35_7 Ctr_35_16
Trt_Am_0 Trt_35_4 Trt_35_7 Trt_35_16

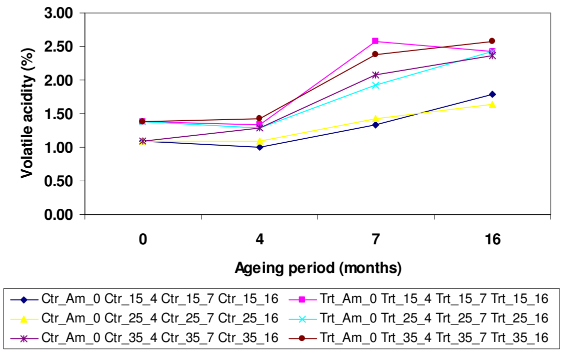

Insufficient colour (%)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0
4
7
16
Ageing period (months)
Ctr_Am_0 Ctr_15_4 Ctr_15_7 Ctr_15_16
Trt_Am_0 Trt_15_4 Trt_15_7 Trt_15_16
Ctr_Am_0 Ctr_25_4 Ctr_25_7 Ctr_25_16
Trt_Am_0 Trt_25_4 Trt_25_7 Trt_25_16
Ctr_Am_0 Ctr_35_4 Ctr_35_7 Ctr_35_16
Trt_Am_0 Trt_35_4 Trt_35_7 Trt_35_16

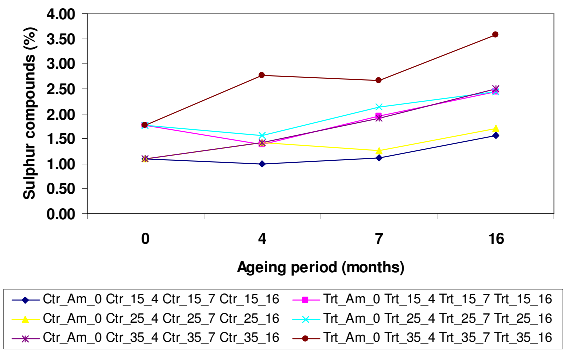

Oxidative character (%)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
4
7
16
Ageing period (months)
Ctr_Am_0 Ctr_15_4 Ctr_15_7 Ctr_15_16
Trt_Am_0 Trt_15_4 Trt_15_7 Trt_15_16
Ctr_Am_0 Ctr_25_4 Ctr_25_7 Ctr_25_16
Trt_Am_0 Trt_25_4 Trt_25_7 Trt_25_16
Ctr_Am_0 Ctr_35_4 Ctr_35_7 Ctr_35_16
Trt_Am_0 Trt_35_4 Trt_35_7 Trt_35_16

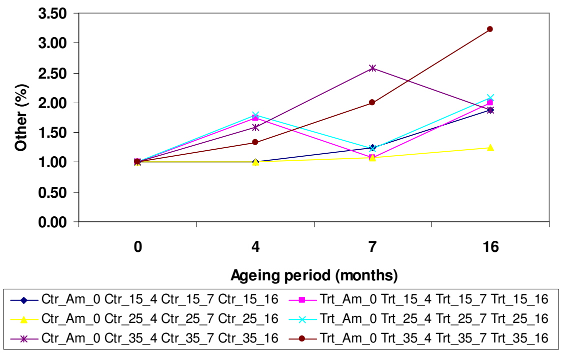

Faulty acid balance (%)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
4
7
16
Ageing period (months)
Ctr_Am_0 Ctr_15_4 Ctr_15_7 Ctr_15_16
Trt_Am_0 Trt_15_4 Trt_15_7 Trt_15_16
Ctr_Am_0 Ctr_25_4 Ctr_25_7 Ctr_25_16
Trt_Am_0 Trt_25_4 Trt_25_7 Trt_25_16
Ctr_Am_0 Ctr_35_4 Ctr_35_7 Ctr_35_16
Trt_Am_0 Trt_35_4 Trt_35_7 Trt_35_16


Thin consistency (%)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
4
7
16
Ageing period (months)
Ctr_Am_0 Ctr_15_4 Ctr_15_7 Ctr_15_16
Trt_Am_0 Trt_15_4 Trt_15_7 Trt_15_16
Ctr_Am_0 Ctr_25_4 Ctr_25_7 Ctr_25_16
Trt_Am_0 Trt_25_4 Trt_25_7 Trt_25_16
Ctr_Am_0 Ctr_35_4 Ctr_35_7 Ctr_35_16
Trt_Am_0 Trt_35_4 Trt_35_7 Trt_35_16


Astringency (%)
2.50
2.00
1.50
1.00
0.50
0.00
0
4
7
16
Ageing period (months)
Ctr_Am_0 Ctr_15_4 Ctr_15_7 Ctr_15_16
Trt_Am_0 Trt_15_4 Trt_15_7 Trt_15_16
Ctr_Am_0 Ctr_25_4 Ctr_25_7 Ctr_25_16
Trt_Am_0 Trt_25_4 Trt_25_7 Trt_25_16
Ctr_Am_0 Ctr_35_4 Ctr_35_7 Ctr_35_16
Trt_Am_0 Trt_35_4 Trt_35_7 Trt_35_16


Volatile acidity (%)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
4
7
16
Ageing period (months)
Ctr_Am_0 Ctr_15_4 Ctr_15_7 Ctr_15_16
Trt_Am_0 Trt_15_4 Trt_15_7 Trt_15_16
Ctr_Am_0 Ctr_25_4 Ctr_25_7 Ctr_25_16
Trt_Am_0 Trt_25_4 Trt_25_7 Trt_25_16
Ctr_Am_0 Ctr_35_4 Ctr_35_7 Ctr_35_16
Trt_Am_0 Trt_35_4 Trt_35_7 Trt_35_16


Sulphur compounds (%)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
4
7
16
Ageing period (months)
Ctr_Am_0 Ctr_15_4 Ctr_15_7 Ctr_15_16
Trt_Am_0 Trt_15_4 Trt_15_7 Trt_15_16
Ctr_Am_0 Ctr_25_4 Ctr_25_7 Ctr_25_16
Trt_Am_0 Trt_25_4 Trt_25_7 Trt_25_16
Ctr_Am_0 Ctr_35_4 Ctr_35_7 Ctr_35_16
Trt_Am_0 Trt_35_4 Trt_35_7 Trt_35_16


Other (%)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
4
7
16
Ageing period (months)
Ctr_Am_0 Ctr_15_4 Ctr_15_7 Ctr_15_16
Trt_Am_0 Trt_15_4 Trt_15_7 Trt_15_16
Ctr_Am_0 Ctr_25_4 Ctr_25_7 Ctr_25_16
Trt_Am_0 Trt_25_4 Trt_25_7 Trt_25_16
Ctr_Am_0 Ctr_35_4 Ctr_35_7 Ctr_35_16
Trt_Am_0 Trt_35_4 Trt_35_7 Trt_35_16

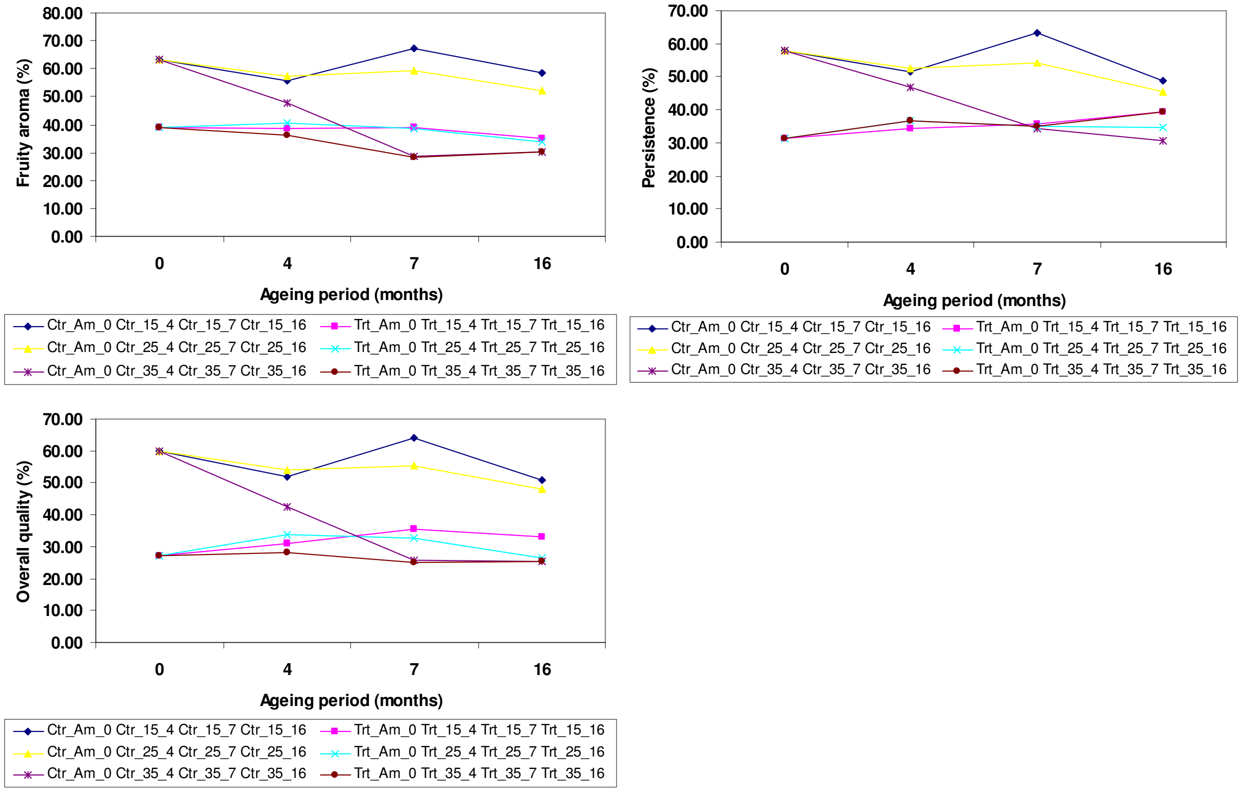


FIGURE 6
Sensory descriptors as a function of time of storage. Untreated or control (ctr) wine, and Chenin blanc treated (trt) with resin to remove metals or decrease metal concentrations, were stored for 16 months at different temperatures and evaluated organoleptically and chemically at regular time intervals. Abbreviations: e.g. Ctr_Am_0, control wine before storage; Trt_Am_0, treated wine before storage; Ctr_15_4, control wine stored at 15ºC for four months; Trt_35_16, treated wine stored at 35 ºC for 16 months.

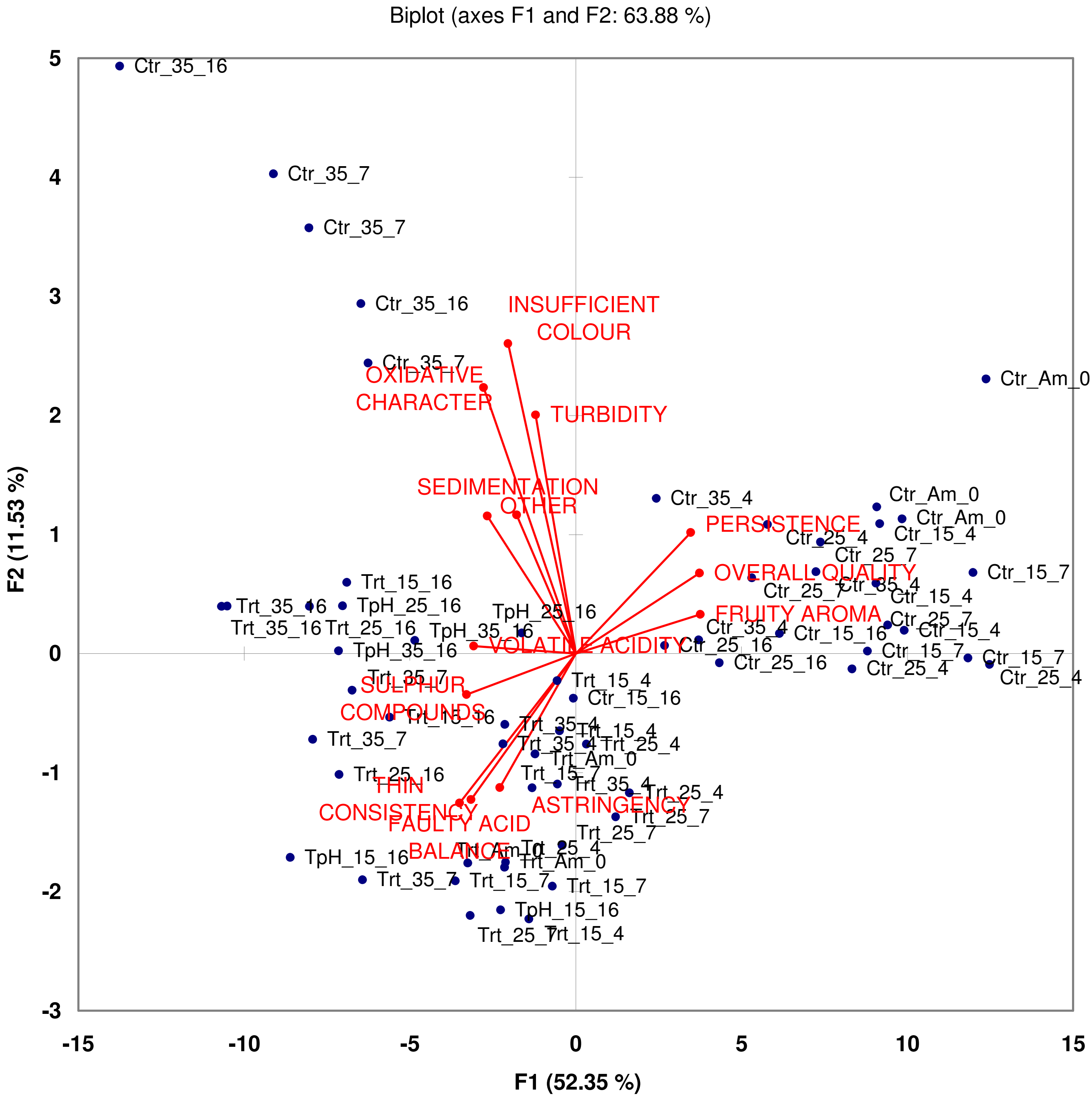
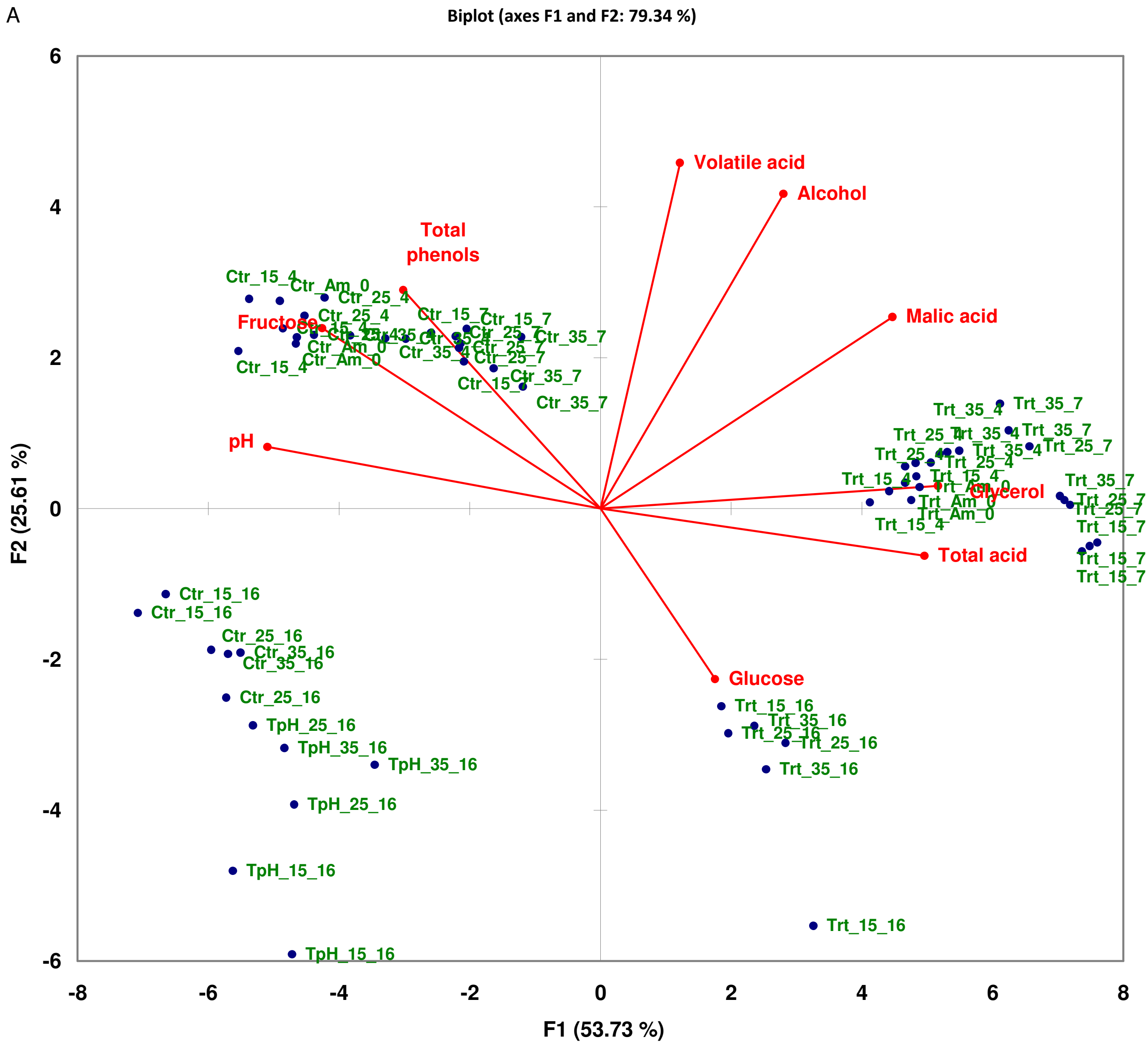


FIGURE 7
Principal component analysis (PCA) plot of the first two discriminant factors (F1, F2) for Chenin blanc wines defined by the sensory variables. Untreated or control (ctr) wine, Chenin blanc treated (trt) with resin to remove metals or decrease metal concentrations, and treated wines of which the pH was adjusted at 16 months (TpH), were stored for 16 months at different temperatures and evaluated organoleptically and chemically at regular time intervals. Abbreviations: e.g. Ctr_Am_0, control wine before storage; Trt_Am_0, treated wine before storage; Ctr_15_4, control wine stored at 15ºC for four months; Trt_35_16, treated wine stored at 35 ºC for 16 months.

A


Biplot (axes F1 and F2: 79.34 %)
F1 (53.73 %)
F2 (25.61 %)
Volatile acid
Alcohol
Total phenols
Malic acid
Fructose
pH
Glycerol
Total acid
Glucose
Ctr_15_16
Ctr_25_16
Ctr_35_16
TpH_25_16
TpH_35_16
TpH_15_16
Trt_15_16
Trt_35_16
Trt_25_16
Trt_35_7
Trt_25_7
Trt_15_7
Ctr_35_7

B

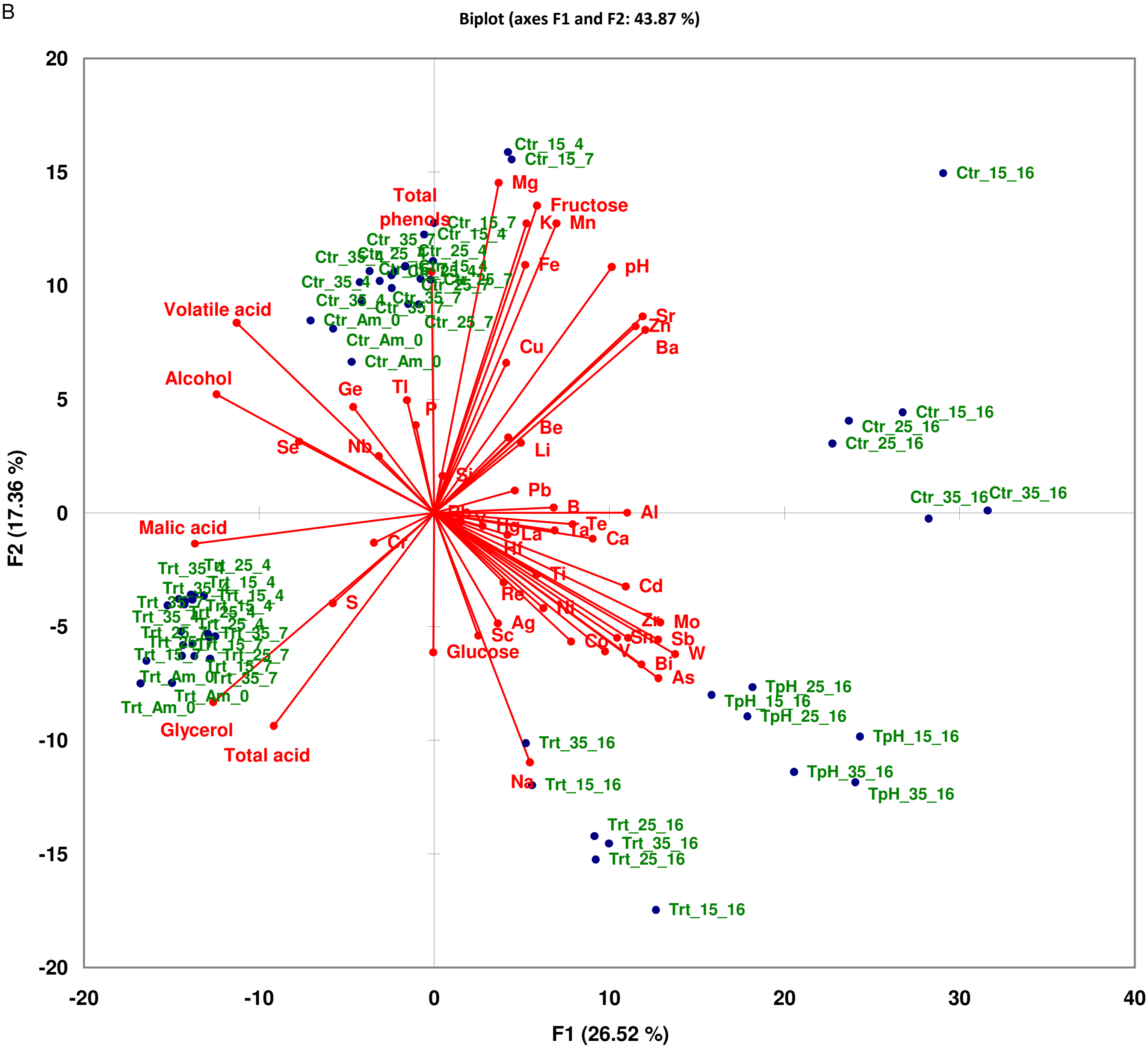


FIGURE 8

Principal component analysis (PCA) plot of the first two discriminant factors (F1, F2) for Chenin blanc wines defined by chemical variables A (without) and B (with) metals. Untreated or control (ctr) wine, Chenin blanc treated (trt) with resin to remove metals or decrease metal concentrations, and treated wines of which the pH was adjusted (TpH) at 16 months, were stored for 16 months at different temperatures and evaluated organoleptically and chemically at regular time intervals. Abbreviations: e.g. Ctr_Am_0, control wine before storage; Trt_Am_0, treated wine before storage; Ctr_15_4, control wine stored at 15ºC for four months; Trt_35_16, treated wine stored at 35 ºC for 16 months.

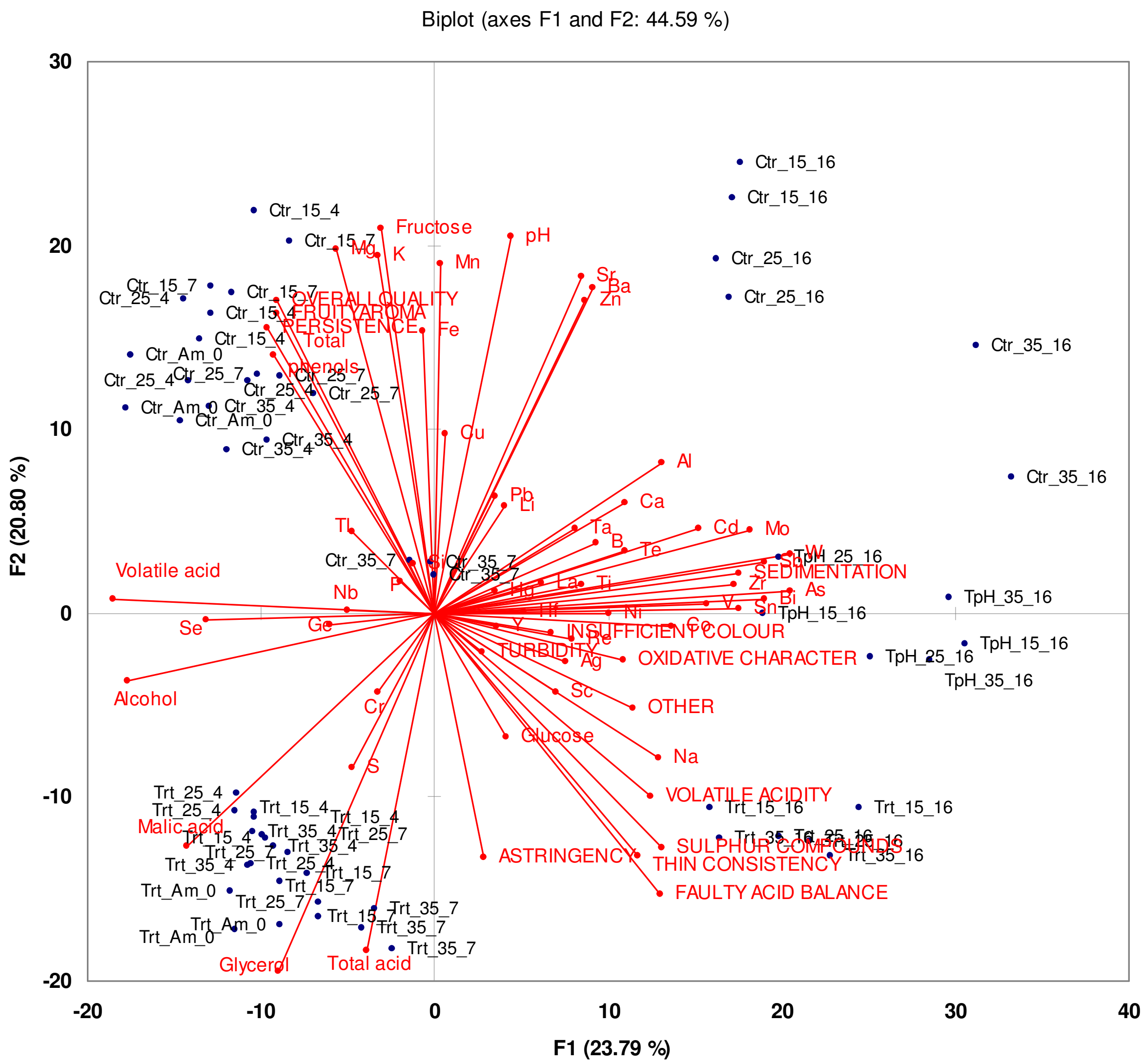


FIGURE 9
Principal component analysis (PCA) plot of the first two discriminant factors (F1, F2) for Chenin blanc wines defined by sensory and chemical variables. Untreated or control (ctr) wine, Chenin blanc treated (trt) with resin to remove metals or decrease metal concentrations, and treated wines of which the pH was adjusted (TpH) at 16 months, were stored for 16 months at different temperatures and evaluated organoleptically and chemically at regular time intervals. Abbreviations: e.g. Ctr_Am_0, control wine before storage; Trt_Am_0, treated wine before storage; Ctr_15_4, control wine stored at 15ºC for four months; Trt_35_16, treated wine stored at 35 ºC for 16 months.

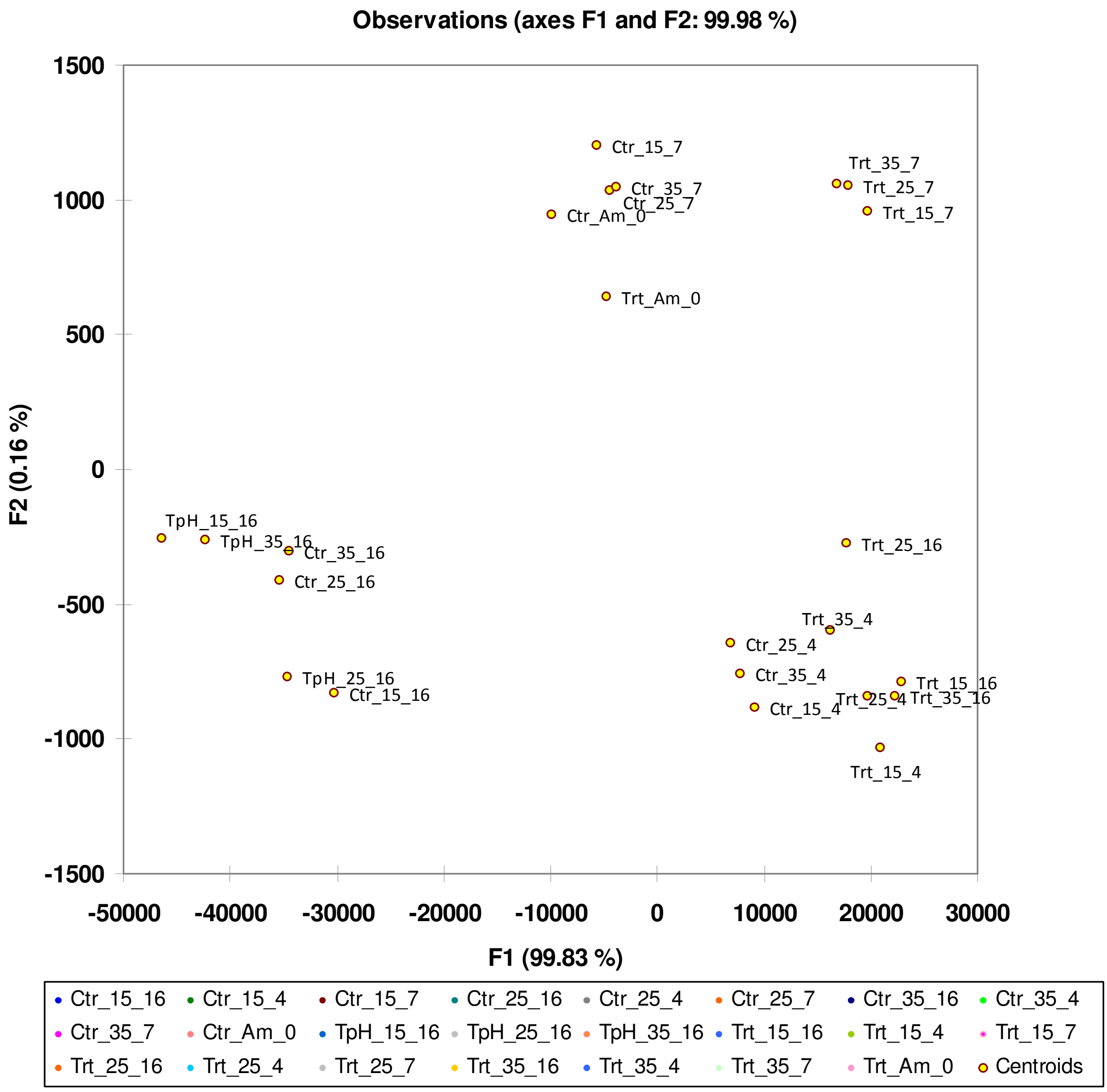


FIGURE 10.
Plot of discriminant scores of the first two discriminant factors (F1, F2) of Chenin blanc wine aged for 16 months in glass bottles for the treatment classes Ctr_Am_0, Trt_Am_0, Ctr_15_4, Ctr_25_4, Ctr_35_4, Ctr_15_7, Ctr_25_7, Ctr_35_7, Ctr_15_16, Ctr_25_16, Ctr_35_16, Trt_15_7, Trt_25_7, Trt_35_7, Trt_15_16, Trt_25_16, Trt_35_16, TpH_15_16, TpH_25_16, TpH_35_16, defined by turbidity, sedimentation, insufficient colour, sulphur compounds, volatile acidity, faulty acid balance, oxidative character, astringency, thin consistency, other, fruity aroma, persistence, overall quality, Ag, Al, As, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ge, Hf, Hg, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, S, Re, Sb, Sn, Sc, Se, Si, Sr, Te, Ta, Ti, Tl, V, Y, Zr, Zn, W, total phenols, pH, volatile acid, total acid, malic acid, glucose, fructose, alcohol and glycerol. Abbreviations: e.g. Ctr_Am_0, untreated control wine stored at ambient temperature and unmatured; Ctr_15_4, untreated control wine stored at 15ºC for 4 months; Trt_35_7, treated wine from which metals were removed stored at 35ºC for 7 months; TpH_35_16, pH adjusted treated wines stored at 35ºC for 16 months in glass bottles.

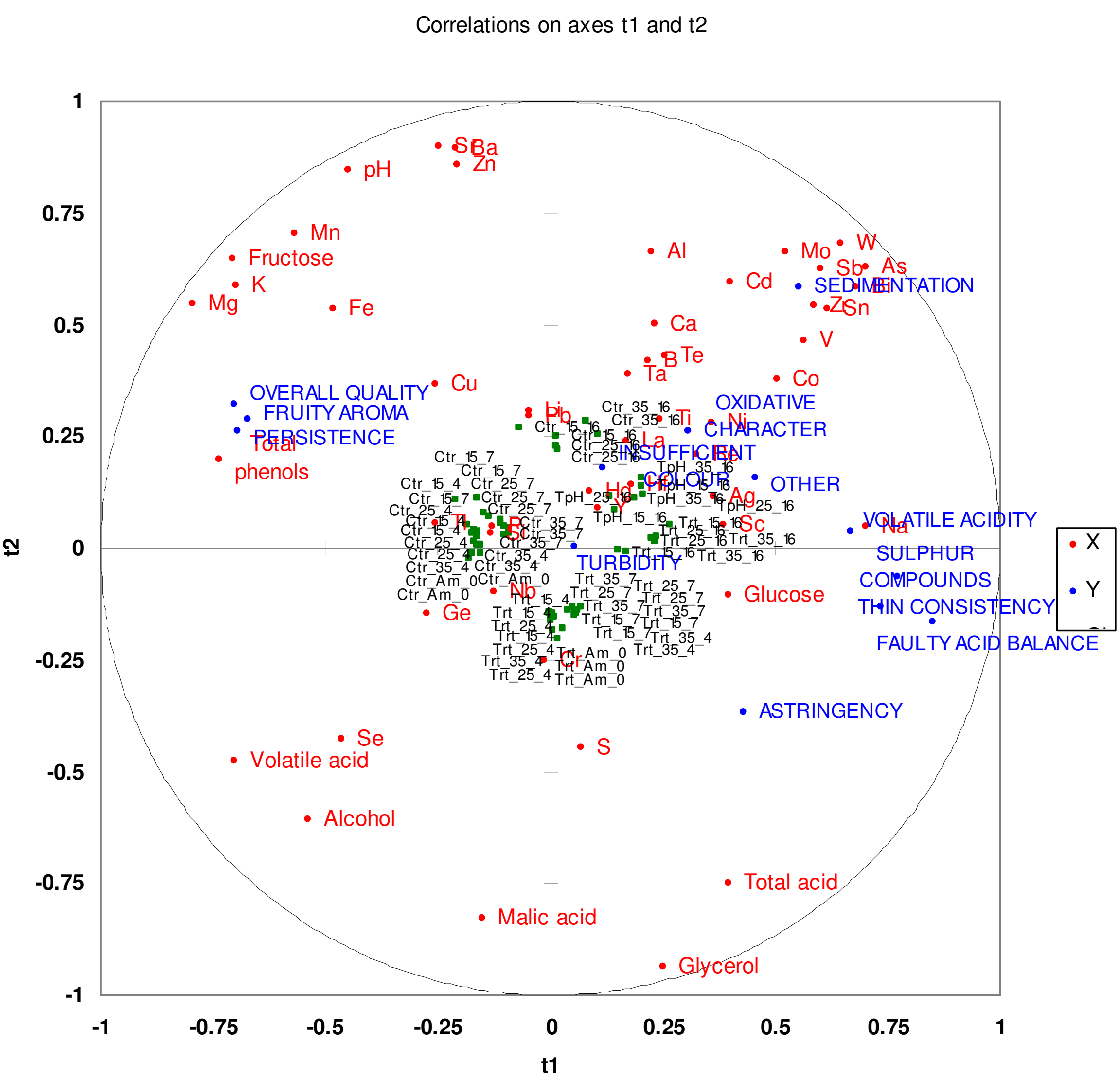


FIGURE 11
Partial Least Square Analysis of sensory and chemical parameters obtained for untreated or control (ctr) wine, Chenin blanc treated (trt) with resin to remove metals or decrease metal concentrations, and treated wines of which the pH was adjusted (TpH) at 16 months, were stored for 16 months at different temperatures and evaluated organoleptically and chemically at regular time intervals. Abbreviations: e.g. TpH_35_16, treated and pH adjusted wine, stored at 35ºC for 16 months.

Conclusions

The study aimed at investigating the role of metals on the shelf-life of white wine. Untreated or control, and treated wines from which metals were removed, were stored at different temperatures and evaluated chemically and organoleptically at different periods of ageing up to 16 months. Although resin treatment to remove metals from wine impacted on the wine organoleptically and chemically, treated wines from which metals were removed showed improved shelf-life potential compared to untreated wines, particularly under accelerated conditions at higher storage temperatures. In addition to treatment, storage temperature and time of bottle ageing also impacted on the quality and shelf-life of white wine. Future investigations should investigate other metal-chelating resins or methods for the removal or reduction of metals in wine in order to improve the shelf-life of the wine.

5. Accumulated outputs

List ALL the outputs from the start of the project.
The year of each output must also be indicated.

Technology development, products and patents

Indicate the commercial potential of this project (intellectual property rights or a commercial product(s)).

Optimisation of the protocol for the use of chelating resins in white wine, i.e. exploration or determination of optimal metal-chelating capacities / dose-dependence, efficiencies and selectivity's of commercial resins for optimisation purposes.

Human resources development/training

Indicate the number and level (e.g. MSc, PhD, post doc) of students/support personnel that were trained as well as their cost to industry through this project. Add in more lines if necessary.

By request from the Department of Viticulture and Oenology, Stellenbosch University, arrangements were made for Ms Florie Bedouet, a French student in Oenology, to do her practical work at Nietvoorbij as part of her internship. The Department of Viticulture and Oenology, Stellenbosch University, has an exchange program with ESA (Ecole Supérieure d'Agriculture) in Angers, France. Her internship was for three months from August to November 2009. All costs involved regarding her accommodation and practical work was the responsibility of the Department of Viticulture and Oenology and the student. Ms Bedouet assisted in this (WW 08/30) and other current projects in the Post-harvest & Wine Technology Division.

	Student level (BSc, MSc, PhD, Post doc)	Cost to project (R)
1.		
2.		
3.		
4.		
5.		

Publications (popular, press releases, semi-scientific, scientific)

Van Jaarsveld, F. (2010). Die belangrike rol van metaalspesiasie, chemiese en fisiese eienskappe in wyn en ander alkoholiese dranke. Wineland / Wynland (incorporating Wynboer), March 2010 edition, 83-84. **Popular publication**

Van Jaarsveld F. (2010). Metal speciation, chemical and physical properties – importance in wine and other alcoholic beverages. Wynboer Technical Yearbook 2010, 31-32. **Technical scientific report**

van Jaarsveld, F. & Jolly, N. (2011). Metale in wyn en ander alkoholiese drankies (Deel 1): 'n bondige oorsig oor die oorsprong daarvan. Wynland / Wineland Magazine (incorporating Wynboer), March 2011 edition, 72-73. **Popular publication**

van Jaarsveld, F. (2011). Metale in wyn en ander alkoholiese drankies, en die uitwerking daarvan op die mens (Deel 2): toksikologie en konsentrasieperke. Wynland / Wineland Magazine (incorporating Wynboer), April 2011 edition, 81 **Popular publication**

van Jaarsveld, F.P. (2011) Die rol van metale in wyn (Deel 3): 'n Bondige oorsig. Wineland, May 2011 edition, 82-83. **Popular publication**

<u>Presentations/papers delivered</u>

At the 2011/12 SASEV congress upon completion of project and final reporting.

4. Total cost summary of project

	Year	CFPA	Deciduous	DFTS	Winetech	THRIP	Other	TOTAL
Total cost in real terms for year 1	2009/10				86118		89632	175750
Total cost in real terms for year 2	2010/11				92849		96638	189487
Total cost in real terms for year 3	2011/12*				48825		50818	99642
Total cost in real terms for year 4								
Total cost in real terms for year 5								
TOTAL					**227792**		**237088**	**464879**