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# Sensory and chemical characteristics of wines from the variety 'Grüner Veltliner' in connection with the *sur lie* method

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*The influence of ageing on lees on the chemical composition as well as on sensory properties of 'Grüner Veltliner' wine was monitored over a period of five months. Two commercially available yeast strains, Oenoferm Veltliner and Lalvin EC 1118, were applied for vinification and ageing on lees. Products were compared after six weeks and five months. Both the sensory attributes and the composition of the wines changed positively during this period. The total amount of free amino acids in the wine correlated with the time of ageing on lees. The content of higher alcohols formed during the alcoholic fermentation was different for the two yeasts and slightly changed during ageing. The sensory quality of the wines gained in body, harmony and overall impression as a consequence of yeast contact. Contact time with lees and the yeast used are important factors for the observed changes. The experiments revealed that ageing on lees is a process which allows obtaining 'Grüner Veltliner' wines of a new agreeable type.*
**Keywords:** wine, sur lie, amino acids, higher alcohols, sensory analysis

***Sensorische und analytische Eigenschaften von*** sur lie ***ausgebauten Weinen der Sorte 'Grüner Veltliner'.*** *Der Einfluss eines* sur lie-*Ausbaus auf die analytischen und sensorischen Eigenschaften von Weinen der Sorte 'Grüner Veltliner' wurde über einen Zeitraum von fünf Monaten beobachtet. Zwei handelsübliche Hefestämme, Oenoferm Veltliner and Lalvin EC 1118, wurden für Vinifizierung und* sur lie-*Ausbau verwendet. Die resultierenden Produkte wurden nach sechs Wochen und auch nach fünf Monaten miteinander verglichen. Sowohl die sensorischen Eigenschaften wie auch die chemische Zusammensetzung der Weine haben sich in diesem Zeitraum positiv verändert. Der Gesamtgehalt an freien Aminosäuren korrelierte mit der Dauer der* sur lie-*Lagerung. Die Gehalte an höheren Alkoholen, die während der alkoholischen Gärung gebildet wurden, variierten für die zwei Hefen und veränderten sich leicht während der Lagerung. Als Folge des Hefekontakts nahm die sensorische Qualität vor allem bei den Parametern Körper, Harmonie und Gesamteindruck zu. Die Hefekontaktzeit und auch die verwendete Hefe sind wichtige Faktoren für die beobachteten Veränderungen. Die Untersuchung hat gezeigt, dass eine* sur lie-*Lagerung die Produktion eines neuen ansprechenden Veltliner-Typs ermöglicht.*
**Schlagwörter:** Wein, *sur lie*, Aminosäuren, höhere Alkohole, sensorische Analyse

***Les caractéristiques sensorielles et analytiques des vins du cépage 'Grüner Veltliner', élevés*** sur lie. *L'influence de l'élevage* sur lie *sur les caractéristiques analytiques et sensorielles des vins du cépage 'Grüner Veltliner' a été observée sur une période de cinq mois. Deux souches de lies en vente dans le commerce, Oenoferm Veltliner et Lalvin EC 1118, ont été utilisées pour la vinification et pour l'élevage* sur lie. *Les produits qui en ont résulté ont été comparés au bout de six semaines ainsi qu'après cinq mois. Tant les caractéristiques sensorielles que la composition chimique des vins se*

*sont modifiées de manière positive au cours de cette période. La teneur totale en acides aminés libres était en corrélation avec la durée du stockage* sur lie. *Les teneurs en alcools supérieurs, qui s'étaient formés au cours de la fermentation alcoolique, variaient pour les deux lies et se sont modifiées légèrement au cours du stockage. À la suite du contact avec les lies, la qualité sensorielle a surtout augmenté au niveau des paramètres corps, harmonie et impression générale. Le temps de contact avec les lies ainsi que les lies utilisées sont des facteurs importants pour les modifications observées. L'étude a montré que le stockage sur lie permet la production d'un nouveau type intéressant de Veltliner.*
**Mots clés :** vin, *sur lie,* acides aminés, alcools supérieurs, analyse sensorielle

The so-called *sur lie* method is a vinification technique more frequently used in France, the United States, Japan and Australia. In Austria, the ageing on lees is not so often applied, and there are no published studies in this respect on 'Grüner Veltliner' wines.
Yeast autolysis during the contact of wines with lees is an important part in the formation of flavour and body of the famous Champagne and sparkling wines (Feuillat and Charpentier, 1982; Herraiz et al., 1993; Leroy et al., 1990). Different yeast strains have varying tendencies to autolyse. In wines, two types of lees can be distinguished: a) heavy lees made up of particles that settle within 24 hours, when the pectin is degraded and b) light lees which remain suspended 24 hours after the wine has been moved (Delteil, 2002). Ageing on lees results in different properties of the products: wines gain more complexity, more body and a better stability due to mannoproteins, fatty acids, amino acids, esters and higher alcohols (Fornairon-Bonnefond et al., 2002; Martinez-Rodriguez and Polo, 2000; Perez-Serradilla et al., 2008). On the other hand, ageing on lees may disadvantageously lead to the development of sulphur compounds, which are associated with a reductive off-flavour. The yeast lees possess a sulphite reducing effect, which can lead to the formation of $H_2S$ (Karagiannis and Lanaridis, 1999). Malolactic fermentation can also occur, thereby reducing total acidity and, if not sufficiently monitored, it can increase the volatile acidity as well as other flaws.
Usually, the ageing process is long lasting and causes increased production costs. However, with the use of enzymes the contact time with lees can be reduced. The yeast cell wall possesses a complex structure that accounts for 15 to 25 % of the dry weight of the cell. The mechanical strength of the wall is mainly due to the inner layer, which consists of ß-1,3-glucans and chitin (Klis et al., 2002). Enzyme preparations possessing ß-glucanase activities can be used to decompose the cell wall. Such enzyme preparations are complex mixtures of natural origin usually derived from fungi and display various enzymatic activities.
The purpose of this study was to investigate the effect of applying the *sur lie* method to the production of 'Grüner Veltliner' wines. Besides chemical parameters, sensory attributes of this product were examined, in comparison with the control wine.

## Materials und methods

### Wine samples

'Grüner Veltliner' (2007 vintage), a typical Austrian white wine, was used in this study. The must was inoculated with two yeast strains, *Saccharomyces bayanus* Lalvin EC 1118 (Lallemand, Madrid, Spain) and *Saccharomyces cerevisiae* Oenoferm Veltliner (Erbslöh, Geisenheim, Germany); dosage 20 g/hl. The yeasts were rehydrated according to manufacturer's instructions.
After fermentation, the wines produced with the two yeasts were divided into 34 l glass carboys with a controlled amount of lees. Triplicate samples were stored on lees without sulfur dioxide addition for 6 weeks and 5 months. The control wine was filtered, sulfited and also stored in 34 l glass carboys. After the desired yeast contact time wines were prepared for analysis: they were racked, sulfited, filtered and bottled.

### Wine composition

The basic wine composition was analysed by means of Fourier Transformed Infrared Spectroscopy (Foss WineScan FT 120, Foss Electric, Denmark).

### Amino acid analysis

Quantification of free amino acids was performed using ultra-performance liquid chromatography (Acquity™ UPLC™) involving pre-column derivatization and reversed-phase separation according to AccQ-Tag™ method. A tunable ultraviolet detector set at 254 nm and the software package "Empower 2 Chromatography" were used; all instruments were from Waters (Milford, MA, USA). Pre-column with 6-aminoquinolyl-N-Hydroxysucccinimidyl carbamate (AQC) derivatization of primary and secondary amino groups was made according to Waters AccQ. Fluor™ protocol. The quantification was performed on the basis of a seven-point calibration, using in-house prepared standards containing 24 amino acids (Pierce, Rockford, IL, USA and Sigma-Aldrich, St. Louis, MI, USA) ranging from 2 to 64 pmol/injection. α-Amino butyric acid (Fluka, Buchs, Switzerland) was used as an internal standard, added in an equal amount (16 pmol/injection) during derivatization.

## Preparation of wine samples

Homogenized aliquots (10 ml) of wine samples were mixed with 0.5 g of polyvinylpolypyrrolidone (Sigma-Aldrich, St. Louis, MI, USA) and stirred for 10 min at room temperature. Samples were then centrifuged for 10 min at 4 °C and 1400 g. For further clarification, supernatant aliquots were collected and again centrifuged for 10 min at 4 °C and 1600 g. To meet the calibration range, clear wine samples were diluted in 50 mM boric acid buffer, pH 9.0 (Roth, Karlsruhe, Germany) depending on their original free amino acid concentration (corresponding to a dilution 1:5 to 7.5). Diluted and pH-adjusted samples were combined with the internal standard solution, derivatized and subsequently filtered through a 0.22 µm RC-membrane filter unit (Sartorius, Goettingen, Germany) prior to injection.
The following amino acids were determined in each wine sample: aspartic acid, serine, asparagine, glutamic acid, gycine, histidine, glutamine, arginine, threonine, alanine, proline, γ-aminobutyric acid, cysteine, tyrosine, valine, methionine, ornithine, lysine, isoleucine, leucine, phenylalanine, tryptophan.

## Higher alcohols, methanol and ethyl acetate

Higher alcohols were analysed by means of gas liquid chromatography. The equipment used was a Gaschromatograph 5890 II, (Hewlett-Packard, Vienna, Austria) equipped with an FID-Detector, Automatic sampler HP, Injector and Controller 7673, data management system HP Chem Station, column: DB-WAX 60 m, 0,32 ID, 0,25 µm film , carrier gas: He 5.0, FID detector gases: hydrogen ($H_2$: Qual.min. 5.0) and compressed air. Reagents: tetrahydrofuran p.A. (Merck, Darmstadt, Germany), ethanol CHROMASOLV min. 99.8 % (Riedel de Haën 1170, ethyl acetate LiCrosolv, methanol CHROMASOLV, (RdH 34860), butanol-2 (d:0,81), p.A, propanol-1 p.A., i-butanol p.A., butanol-1 p.A., i-pentanol (RdH 32206), hexanol-1 p.A. (RdH 804393). All reagents were of pure grade and of chromatographic purity.
Chromatographic conditions: column head pressure: 10 psi constant, injected volume 1 µl, split rate 1:30, injector temperature 245 °C, detector-temperature 250 °C.

## Sample preparation

Higher alcohols were separated by distillation of 100 ml wine, 80 ml of the distillate were collected and made up to 100 ml with distilled water. Tetrahydrofuran was added to the distillate as an internal standard before gas chromatographic analysis. The calibration was performed with the corresponding standard solutions in ethanol 10 % (v/v) and treated in the same manner as the wine samples. The following compounds were determined in each sample: ethyl acetate, methanol, 1-propanol, isobutanol, isopentanol.

## Statistical analysis

Univariate analysis of variance (ANOVA) using the SPSS (15.0.1) programme was applied to examine significant differences between different lees contact durations and related to wines produced with the two yeasts. Significant level was $p < 0.05$. The Post Hoc test was used to evaluate the significance of the analysis between wines with different contact time.

## Sensory evaluation

The sensory analysis was performed by a panel of 10 expert wine tasters. The descriptors were chosen to put into evidence the particularities of the variety 'Grüner Veltliner' and the changes produced during the maturation on lees. The panelists noted the intensity of each descriptor on a scale from 0 for low or no intensity to 10 for high intensity. The mean values for each descriptor were used to obtain a profile of the experimental wines.

# Results and discussion

## Changes in the general wine composition

At the end of the alcoholic fermentation with the two

selected yeasts, the wines showed a similar general composition and the changes of these parameters during the ageing on lees were also similar (Tables 1, 2).
The ethanol content displayed a very slight decrease, for which we can take into account esterification as well as the influence of weekly stirring. The changes in total acidity, volatile acidity, pH and malic acid are a consequence of correct malolactic fermentation.
Malolactic fermentation was practically finished after five months on lees. It is well known that the autolysis of yeasts creates improved conditions for the development of lactic bacteria and that the lack of sulfitation and the autolysis of yeasts may support the development of lactic bacteria. The increase of tartaric acid during the contact time with lees is a result of the increased pH due to malolactic fermentation and also enhances the solubility of the small potassium hydrogen tartrate crystals present in the lees.

Table 1: General composition of 'Grüner Veltliner' wine fermented with the yeast Oenoferm Veltliner during ageing on lees

| | Control wine | 6 weeks lees contact | 5 months lees contact |
|---|---|---|---|
| Ethanol % v/v | 13.03 | 12.90 ± 0.10 | 12.83 ± 0.05 |
| Sugar g/l | 1.16 | 1.43 ± 0.11 | 1.50 ± 0.10 |
| Acidity g/l | 5.06 | 5.10 ± 0.00 | 4.46 ± 0.05 |
| pH | 3.50 | 3.50 ± 0.00 | 3.60 ± 0.00 |
| Volatile acidity g/l | 0.13 | 0.20 ± 0.00 | 0.30 ± 0.00 |
| Tartaric acid g/l | 2.06 | 2.13 ± 0.05 | 2.40 ± 0.17 |
| Malic acid g/l | 1.43 | 1.50 ± 0.00 | 0.20 ± 0.00 |
| Glycerol g/l | 6.13 | 6.20 ± 0.10 | 6.33 ± 0.11 |

Table 2: General composition of 'Grüner Veltliner' wine fermented with the yeast EC 1118 during ageing on lees

| | Control wine | 6 weeks lees contact | 5 months lees contact |
|---|---|---|---|
| Ethanol % v/v | 13.00 | 12.93 ± 0.05 | 12.86 ± 0.05 |
| Sugar g/l | 0.96 | 0.96 ± 0.05 | 1.20 ± 0.10 |
| Acidity g/l | 5.06 | 4.93 ± 0.05 | 4.46 ± 0.05 |
| pH | 3.43 | 3.50 ± 0.00 | 3.60 ± 0.00 |
| Volatile acidity g/l | 0.10 | 0.16 ± 0.05 | 0.26 ± 0.05 |
| Tartaric acid g/l | 2.10 | 2.13 ± 0.05 | 2.46 ± 0.05 |
| Malic acid g/l | 1.40 | 1.16 ± 0.05 | 0.20 ± 0.00 |
| Glycerol g/l | 5.93 | 5.96 ± 0.05 | 6.06 ± 0.05 |

## Changes in amino acids composition

The most important changes during ageing on lees were noticed in relation to the concentration of amino acids. Figure 1 shows the total concentration of free amino acids at different stages of ageing in the wine produced with the yeast Oenoferm Veltliner, in comparison with the wine produced with the yeast EC 1118. Proline levels were not included in the total amount of amino acids represented in the Figure 1, but considered in the results listed in Table 3 and Table 4.
At the end of fermentation, the wine produced with Oenoferm Veltliner had higher amounts of free amino acids (167 mg/l) compared to the wine produced with the yeast EC 1118 (97 mg/l). This indicates either a lower rate of nitrogen uptake by the yeast Oenoferm Veltliner or advanced cell death and autolysis phenomenon. Alternatively, exsorption from still living cells could also be a reason.
The concentration of total free amino acids increased generally for both yeasts during maturation, whereas the development was faster during the first six weeks of ageing on lees and subsequently declined. The augmentation of amino acids was lower for Oenoferm Veltliner (increase by 30 %, leading to a total content of 225 mg/l) and higher for the yeast EC 1118 (increase by 70 %, leading to a total content of 195 mg/l).
After five months of ageing on lees, the increase of free amino acids was similar for the two yeasts applied, 37 % for Oenoferm Veltliner leading to a total content of 307 mg/l and 46 % for EC 1118 leading to a total concentration of 266 mg/l.
The levels of the individual free amino acids in wines

produced with yeast Oenoferm Veltliner and EC 1118 after six weeks and after five months of storage on lees are listed in Tables 3 and 4. Only proline, which is the most abundant amino acid in wine, showed almost no variation, as it cannot be utilized as a source of nitrogen assimilation (Flanzy, 1998). It is evident from our observations that for the yeast Oenoferm Veltliner the amino acids aspartic acid, asparagine, arginine, threonine, alanine, methionine, lysine, isoleucine, leucine and phenylalanine increased by more than 200 % during contact with yeast. This could also be observed with yeast EC 1118 regarding all amino acids, except for serine, glutamic acid and gamma-aminobutyric acid.

During the ageing on lees the increase of amino acid concentrations was different for the two yeasts used. Gamma-amino butyric acid was the only amino acid that did not significantly differ between the two yeasts applied ($p < 0.05$).

Our findings are in contrast to those of Martinez-Rodriguez et al. (2001) who reported that the histidine concentration was not significantly influenced by the ageing factor and the methionine content and different yeasts did not lead to different asparagine levels. Other authors (Arizumi et al., 1994; Sato et al., 1997) also observed that aspartic acid, threonine, methionine, isoleucine, tyrosine, phenylalanine, histidine, and lysine at least double in wines from the Koshu region during storage of four months.

## Higher alcohols evolution

It is well-known that higher alcohols containing more than 3 carbon atoms in their molecule may contribute to the typical flavour of wine (Bautista et al., 2007, Bueno et al., 2006, Riu-Aumatell et al., 2006). However, to avoid the development of unpleasant off-flavour, their content should not exceed 300 mg/l. Yeast autolysis exerts a strong effect on the concentration of higher alcohols. Propanol, isobutanol and isoamyl alcohols can be detected in yeast extracts from wine under biological ageing (Muñoz et al., 2002).

At the end of the alcoholic fermentation the wine fermented with Oenoferm Veltliner had lower amounts of hexanol, propanol and isobutanol compared with the wine fermented with EC 1118 (Tables 5, 6). The concentrations of 1-hexanol, 1-propanol, ethyl acetate, isobutanol and methanol were very similar during the ageing on lees for the wines fermented with Oenoferm Veltliner and EC 1118. This is in agreement with the findings of Bautista et al. (2007).

The concentration of isopentanol increased after six weeks of lees contact, followed by a slight decrease during the following period. 1-Butanol, 2-butanol, benzaldehyde and ethyl lactate levels were not detectable in the wines produced with the two yeasts.

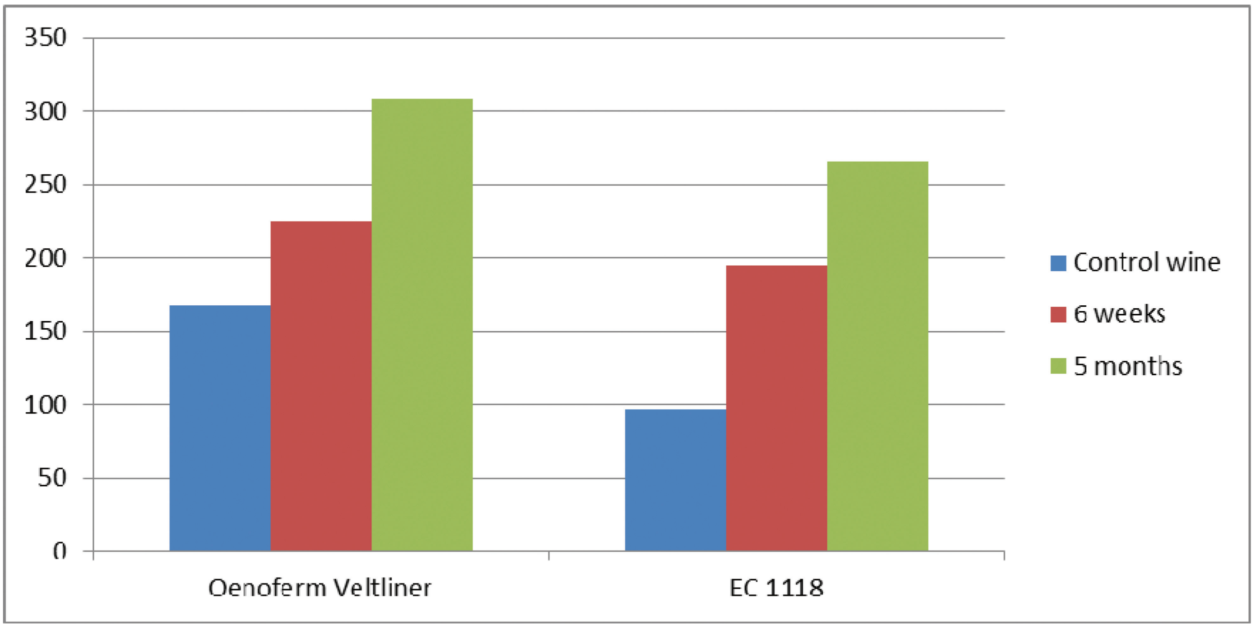


Fig. 1: Total amino acid concentrations (mg/l) in Grüner Veltliner wines produced with yeast Oenoferm Veltliner and yeast EC 1118 at different stages of ageing on lees

Table 3: Amino acid concentrations (mg/l) in 'Grüner Veltliner' wine fermented with yeast Oenoferm Veltliner at different stages of maturation on lees

| Amino acids | Control wine | 6 weeks lees contact | 5 months lees contact |
|---|---|---|---|
| Aspartic acid | 11.7 | 15.59 ± 0.18 | 21.47 ± 0.12 |
| Serine | 6.03 | 7.16 ± 0.45 | 9.92 ± 0.08 |
| Asparagine | 5.63 | 7.02 ± 0.08 | 10.38 ± 0.33 |
| Glutamic acid | 27.73 | 32.01 ± 0.56 | 39.41 ± 0.14 |
| Glycine | 6.06 | 6.99 ± 0.08 | 8.87 ± 0.05 |
| Histidine | 7.43 | 9.63 ± 0.07 | 12.34 ± 0.04 |
| Glutamine | 1.92 | 2.89 ± 0.19 | 3.68 ± 0.10 |
| Arginine | 14.56 | 23.40 ± 0.33 | 32.39 ± 0.45 |
| Threonine | 3.54 | 4.56 ± 0.15 | 6.78 ± 0.06 |
| Alanine | 14.69 | 17.48 ± 0.37 | 21.86 ± 0.31 |
| Proline | 466.56 | 460.86 ± 6.57 | 481.99 ± 5.58 |
| □ Aminobutyric acid | 5.62 | 6.04 ± 0.29 | 6.57 ± 0.12 |
| Cysteine | 1.14 | 1.50 ± 0.02 | 1.91 ± 0.13 |
| Tyrosine | 9.52 | 11.79 ± 0.12 | 16.54 ± 0.25 |
| Valine | 4.45 | 6.79 ± 0.17 | 10.11 ± 0.18 |
| Methionine | 3.30 | 4.79 ± 0.08 | 7.16 ± 0.09 |
| Ornithine | 1.03 | 0.87 ± 0.01 | 2.06 ± 0.04 |
| Lysine | 17.16 | 26.97 ± 0.32 | 39.53 ± 0.30 |
| Isoleucine | 2.84 | 4.53 ± 0.13 | 6.72 ± 0.25 |
| Leucine | 13.71 | 21.10 ± 0.64 | 29.79 ± 0.35 |
| Phenylalanine | 8.48 | 12.49 ± 0.18 | 18.37 ± 0.39 |
| Tryptophan | 1.03 | 1.58 ± 0.06 | 1.88 ± 0.07 |

Table 4: Amino acid concentration (mg/l) in 'Grüner Veltliner' wine fermented with yeast EC 1118 at different stages of maturation on lees

| Amino acids | Control wine | 6 weeks lees contact | 5 months lees contact |
|---|---|---|---|
| Aspartic acid | 6.28 | 12.92 ± 0.66 | 18.61 ± 0.85 |
| Serine | 4.08 | 6.64 ± 0.62 | 8.77 ± 0.64 |
| Asparagine | 3.18 | 6.31 ± 0.56 | 9.29 ± 0.53 |
| Glutamic acid | 20.34 | 29.01 ± 0.45 | 36.55 ± 0.86 |
| Glycine | 3.72 | 6.10 ± 0.32 | 7.86 ± 0.52 |
| Histidine | 5.23 | 8.71 ± 0.18 | 11.17 ± 0.09 |
| Glutamine | 1.38 | 2.36 ± 0.17 | 3.19 ± 0.06 |
| Arginine | 6.85 | 18.98 ± 0.97 | 22.33 ± 2.90 |
| Threonine | 2.07 | 4.14 ± 0.10 | 6.13 ± 0.31 |
| Alanine | 9.73 | 16.05 ± 0.81 | 20.14 ± 1.00 |
| Proline | 448.66 | 446.47 ± 19.64 | 452.61 ± 13.26 |
| □ Aminobutyric acid | 4.14 | 7.30 ± 0.26 | 7.72 ± 0.37 |
| Cysteine | 0.83 | 1.30 ± 0.08 | 1.55 ± 0.02 |
| Tyrosine | 5.64 | 10.40 ± 0.59 | 14.31 ± 0.27 |
| Valine | 2.11 | 5.53 ± 0.13 | 8.40 ± 0.34 |
| Methionine | 1.55 | 3.96 ± 0.16 | 6.02 ± 0.11 |
| Ornithine | 0.45 | 0.67 ± 0.06 | 2.51 ± 0.15 |
| Lysine | 7.40 | 22.38 ± 0.98 | 33.92 ± 1.24 |
| Isoleucine | 1.18 | 3.47 ± 0.14 | 5.71 ± 0.43 |
| Leucine | 5.68 | 16.66 ± 1.24 | 24.77 ± 1.33 |
| Phenylalanine | 4.63 | 10.40 ± 0.52 | 15.52 ± 0.49 |
| Tryptophan | 0.67 | 1.50 ± 0.09 | 1.70 ± 0.09 |

Table 5: Concentrations (mg/l) of higher alcohols, methanol, ethyl acetate and ethyl lactate in 'Grüner Veltliner' wine fermented with yeast Oenoferm Veltliner at different stages of maturation

| | Control wine | 6 weeks lees contact | 5 months lees contact |
|---|---|---|---|
| 1-Butanol | n.d. | n.d. | n.d. |
| 1-Hexanol | 1.73 | 1.73 ± 0.05 | 1.66 ± 0.05 |
| 1-Propanol | 36.50 | 37.16 ± 0.49 | 35.36 ± 0.28 |
| 2-Butanol | n.d. | n.d. | n.d. |
| Benzaldehyde | n.d. | n.d. | n.d. |
| Ethyl acetate | 38.00 | 41.30 ± 0.40 | 39.76 ± 0.65 |
| Ethyl lactate | n.d. | n.d. | n.d. |
| Isobutanol | 27.86 | 27.70 ± 0.34 | 26.56 ± 0.30 |
| Isopentanol | 150.40 | 162.30 ± 1.90 | 152.90 ± 1.89 |
| Methanol | 40.93 | 42.70 ± 0.70 | 40.56 ± 0.30 |

n.d.: not detectable

Table 6: Concentrations (mg/l) of higher alcohols, methanol, ethyl acetate and ethyl lactate in 'Grüner Veltliner' wine fermented with yeast EC 1118 at different stages of maturation

| | Control wine | 6 weeks lees contact | 5 months lees contact |
|---|---|---|---|
| 1-Butanol | n.d. | n.d. | n.d. |
| 1-Hexanol | 1.86 | 1.86 ± 0.05 | 1.83 ± 0.05 |
| 1-Propanol | 40.16 | 40.30 ± 0.60 | 39.63 ± 0.45 |
| 2-Butanol | n.d. | n.d. | n.d. |
| Benzaldehyde | n.d. | n.d. | n.d. |
| Ethyl acetate | 39.33 | 42.10 ± 1.04 | 40.53 ± 0.15 |
| Ethyl lactate | n.d. | n.d. | n.d. |
| Isobutanol | 32.86 | 33.60 ± 0.51 | 32.33 ± 0.30 |
| Isopentanol | 140.70 | 143.33 ± 1.93 | 137.93 ± 1.36 |
| Methanol | 41.66 | 42.66 ± 0.58 | 41.06 ± 0.47 |

n.d.: not detectable

Table 7: Sensory evaluation results and analysis of variance for each attribute

| Attributes | Taster | Yeast | Time | Yeast*Time |
|---|---|---|---|---|
| Autolytic | p < 0.05 | n.s. | p < 0.05 | n.s. |
| Color | p < 0.05 | n.s. | p < 0.05 | n.s. |
| Freshness | p < 0.05 | n.s. | p < 0.05 | n.s. |
| Fruity/smell | p < 0.05 | n.s. | p < 0.05 | p < 0.05 |
| Fruity/taste | p < 0.05 | n.s. | n.s. | n.s. |
| Harmony | p < 0.05 | n.s. | p < 0.05 | n.s. |
| Body | p < 0.05 | n.s. | p < 0.05 | n.s. |
| Peppery/smell | p < 0.05 | p < 0.05 | n.s. | n.s. |
| Peppery/taste | p < 0.05 | n.s. | n.s. | n.s. |
| Sulfureous/smell | p < 0.05 | n.s. | n.s. | n.s. |
| Sulfureous/taste | p < 0.05 | n.s. | n.s. | n.s. |
| Spicy | p < 0.05 | n.s. | n.s. | n.s. |

n.s.: not significant

## Sensory analysis

The sensory evaluation revealed differences between the control wines and the wines aged on lees. Differences regarding the influence of the individual yeast strains were also noticed. The sensory data obtained from the panel was analysed with the Univariate analysis of variance (ANOVA) using SPSS programme. The results showed that the factor time displays significant differences ($p < 0.05$) for the attributes "autolytic", "colour", "freshness", "fruity smell", "harmony" and "body" (Table 7).
Figure 2 depicts the sensory profile for the wines produced with the yeast Oenoferm Veltliner. The wine matured six weeks on lees showed the highest intensities for the descriptors "fruity smell", "spicy", "fresh-

ness", "body" and "harmony". The panelists rated the wine matured six weeks on lees with the highest value for overall impression. The autolytic character was expressed fairly well after six weeks on lees, but it increased by time, being more pronounced after five months on lees. The gain in autolytic character was accompanied by an increase of colour and a loss of "freshness" and "fruitiness". The "peppery taste" was marked in all wines at the same intensity.
Figure 3 shows the sensory profile for the wines produced with the yeast EC 1118. In this case the "peppery smell" and the"fruity smell" had the highest intensities in the control wine. In all wines the panelists marked the descriptors "peppery taste" and "spicy" with the same intensity, but the intensities were slightly lower in the wine after five months of lees contact. The "freshness" was marked with the same value for the control wine and the wine after six weeks on lees. However, after five months of lees the "freshness" decreased. The descriptors "autolytic", "body" and "harmony" had the highest intensity in the wine after five months on lees. For the yeast EC 1118 the assessors did not find any difference in the overall impression between the control and the treated wine. Colour was of identical intensity in the wines matured on lees, but less pronounced in the control wine, which was early sulfited and kept in closed bowls.

## Conclusions

To our knowledge, ageing on lees of 'Grüner Veltliner' wines was investigated for the first time in this study. Results indicate that this vinification process can be successfully applied to this Austrian variety, also generating wines of a new character. The sensory properties of the wine typically change during its evolution on lees, by gaining more body, harmony and complexity. The autolysis character can be seen as a particular feature of the wines aged for longer periods on lees. During contact with lees the amount of free amino acids being valuable compounds and precursors of aromatic substances increases in the wine.
From the industrial point of view, the results presen-

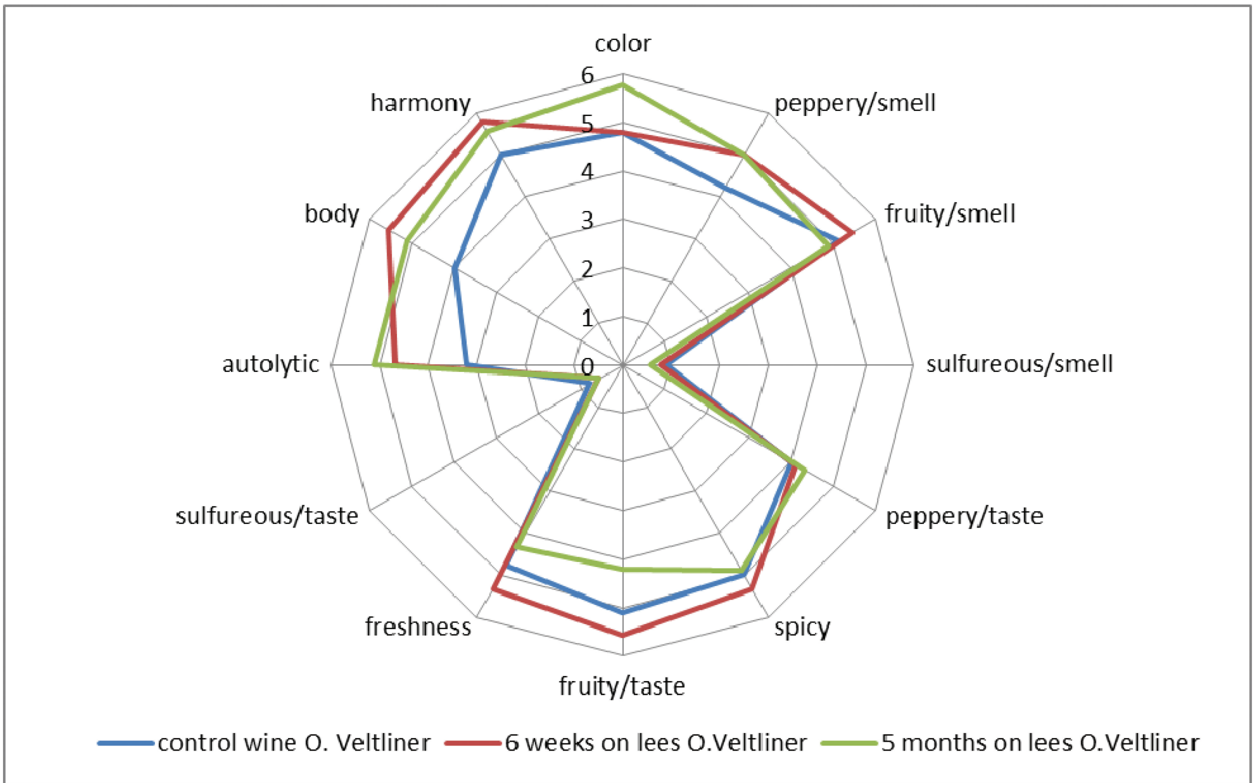


Fig. 2: Aroma profile of Grüner Veltliner wines produced with yeast Oenofem Veltliner at different stages of ageing on lees

ted may help the winemaker to select the suited yeast preparation for *sur lie* ageing of wines. It also should be pointed out that the autolysis is a long-lasting process. If ageing on lees is carried out without the addition of sulphite, malolactic fermentation is very hard to control.

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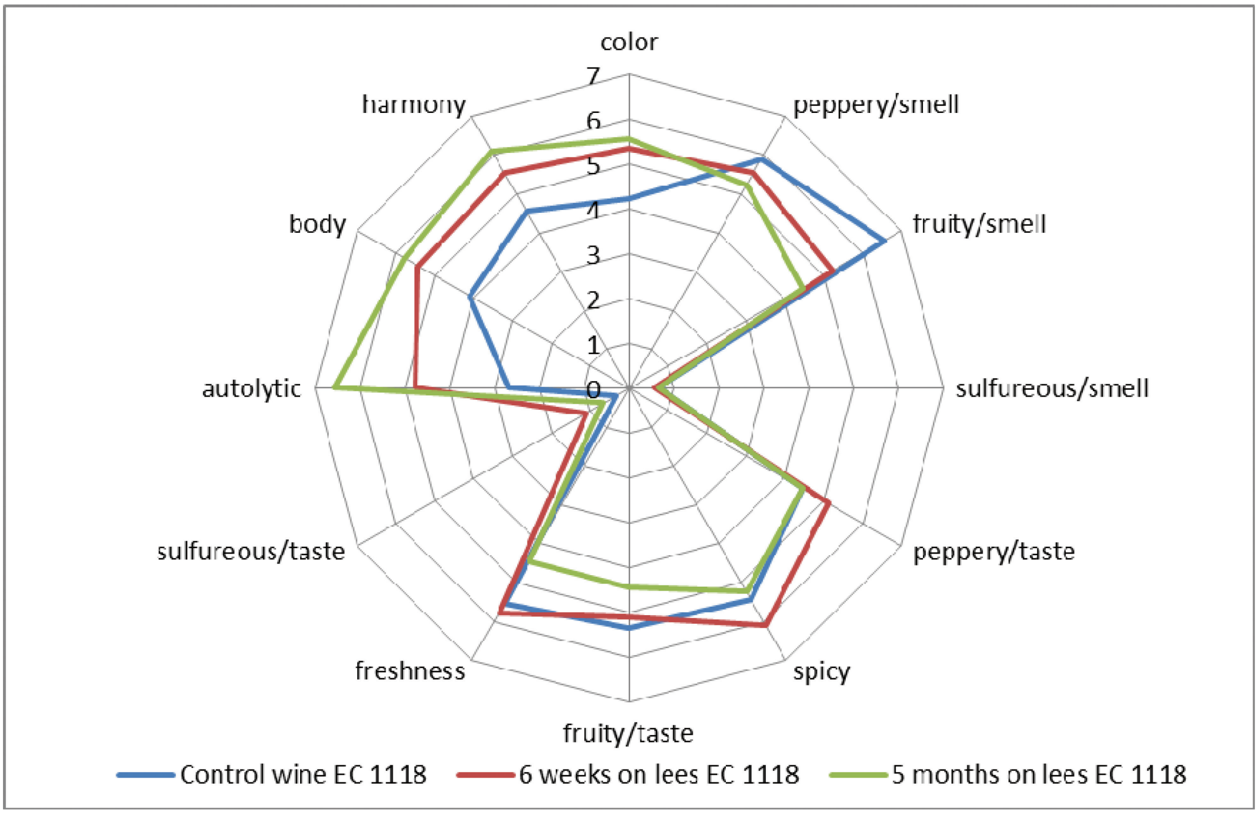


Fig. 3: Aroma profile of Grüner Veltliner wines produced with yeast EC 1118 at different stages of ageing on lees

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