OENO One
vine & wine

DOI: https://doi.org/10.20870/oeno-one.2025.59.2.8446

OPEN ACCESS

ENOLOGY ORIGINAL RESEARCH ARTICLES

Influence of grape maturity and maceration time on sensory characteristics and phenolics in Pinot noir and Cabernet-Sauvignon wines

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Article number: 8446

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Associate editor:
Victor de Freitas

Received:
19 December 2024

Accepted:
20 May 2025

Published:
24 June 2025

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ABSTRACT

Measures of grape phenolics have become important indicators to determine grape maturity, though varietal differences must be considered. The objective of this study was to determine whether maceration time can modulate the phenolic profile and sensory characteristics of wines produced from grapes of different maturities. Pinot noir and Cabernet-Sauvignon grapes were harvested at three different stages of grape maturity, in a range of 20–25 Brix, and vinified using 7-day and 14-day maceration times in experimental fermenters. Sensory evaluation and analysis of phenolic composition were carried out after bottling. The effect of maceration time was found to be different from the influence of grape maturity as shown by sensory evaluation and phenolic composition. Extended maceration neither compensated for grape immaturity nor enhanced the effects of immaturity. Changes in the phenolic composition with progressing grape maturity and extending maceration time were reflected in the wine colour as well as in taste and tactile ratings in the sensory evaluation of the wines. Skin-associated phenolics such as anthocyanins and polymeric pigments correlated with grape maturity, while extended maceration enhanced the extraction of seed-associated phenolics such as monomeric catechins, procyanidins and procyanidin gallates. The influences of grape maturity and maceration time on gallocatechins and prodelphinidins were different for Pinot noir and Cabernet-Sauvignon. The concept of "phenolic maturity" therefore requires a differentiated view on individual phenolic compounds, seed- and skin-associated phenols, and must take varietal differences into account. It is suggested that concentrations of anthocyanins and polymeric pigments are suitable indicators for grape maturity, whereas concentrations of monomeric catechins and procyanidins are good indicators for maceration time.

KEYWORDS: grape maturity, phenolics, extended maceration, sensory, tannins, anthocyanins, polymeric pigments

INTRODUCTION

Winemakers aim to adapt winemaking operations to grape maturity. Recent research suggests that the phenolic composition or individual phenolic compounds might be used as more accurate indicators to monitor grape maturity than the traditionally used total soluble solids (TSS) and titratable acidity, but also to predict the composition in wine (Feifel *et al.,* 2024; Kontoudakis *et al.,* 2010; Pérez-Magariño & González-San José, 2006). Ristic *et al.* (2010) concluded that higher concentrations of anthocyanins and skin tannins in Shiraz grape berries coupled with a lower concentration of seed tannins were associated with higher wine quality. Gil *et al.* (2015) observed that the total polysaccharide concentration in Cabernet-Sauvignon wine increased with both grape maturity and maceration time, but the effect of maceration time was more pronounced. Vidal *et al.* (2004b) showed that polysaccharides contribute the sensation of "fullness" to wine while decreasing astringency, dryness, and roughness. However, studies by del Llaudy *et al.* (2008) showed, for immature Cabernet-Sauvignon grapes, that an extended maceration produced wines that were too astringent, due to an excess of seed tannin extraction. For more mature grapes, de-pectination during ripening otherwise decreases the extractability of seed tannins into the wine while increasing the extractability of skin tannins (del Llaudy *et al.,* 2008; Garrido-Bañuelos *et al.,* 2019). An extended maceration favours the formation of polymeric pigments which contribute to colour stability and reduce the puckering sensation and astringency in wines (Vidal *et al.,* 2004a).

The effect of grape maturity on the sensory characteristics of red wines has been the focus of many studies. Sherman *et al.* (2017) harvested Merlot grapes at three different harvest dates with TSS in the range of 20.7–27.4 Brix. They observed that a later harvest resulted in fruitier, sweeter wines with a fuller body which were less vegetal than wines from earlier harvested grapes. These findings are in agreement with the study conducted by Casassa *et al.* (2013b) who harvested Merlot grapes at two different harvest dates with a TSS range of 20.35 ± 0.16 Brix to 24.91 ± 0.46 Brix. Their late-harvest wines were also rated higher in sweetness, viscosity, and fruit-derived aromas, while early-harvest wines were described as having a sour taste, low colour intensity, and the aroma of fresh vegetables. A decrease in green flavour attributes with progressing maturity was also observed by Schelezki *et al.* (2018) for Cabernet-Sauvignon wine, which was explained by higher 2-isobutyl-3-methoxypyrazine IBMP concentrations at early-harvest that decreased towards late-harvest (Dunlevy *et al.,* 2010; Schelezki *et al.,* 2018). Late-harvest Cabernet-Sauvignon wine received higher ratings in port wine aroma and hotness (Schelezki *et al.,* 2018) which is in agreement with the findings of Bindon *et al.* (2014a) for late-harvest Cabernet-Sauvignon wine that was rated lower for red colour, red fruit, and fresh green aroma, and higher for dark fruit aroma, overall fruitiness, hotness, pungency, opacity, earthiness, and bitterness. A consumer preference rating for wine quality was performed to evaluate whether measures of phenolic maturity matched with a targeted "optimal ripeness", which was not necessarily the case (Bindon *et al.,* 2014a).

The cited studies have been carried out in warm climate conditions with Cabernet-Sauvignon, Cabernet franc, Merlot, and Tempranillo. The studies of Bindon *et al.* (2014a) and Schelezki *et al.* (2018) were conducted in Langhorne Creek, South Australia, and McLaren Vale, South Australia, respectively, at a subtropical climate zone (lat. 35° 16' S). The studies of del Llaudy *et al.* (2008) and Gil *et al.* (2012) were carried out in Tarragona, Spain, in a temperate climate zone (lat. 41° 07' N). The studies of Casassa *et al.* (2013a) and Sherman *et al.* (2017) took place in Paterson, WA, USA (lat. 45° 5'' N) which is also categorised as temperate.

The experimental vineyards in our study were further north in the Pfalz region in Germany (lat. 49° 24' N) than the aforementioned vineyards. Our study aims to investigate grape maturity in Pinot noir, which is considered an important cool climate variety, and Cabernet-Sauvignon, a well-studied warm climate variety. The Pfalz region is located in the winegrowing zone A which is considered a "cool climate". The 10-year average growing degree days GDD at the vineyard location is 1548 (20-year average 1540) which is within Winkler region II (cool). The year 2018 was an extremely hot vintage with 1884 GDD (Winkler region III, temperate) and it may be considered as an example of what we can expect from progressing climate change. The objective of our study is to explore the extent to which different maceration times can modulate the phenolic profile and sensory characteristics of wine made from grapes of different maturities. In particular, the question is raised whether extending maceration can improve the sensory characteristics of wine from immature grape material and if sensory effects can be explained by chemical data of phenols. The study also aims to contribute to the understanding of how grape maturity is related to the phenolic composition and the sensory characteristics of Pinot noir and Cabernet-Sauvignon.

MATERIALS AND METHODS

1. Wine production

Vitis vinifera L. cv. Pinot noir (PN; clone Mariafeld on SO4 rootstock) grapes and *Vitis vinifera* L. cv. Cabernet-Sauvignon (CS; clone 1Gm on Binova 1Opp rootstock) grapes were harvested in the 2018 vintage from vines grown in the experimental vineyards of the DLR Rheinpfalz located in the Pfalz region of Germany (49° 24' N 8° 11' E). The growing degree days (GDD) were calculated with data from an on-site weather station yielding 1884 GDD according to Method 1 by McMaster and Wilhelm (1997). A Huglin Index (HI) of 2412 was calculated according to Huglin (1978). The yield was 8 t/ha for both grape varieties.

The grape bunches were harvested manually at three different stages of grape maturity in a range which is realistic for winemaking in Germany (20–25 Brix). Harvest dates were two weeks apart, starting with "early-harvest" at 20.7 Brix

for Pinot noir and 20.2 Brix for Cabernet-Sauvignon, "commercial harvest" at 22.5 Brix for Pinot noir and 23.0 Brix for Cabernet-Sauvignon, and "late-harvest" at 24.8 Brix for Pinot noir and 24.0 Brix for Cabernet-Sauvignon. After destemming, grapes were crushed and transferred into 100 L experimental stainless-steel fermenters. Per grape variety and harvest date, four lots, each with 70 kg, were processed.

Potential alcohol adjustment to achieve a set potential alcohol for all experimental treatments was not performed, because previous studies have shown that the enhanced potential alcohol has a varying influence on the extraction of phenolics depending on the phenolic maturity of the grapes (Feifel *et al.,* 2024). All musts were inoculated with 200 mg/L ZYMAFLORE® RB2 yeast (LAFFORT®, Bordeaux, France) and allowed to warm up to 28 °C within 24 hours. Once fermentation commenced, fermenting wines were maintained at 24 °C and manually punched down six times per day for two days. From the third day until the end of alcoholic fermentation (< 1 g/L residual sugar), three punch downs per day were conducted. Afterwards, until the end of maceration, no punch downs were performed. Fermentations were monitored with a handheld density meter (DMA 35 Basic, Anton Paar, Graz, Austria).

Two of the four lots per grape variety and harvest date (experimental replicates) were kept on skins and seeds for a total maceration time of either 7 days or 14 days. After maceration, all wines were < 1 g/L residual sugar. Wines were pressed off (1.6 bar) with a tank press (T1, Scharfenberger, Bad Dürkheim, Germany). The wines were transferred into 50 L carboys and inoculated with 10 mg/L *Oenococcus oeni* VP41 (ZEFÜG GmbH & Co. KG, Bingen, Germany). After completion of malolactic fermentation, 60 mg/L SO_2 (IOC Sulfivin K150, ZEFÜG GmbH & Co. KG, Bingen, Germany) was added. Wines were kept for two months at 15 °C until filtration and bottling. Before bottling, SO_2 was adjusted to obtain 35 mg/L free SO_2. Wines were filled into 0.75 L Alsace-style wine bottles, closed with screw caps and stored for two months at 16 °C until chemical analyses and sensory evaluation.

2. Chemicals

Hydrochloric acid, propan-2-ol, caffeine anhydrous, Folin–Ciocalteu reagent, and sodium chloride were purchased from AppliChem (Darmstadt, Germany). Ethanol, *ortho*-phosphoric acid, acetic acid, and potassium metabisulfite were purchased from ORG Laborchemie (Bunde, Germany). Procyanidin B_2 and procyanidin C_1 were purchased from PhytoLab (Vestenbergsgreuth, Germany). Caftaric acid, cyanidin-3-*O*-rutinoside, (–)-epicatechin-3-*O*-gallate, (–)-epigallocatechin, (+)-gallocatechin, and oenin chloride were purchased from PhytoPlan (Heidelberg, Germany). L(+)-tartaric acid and sodium carbonate were purchased from Roth (Karlsruhe, Germany). Caffeic acid, (+)-catechin hydrate, (–)-epicatechin, gallic acid monohydrate, sodium hydroxide, maleic acid, sodium dodecyl sulphate, tannic acid, aluminium sulphate, 3-isobutyl-2-methoxypyrazine, triethanolamine, and iron(III) chloride were purchased from Sigma Aldrich (Steinheim, Germany). Acetonitrile and formic acid were purchased from Bernd Kraft (Duisburg, Germany) and Honeywell (Morris Plains, New Jersey), respectively. Albumin fraction V (BSA), acetic acid, and potassium dihydrogen phosphate were purchased from Merck (Darmstadt, Germany) and VWR International (Darmstadt, Germany), respectively. Ultrapure water was obtained from a PURELAB flex (ELGA LabWater, Celle, Germany) water purification system. All chromatographic solvents were HPLC grade.

3. Basic analytical parameters

Grape juice parameters (relative density, titratable acidity, pH, glucose, and fructose) were measured by Fourier transform infrared spectroscopy (FT-IR) (WineScan™ FT120 Basic, FOSS GmbH, Hamburg, Germany) using a calibration method provided by the manufacturer. Each harvest date, early-, commercial and late-harvest, including experimental replicates, was analysed in duplicate. Wine parameters (alcohol, titratable acidity, tartaric acid, malic acid, lactic acid, pH, acetic acid, and residual sugars) were measured by FT-IR (WineScan™ Auto, FOSS GmbH, Hamburg, Germany) using a calibration method provided by the manufacturer. Samples were centrifuged for 5 min at 4,500 rpm (4,754 rcf) and degassed prior to FT-IR analysis. For each experimental treatment, the sample was analysed in duplicate.

4. Spectrophotometric analysis

The photometric analyses were scheduled to coincide with the sensory evaluation. Iron reactive phenolics, tannins, protein-precipitable polymeric pigments (p-PP) and non-precipitable polymeric pigments (np-PP) were measured by the assay described by Harbertson *et al.* (2003). A Varian Cary 100 scan UV-visible spectrophotometer (Agilent Technologies, Waldbronn, Germany) was used for all measurements. Oxidisable phenolics were determined by the Folin–Ciocalteu assay as described by Singleton and Rossi (1965) with an automated Konelab 20i (Thermo Fisher Scientific, Waltham, USA). For each experimental treatment, the sample was analysed in duplicate.

5. HPLC-DAD/FD analysis

The analysis was performed using a HPLC-DAD/FD (Jasco, Pfungstadt, Germany) comprising a PU-2080 Plus Intelligent HPLC Pump, a DG-2080-53 3-Line Degasser, a LG-2080-02 Ternary Gradient Unit, an AS-2055 Plus Intelligent Sampler, a MD-2010 Plus Multiwavelength Detector, and a FP-2020 Plus Intelligent Fluorescence Detector.

Separation of phenolic compounds was achieved with a reversed-phase Gemini® NX-C18 (110 Å, 250 × 4.6 mm, 5 µm; Phenomenex, Torrance, USA) column, protected by a guard column containing the same material (Security Guard Cartridge System C18; Phenomenex, Torrance, USA) at a temperature of 40 °C (CO-2067 Plus Intelligent Column Oven; Jasco, Pfungstadt, Germany). A gradient consisting of eluent A (phosphate buffer (1.36 g/L KH_2PO_4,

pH = 1.5 (85 % H_3PO_4))/acetonitrile 95/5 (v/v)) and eluent B (phosphate buffer (1.36 g/L KH_2PO_4, pH = 1.5 (85 % H_3PO_4))/acetonitrile 50/50 (v/v)) was applied at a flow rate of 1.2 mL/min as follows: 0 % B at 0 min, 12 % B at 12 min (6 min hold), 51 % B at 37.5 min, 75 % B at 38 min (3 min hold), 0 % B at 42 min (1 min hold). The injection volume was 20 µL. The phenolic compounds were identified according to their order of elution and the retention times of reference compounds. The compounds were: malvidin-3-*O*-glucoside (mv-3-gl), caffeic acid, caftaric acid, gallic acid, (+)-catechin and (–)-epicatechin. Detection took place at 520 nm for anthocyanins, 320 nm for hydroxycinnamic acids and 280 nm for gallic acid. Flavan-3-ols were quantified by fluorescence with excitation and emission wavelengths of 300 nm and 325 nm, respectively, to avoid interferences with the other compounds. External standards were used for quantification in the ranges of 0.5–125 mg/L for (–)-epicatechin and caftaric acid, 1.0–250 mg/L for gallic acid and (+)-catechin, and 1–450 mg/L for anthocyanins. Anthocyanins were quantified as mv-3-gl equivalents. (–)-epicatechin and (+)-catechin were expressed as "monomeric catechins".

Samples were filtered through 0.45 µm cellulose acetate membranes (Graphic Controls, Totnes, UK) and then analysed directly. Galaxy Chromatography Software (version 1.10.0.5590, Agilent Technologies, Waldbronn, Germany) was used for HPLC data acquisition and evaluation. Analysis was performed in duplicate.

6. LC-QToF-MS analysis

The analysis was performed using an LC-QToF-MS (Agilent Technologies, Waldbronn, Germany) comprising an Agilent 1260 Infinity Binary Pump, an Agilent 1260 Infinity HiP Degasser, an Agilent 1260 Infinity HiP ALS Autosampler, an Agilent Jet Stream Technology Ion Source (AJS) G-1958-65138, an Agilent 1260 DAD, and a 6530 Accurate-Mass Q-TOF LC/MS.

Separation of phenolics was achieved with a reversed-phase Kinetex® C18 (100 Å, 150 × 2.10 mm, 2.6 µm; Phenomenex, Torrance, USA) column at a temperature of 40 °C (Agilent 1260 TCC; Agilent Technologies, Waldbronn, Germany). A gradient consisting of eluent A (H_2O/acetonitrile/formic acid 93/5/2 (v/v/v)) and eluent B (H_2O/acetonitrile/formic acid 5/93/2 (v/v/v)) was applied at a flow rate of 0.4 mL/min as follows: 0 % B at 0 min (2 min hold), 30 % B at 18 min, 100 % B at 22 min (1 min hold), 0 % B at 24 min (8 min hold). The injection volume was 5 µL.

MS analysis was performed in the positive ionisation mode. The MS parameters were as follows: nebuliser pressure 35 psig, fragmentation at 170 V, skimming at 65 V, VCap at 3000 V, gas flow 8 L/min, gas temperature 320 °C, sheath gas temperature 380 °C, rate 5 spectra/sec, scan at *m/z* 100-1700.

B-prodelphinidins and B-procyanidin gallates were identified according to their *m/z*. Gallocatechin, epigallocatechin, B-procyanidins, and C-procyanidins were identified according to the retention times of reference compounds. Cyanidin-3-*O*-rutinoside was used as internal standard and external standards were used for quantification. B-procyanidins, B-prodelphinidins, and B-procyanidin gallates were quantified as procyanidin B_2 equivalents. C-procyanidins were quantified as procyanidin C_1 equivalents. A calibration range of 0.1–15 mg/L was used for all reference compounds.

Samples were filtered through 0.45 µm cellulose acetate membranes (Graphic Controls, Totnes, UK) and then analysed directly. MassHunter Workstation Software (version B.05.00, Build 5.0.291; Agilent Technologies, Waldbronn, Germany) was used for MS data acquisition and evaluation. Analysis was performed in duplicate.

7. HS-SPME-H/C-MDGC-MS-MS analysis

Analyses of 2-isobutyl-3-methoxypyrazine (IBMP) were performed using an established method (Slabizki *et al.,* 2015; Slabizki *et al.,* 2014). For each experimental treatment, the sample was analysed in duplicate.

8. Sensory evaluation

Descriptive analysis (DA) was performed three months after bottling (eight months after alcoholic fermentation) by a trained sensory panel. The panel was composed of 16 judges for Pinot noir wines (8 females, 8 males) and 19 judges for Cabernet-Sauvignon wines (9 females, 10 males) with a range between 22 to 64 years of age. Panellists attended three training sessions (each 90 min) before evaluating Pinot noir wines and another two training sessions before evaluating Cabernet-Sauvignon wines. During the first training session for each grape variety, random wines from this study of the respective grape variety were presented to the panellists. They were asked to describe the aroma of these wines in their own words and then reach a consensus on five aroma descriptors per grape variety that differentiate the wines (Table 1). Training for blind recognition and intensity of aroma, taste, and tactile attributes was carried out to create a common sense for these attributes. Other training sessions were carried out presenting the base wine and the reference standards (Table 1), undiluted and 1:2 diluted with wine, to the judges to familiarise them with the use of unstructured line scales. For training sessions and evaluation sessions, the unstructured line scales were anchored at the left with low intensity and at the right end with high intensity unless stated otherwise in Table 1. Also part of the training was a trial-run DA, which entailed the evaluation of random wines from this study for their appearance, aroma, taste, and mouthfeel on the unstructured line scales, to familiarise panellists with the wines and the evaluation process under the same conditions as those for the formal sessions.

Formal evaluation sessions were held repeatedly for Pinot noir and Cabernet-Sauvignon on separate days. Each flight consisted of six samples. For aroma, taste, and tactile attributes, samples were presented to panellists (30 mL per sample at 16 °C) in black Sensus glasses (DIN 10960 wine-tasting glasses; Schott Zwiesel, Germany) covered with plastic lids. For appearance attributes, the same samples were presented in clear glasses (DIN 10960 wine-tasting

TABLE 1. Descriptors, definitions, reference standards, and anchor terms for scales used in the sensory descriptive analysis.

Descriptor	Definition	Reference Standard[a]
	Appearance attributes	
Colour intensity	How much the wine blocks the passage of light	-
Colour hue[b]	Wine colour from brown to red to purple	-
	Aroma attributes for Pinot noir	
Berries	Aroma of sour cherry and blackcurrant	100 mL sour cherry juice (REWE Beste Wahl) and 100 mL blackcurrant juice (REWE Beste Wahl) to 1 L base wine
Jammy	Aroma of sweet, cooked fruits like plum puree	1.5 soft prunes (Seeberger) to 100 mL base wine, pureed and stirred for 10 min and centrifuged. Supernatant collected. 2 µL acetaldehyde (Sigma Aldrich, certified reference material, pharmaceutical secondary standard) added to supernatant. 100 mL of this mixture and 80 mL juice from canned plums (Jütro) to 1 L base wine
Herbaceous	Fresh, essential oil aromas with Mediterranean herbs	20 mL eucalyptus mixture (1 cough drop eucalyptus (Wick) to 100 mL base wine) and 100 mL herbs mixture (in 100 mL base wine: 0.1 g dried oregano (Ostmann), 1 juniper berry (0.15–0.2 g) (Ostmann), 0.35 g/L fresh rosemary, 1.5 g green tea (Westminster), 1.5 g black tea (Lipton), a pinch of black pepper (Ostmann), a pinch of cloves (Ostmann), stirred for 10 min, then strained)
Spices	Spicy or savoury aroma	In 100 mL base wine: a pinch of black pepper (Ostmann), a pinch of cloves (Ostmann), 20 mL wood mixture (in 50 mL base wine 1 wooden chip, stirred for 3 min), stirred for 10 min, then strained
Oxidised	Aroma of nail polish remover	75 µL ethyl acetate (Sigma Aldrich, EMPROVE® ESSENTIAL) and 1.5 mL acetic acid (Merck, food grade) to 1 L base wine
	Aroma attributes for Cabernet-Sauvignon	
Sour cherry	Aroma of sour cherry	200 mL sour cherry juice (REWE Beste Wahl) to 1 L base wine
Dark fruit	Aroma of dark fruits such as blackberry and blackcurrant	200 mL blackcurrant juice (REWE Beste Wahl) to 5 g blackberry tea (Westcliff) in 1 L base wine, stirred for 5 min, then strained
Green bell pepper	Aroma of green bell pepper, unripe	2 mL 3-Isobutyl-2-methoxypyrazine (c = 10 mg/L) (Sigma Aldrich, food grade) to 1 L base wine
Eucalyptus	Fresh, cooling eucalyptus aroma	4 cough drop eucalyptus (Wick) finely crushed and 50 mL ethanol to 1 L base wine
Spices	Spicy or savoury aroma	In 100 mL base wine: a pinch of black pepper (Ostmann), a pinch of cloves (Ostmann), ¼ soft liquorice (Katjes), stirred for 10 min, then strained
	Taste and tactile attributes	
Bitter	The intensity of bitter taste perceived in the back part of the palate	0.8 g/L caffeine (AppliChem, food grade)
Sour	The intensity of sour taste/acidity perceived in the mouth	2.0 g/L tartaric acid (Carl Roth, food grade)
Sweet	The intensity of sweetness perceived in the mouth	-
Dry astringency	Reduction of the natural lubrication in the mouth, giving a drying feeling	0.8 g/L tannic acid (Sigma Aldrich, reference material, pharmaceutical secondary standard)
Smooth astringency[c]	Mouth feeling from rough to smooth	1 g/L aluminium sulphate (Sigma Aldrich, United States Pharmacopeia Reference Standard)
Green astringency	Palate drying effect with an unripe aftertaste	1.2 g/L catechin (Sigma Aldrich, Pharmaceutical Secondary Standard, Certified Reference Material)
Full body[d]	Perception of the body, weight or thickness of the wine from light to full	-
Harsh mouthfeel[e]	Mouthfeel from harmonious to harsh	-

[a] Standards were produced with a red base wine, grape variety: Regent, 2018 vintage. A volume of 1 L was used unless otherwise stated.

[b] Scale was anchored on the left with brown colour hue, in the middle with red colour hue and on the right with a purple colour hue.

[c] Scale was anchored on the left with rough and on the right with smooth.

[d] Scale was anchored on the left with light and on the right with full.

[e] Scale was anchored on the left with harmonious and on the right with harsh.

glasses; Schott Zwiesel, Germany) covered with plastic lids. All samples were coded with a three-digit number. The wines were presented in a randomised order. Formal evaluations were held in an air-conditioned sensory laboratory with individual booths at 20 °C. Data were acquired using FIZZ software (Version 2.51 c 02, Biosystèmes, Couternon, France). All samples were expectorated. To avoid sensory fatigue, panellists were required to rest for 45 sec while cleansing their palate with water after each sample.

9. Statistical analysis

An analysis of variance (ANOVA) was performed for the chemical data. The analytical repetitions and the experimental replicates were additionally regarded as separate factors. The sensory data was processed by a three-way mixed model ANOVA considering panellist as a random effect and wine and tasting replication as fixed effects. Fisher's least significant difference (LSD) post-hoc test ($p \leq 0.05$) was carried out for all data. Principal component analysis (PCA) was performed for chemical as well as sensory evaluation data using Pearson correlation (n-1). All statistical analyses were performed using XLSTAT SENSORY (Version 2021.2.2.1147 (32 bit), Addinsoft SARL, Paris, France).

RESULTS AND DISCUSSION

1. Sensory evaluation

Figure 1 shows the principal component analysis (PCA) for Pinot noir (Figure 1A) and Cabernet-Sauvignon (Figure 1B) wines produced from grapes of different maturity levels and with 7 d maceration and 14 d maceration. PCA space was calculated for 15 sensory attributes. For both grape varieties, the different maturity levels were separated on PC1, the maceration time was separated on PC2. This shows that the effect of maceration time is different from the influence of grape maturity suggesting that sensory characteristics of wine made from immature grape material cannot be driven towards those associated with a higher grape maturity by manipulating maceration time. Results for Cabernet franc in a study by Cadot *et al.* (2012), who investigated two different maturity levels and two different maceration times, indicated similar findings. It is thought that extended maceration cannot compensate for grape immaturity because of the lack of desired substances in grape skins (Ribéreau-Gayon *et al.,* 2006) and/or their low extractability caused by pectin (Garrido-Bañuelos *et al.,* 2019). Extended maceration is known to enhance seed extraction (del Llaudy *et al.,* 2008; Gil *et al.,* 2012) and is therefore not practical. For both grape varieties, the list of sensory attributes could discriminate grape maturity better than maceration times. This is in agreement with Casassa *et al.* (2013b) who concluded that the harvest date defines the sensory profile of the wines and outweighs sensory effects arising from extended maceration.

Both grape varieties showed a slight tendency in the effect of maceration time being more pronounced at higher grape maturity. Tables S1 and S2 reveal this for the sensory descriptors herbaceous and green astringency in Pinot noir as well as for sweetness and full body in Cabernet-Sauvignon The higher susceptibility of late-harvest wines to be influenced by maceration time can be explained by a greater de-pectination and de-esterification of the grape berry cell walls with increasing grape maturity (Garrido-Bañuelos *et al.,* 2019).

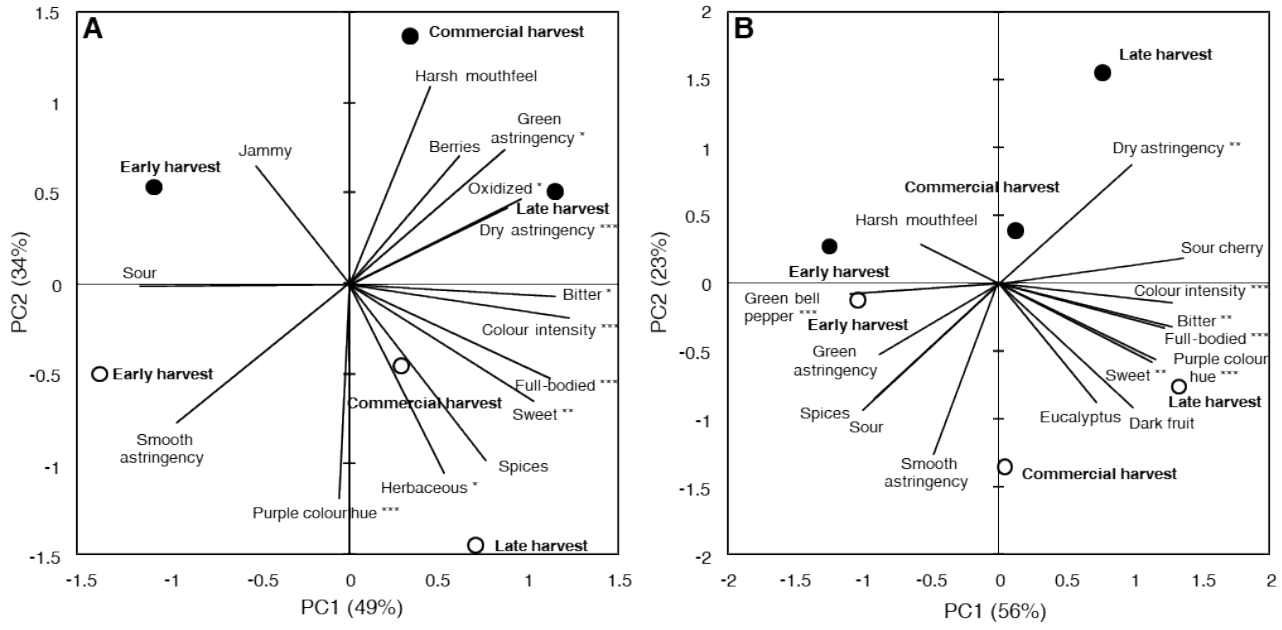


FIGURE 1. Principal component analysis for Pinot noir (A) and Cabernet-Sauvignon (B) wines produced from grapes of different maturity levels and with 7 d maceration (open symbols) and 14 d maceration (filled symbols). PCA space was calculated for the fifteen displayed sensory attributes. * significant at $p < 0.05$, ** significant at 0.01, *** significant at 0.001.

Also, another explanation for the effect of maceration time being more pronounced at higher grape maturity is that higher alcohol concentrations are present. Accordingly, longer maceration times can potentially lead to an enhanced extraction.

The observation of higher ratings in acidity/sourness and green bell pepper/vegetal aroma in early-harvest wines is in agreement with the results of Gil *et al.* (2012), Cadot *et al.* (2012), and Casassa *et al.* (2013b). Increasing grape maturity resulted in higher ratings in colour intensity, fruity aroma attributes, sweetness, dry astringency, bitterness, and a full body, which is in agreement with the findings of Cadot *et al.* (2012). The higher ratings in bitterness for late-harvest grapes of both varieties are in contrast with the observations of Gil *et al.* (2012) who showed a decrease in bitterness and astringency with increasing grape maturity. However, the increased bitterness observed here in late-harvest wines may be explained by their higher ethanol content, which is known to enhance bitterness (Fischer & Noble, 1994; Fontoin *et al.,* 2008).

The green bell pepper aroma observed in Cabernet-Sauvignon early-harvest wine is most likely elicited by its concentration of IBMP (5.90 ± 0.71 ng/L), significantly higher than that of late-harvest wine (3.00 ± 0.32 ng/L). Roujou de Boubée *et al.* (2000) suggested IBMP as a marker for grape unripeness. A study by Bindon *et al.* (2013) observed a decline in IBMP from 14.3 ± 0.4 ng/L to 7.03 ± 0.6 ng/L during ripening in Cabernet-Sauvignon wine made from grapes with five levels of grape maturity ranging from 20.3 ± 0.12 Brix to 26.0 ± 0.00 Brix.

Extending maceration resulted in wines with higher ratings in astringency as well as tendencies to a lighter colour and yellow hue. Such effects of maceration time have been reported across different grape varieties such as Merlot, Cabernet-Sauvignon, Cabernet franc, and Tempranillo (Cadot *et al.,* 2012; Casassa *et al.,* 2013b; Gil *et al.,* 2012). The findings here extend such observations to Pinot noir.

For both grape varieties, ratings for green astringency were significantly higher in early-harvest wines. This might be due to an enhanced astringency perception of catechins in wines with a lower pH (Peleg *et al.,* 1998). Previous studies have also shown that astringency perception decreases with increasing ethanol concentration (Fontoin *et al.,* 2008; Noble, 1998).

However, only in Pinot noir wine green astringency was also significantly higher with the 14 d maceration than with the 7 d maceration, outweighing the effect of immaturity. The effect of extended maceration on catechin extraction was likely more pronounced in Pinot noir than in Cabernet-Sauvignon. For both grape varieties ratings for purple hue were significantly higher in 7 d maceration wines than in 14 d maceration wines, which is in agreement with the findings of Casassa *et al.* (2013b). Longer maceration may allow browning reactions to take place, such as the oxidation of caftaric acid (Singleton *et al.,* 1985). At the same time, monomeric anthocyanins might undergo polymerisation reactions (Romero-Cascales *et al.,* 2005).

Ratings of purple hue were significantly higher in Cabernet-Sauvignon commercial harvest and late-harvest wines for both maceration treatments relative to early-harvest wine, which is in agreement with the findings of Bindon *et al.* (2014a). More monomeric and polymeric pigments likely increase in Cabernet-Sauvignon wine with progressing grape maturity. In contrast, the effect of progressing maturity on purple hue was only observed for 7 d maceration Pinot noir wines.

2. Basic juice and wine parameters

With increasing grape maturity, glucose and fructose as well as the pH increased, and titratable acidity decreased in grape juice (Table 2). Tables 3 and 4 show the basic wine parameters of the resulting Pinot noir and Cabernet-Sauvignon wines. Late-harvest wines had significantly lower titratable acidity and higher pH than commercial harvest and early-harvest wines. Extended

TABLE 2. Basic chemical analyses of the juice. Average values followed by SD.

	Brix	Titratable acidity [g/L TAE]	pH	Glucose [g/L]	Fructose [g/L]
Pinot noir					
Early-harvest	20.68 ± 0.00 c[a]	9.1 ± 0.1 a	3.3 ± 0.0 b	101.8 ± 0.4 c	101.5 ± 0.4 c
Commercial harvest	22.46 ± 0.00 b	6.6 ± 0.0 b	3.4 ± 0.0 a	111.5 ± 0.2 b	114.2 ± 0.4 b
Late-harvest	24.87 ± 0.00 a	6.2 ± 0.0 c	3.4 ± 0.0 a	125.2 ± 0.3 a	128.8 ± 0.6 a
p	*< 0.0001*	*< 0.0001*	*0.001*	*< 0.0001*	*< 0.0001*
Cabernet-Sauvignon					
Early-harvest	20.01 ± 0.00 c	9.3 ± 0.0 a	3.2 ± 0.0 c	97.6 ± 0.1 c	99.0 ± 0.8 c
Commercial harvest	22.68 ± 0.00 b	6.9 ± 0.1 b	3.4 ± 0.0 b	114.0 ± 0.4 b	117.7 ± 0.9 b
Late-harvest	23.56 ± 0.00 a	4.2 ± 0.1 c	3.6 ± 0.0 a	117.6 ± 0.7 a	123.9 ± 0.5 a
p	*< 0.0001*	*< 0.0001*	*< 0.0001*	*< 0.0001*	*< 0.0001*

[a] Within a column, values followed by the same letter are not significantly different according to Fisher's LSD test at $p \leq 0.05$. Significant p values ($p \leq 0.05$) are shown in italic letters. Data consisted of four experimental replicates.

TABLE 3. Basic chemical analyses of Pinot noir wine. Average values followed by SD.

		Alcohol [g/L]	Alcohol [% vol.]	Residual sugar [g/L]	pH	Titratable acidity [g/L TAE]	Tartaric acid [g/L]	Malic acid [g/L]	Lactic acid [g/L]	Acetic acid [g/L]
Maturity	**Maceration**									
Early-harvest	7 d	89.9 ± 0.6 e[a]	11.36 ± 0.08 e	0.9 ± 0.1 b	3.43 ± 0.01 d	5.4 ± 0.0 a	2.8 ± 0.0 a	0.1 ± 0.0 c	1.8 ± 0.0 a	0.4 ± 0.0 c
	14 d	88.3 ± 0.8 f	11.16 ± 0.10 f	0.9 ± 0.0 b	3.46 ± 0.04 d	5.3 ± 0.1 b	2.5 ± 0.0 b	0.3 ± 0.0 a	1.5 ± 0.0 b	0.5 ± 0.0 b
Commercial harvest	7 d	100.3 ± 0.2 c	12.68 ± 0.03 c	1.2 ± 0.1 a	3.55 ± 0.01 c	4.9 ± 0.1 c	2.3 ± 0.1 c	0.0 ± 0.0 d	1.5 ± 0.0 b	0.5 ± 0.0 b
	14 d	96.2 ± 1.0 d	12.16 ± 0.13 d	0.9 ± 0.1 b	3.67 ± 0.04 b	4.5 ± 0.2 e	2.1 ± 0.0 d	0.2 ± 0.1 b	1.4 ± 0.0 c	0.6 ± 0.0 a
Late-harvest	7 d	112.6 ± 0.1 a	14.23 ± 0.01 a	1.3 ± 0.1 a	3.66 ± 0.02 b	4.7 ± 0.1 d	2.1 ± 0.1 d	0.0 ± 0.0 d	1.4 ± 0.0 c	0.5 ± 0.0 b
	14 d	110.1 ± 1.0 b	13.91 ± 0.13 b	1.2 ± 0.2 a	3.74 ± 0.02 a	4.6 ± 0.0 de	1.8 ± 0.1 e	0.1 ± 0.0 c	1.3 ± 0.0 d	0.6 ± 0.0 a
p		*< 0.0001*	*< 0.0001*	*0.002*	*< 0.0001*	*< 0.0001*	*< 0.0001*	*< 0.0001*	*< 0.0001*	*< 0.0001*
Maturity										
Early-harvest		89.1 ± 1.1 c	11.26 ± 0.14 c	0.9 ± 0.1 b	3.45 ± 0.03 c	5.3 ± 0.1 a	2.7 ± 0.2 a	0.2 ± 0.1 a	1.6 ± 0.1 a	0.5 ± 0.0 b
Commercial harvest		98.2 ± 2.4 b	12.41 ± 0.30 b	1.0 ± 0.2 b	3.61 ± 0.08 b	4.7 ± 0.2 b	2.2 ± 0.2 b	0.1 ± 0.1 b	1.5 ± 0.1 b	0.5 ± 0.1 b
Late-harvest		111.4 ± 1.5 a	14.08 ± 0.19 a	1.2 ± 0.2 a	3.70 ± 0.05 a	4.6 ± 0.1 c	2.0 ± 0.2 c	0.1 ± 0.1 b	1.4 ± 0.1 c	0.6 ± 0.1 a
p		*< 0.0001*	*< 0.0001*	*0.001*	*< 0.0001*	*< 0.0001*	*< 0.0001*	*0.002*	*< 0.0001*	*< 0.0001*
Maceration										
7 d		100.9 ± 10.2 a	12.75 ± 1.29 a	1.1 ± 0.2 a	3.55 ± 0.10 b	5.0 ± 0.3 a	2.4 ± 0.3 a	0.0 ± 0.0 b	1.6 ± 0.2 a	0.5 ± 0.0 b
14 d		98.2 ± 9.9 b	12.41 ± 1.25 b	1.0 ± 0.2 a	3.62 ± 0.13 a	4.8 ± 0.4 b	2.2 ± 0.3 b	0.2 ± 0.1 a	1.4 ± 0.1 b	0.6 ± 0.0 a
p		*< 0.0001*	*< 0.0001*	0.056	*< 0.0001*	*< 0.0001*	*< 0.0001*	*< 0.0001*	*< 0.0001*	*< 0.0001*
Maturity × Maceration										
p		*0.002*	*0.002*	0.142	*0.004*	*0.001*	0.670	0.506	*0.003*	0.139

[a] Within a column, values followed by the same letter are not significantly different according to Fisher's LSD test at $p \leq 0.05$. Significant p values ($p \leq 0.05$) are shown in italic letters. Data consisted of two experimental replicates.

TABLE 4. Basic chemical analyses of Cabernet-Sauvignon wine. Average values followed by SD.

		Alcohol [g/L]	Alcohol [% vol.]	Residual sugar [g/L]	pH	Titratable acidity [g/L TAE]	Tartaric acid [g/L]	Malic acid [g/L]	Lactic acid [g/L]	Acetic acid [g/L]
Maturity	**Maceration**									
Early-harvest	7d	87.4 ± 0.7 e[a]	11.05 ± 0.09 e	0.9 ± 0.0 c	3.59 ± 0.00 f	5.4 ± 0.0 a	2.6 ± 0.1 a	0.4 ± 0.1 c	2.0 ± 0.0 a	0.4 ± 0.0 b
	14d	85.1 ± 0.5 f	10.75 ± 0.06 f	0.9 ± 0.1 c	3.64 ± 0.00 e	5.5 ± 0.0 a	2.5 ± 0.0 b	0.6 ± 0.0 a	1.9 ± 0.0 b	0.5 ± 0.0 a
Commercial harvest	7d	101.6 ± 0.1 c	12.84 ± 0.01 c	1.2 ± 0.0 bc	3.78 ± 0.01 d	5.3 ± 0.0 b	2.3 ± 0.0 c	0.5 ± 0.0 b	2.0 ± 0.0 a	0.4 ± 0.0 b
	14d	98.7 ± 0.0 d	12.47 ± 0.00 d	1.4 ± 0.1 ab	3.86 ± 0.01 c	5.1 ± 0.0 c	1.9 ± 0.0 e	0.6 ± 0.0 a	2.0 ± 0.0 a	0.5 ± 0.0 a
Late-harvest	7d	107.2 ± 0.4 a	13.55 ± 0.05 a	1.5 ± 0.2 a	3.90 ± 0.01 b	4.7 ± 0.1 d	2.2 ± 0.1 d	0.3 ± 0.0 c	1.6 ± 0.0 c	0.4 ± 0.0 b
	14d	106.1 ± 0.7 b	13.41 ± 0.09 b	1.0 ± 0.1 bc	3.99 ± 0.02 a	4.4 ± 0.0 e	1.9 ± 0.1 e	0.5 ± 0.0 b	1.5 ± 0.1 d	0.4 ± 0.0 b
p		*< 0.0001*	*< 0.0001*	*0.002*	*< 0.0001*	*< 0.0001*	*< 0.0001*	*< 0.0001*	*< 0.0001*	*< 0.0001*
Maturity										
Early-harvest		86.3 ± 1.4 c	10.91 ± 0.18 c	0.9 ± 0.0 b	3.62 ± 0.03 c	5.4 ± 0.0 a	2.6 ± 0.1 a	0.5 ± 0.1 a	1.9 ± 0.0 b	0.5 ± 0.1 a
Commercial harvest		100.6 ± 1.7 b	12.71 ± 0.21 b	1.2 ± 0.1 a	3.81 ± 0.05 b	5.2 ± 0.1 b	2.2 ± 0.3 b	0.5 ± 0.1 a	2.0 ± 0.0 a	0.5 ± 0.1 a
Late-harvest		106.6 ± 0.8 a	13.47 ± 0.10 a	1.3 ± 0.3 a	3.95 ± 0.05 a	4.6 ± 0.1 c	2.1 ± 0.1 c	0.4 ± 0.1 b	1.6 ± 0.1 c	0.4 ± 0.0 b
p		*< 0.0001*	*< 0.0001*	*0.002*	*< 0.0001*	*< 0.0001*	*< 0.0001*	*0.003*	*< 0.0001*	*< 0.0001*
Maceration										
7 d		98.7 ± 9.1 a	12.47 ± 1.15 a	1.2 ± 0.3 a	3.83 ± 0.14 a	5.1 ± 0.4 a	2.4 ± 0.2 a	0.4 ± 0.1 b	1.8 ± 0.2 a	0.4 ± 0.0 b
14 d		96.2 ± 9.5 b	12.16 ± 1.20 b	1.0 ± 0.2 a	3.76 ± 0.16 b	5.0 ± 0.5 b	2.1 ± 0.3 b	0.6 ± 0.1 a	1.8 ± 0.2 a	0.5 ± 0.0 a
p		*< 0.0001*	*< 0.0001*	0.237	*< 0.0001*	*< 0.0001*	*< 0.0001*	*< 0.0001*	0.627	*< 0.0001*
Maturity × Maceration										
p		*0.006*	*0.006*	*0.010*	*0.050*	*< 0.0001*	*0.003*	0.205	*0.006*	*0.001*

[a] Within a column, values followed by the same letter are not significantly different according to Fisher's LSD test at $p \leq 0.05$. Significant p values ($p \leq 0.05$) are shown in italic letters. Data consisted of two experimental replicates.

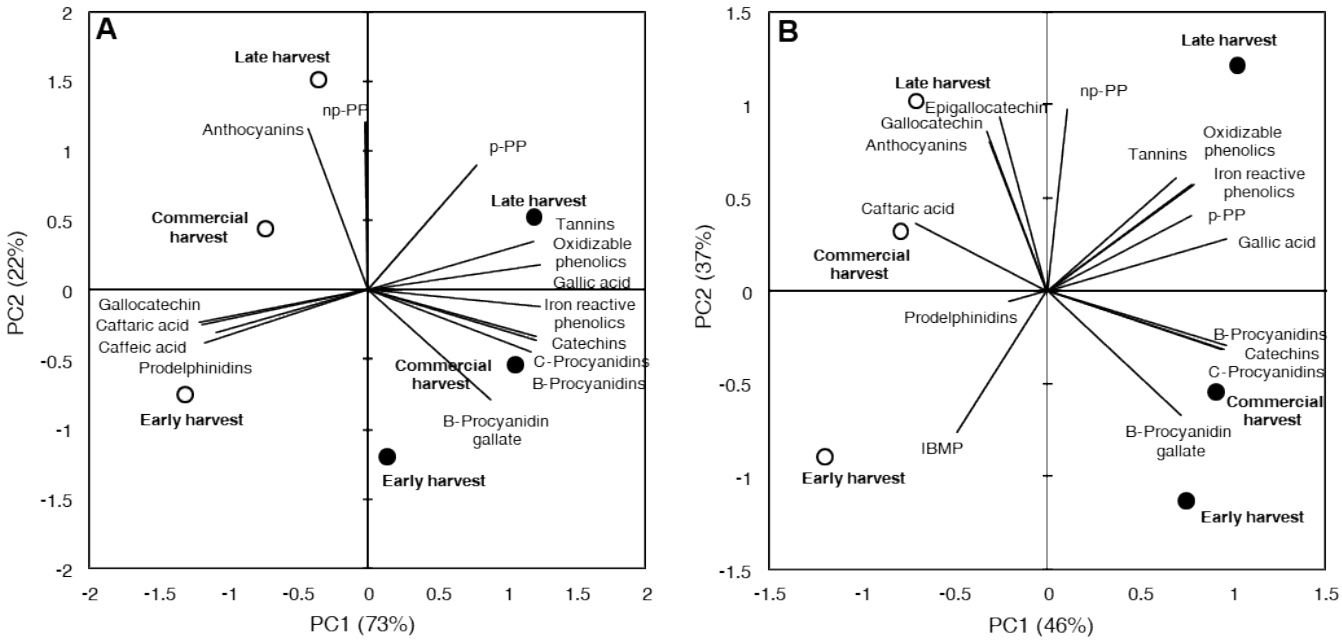


FIGURE 2. Principal component analysis for Pinot noir (A) and Cabernet-Sauvignon (B) wines produced from grapes of different maturity levels and with 7 d maceration (open symbols) and 14 d maceration (filled symbols). PCA space was calculated on the fifteen displayed chemical attributes.

maceration wines of both grape varieties had significantly lower titratable acidity than 7 d maceration wines due to the formation of potassium bitartrate and had higher acetic acid concentrations as a result of oxidation. Irrespective of the maceration, time the acetic acid concentrations were below the sensory threshold (Corison *et al.,* 1979). Extended maceration time also caused significantly lower alcohol concentrations, which is due to the evaporation of alcohol during the post-alcoholic fermentation maceration.

3. Phenolic composition of wines

For both grape varieties, PC1 segregated the wines by maceration time and PC2 segregated the wines by grape maturity, indicating that the effect of maceration time on the phenolic composition of the wines outweighs the influence of grape maturity (Figure 2). This observation contrasts with the sensory data (Figure 1): the influence of grape maturity (PC1) outweighed the effect of maceration time (PC2) on the sensory profile of the wines.

For both grape varieties, the phenolic data in Figure 2 shows that the effect of maceration time is different from the influence of grape maturity suggesting that sensory characteristics of wine made from immature grape material cannot be driven towards those associated with a higher grape maturity by manipulating maceration time. This observation supports the earlier findings with sensory data (Figure 1). However, extended maceration did not enhance the effects of grape immaturity on phenolics in wine either. Extended maceration enhanced seed extraction which is in agreement with the literature (del Llaudy *et al.,* 2008; Gil *et al.,* 2012).

Pinot noir wine (Figure 2A) showed a significant decrease in prodelphinidin dimers with extended maceration suggesting that prodelphinidin dimers react with other phenolic compounds to form polymerised proanthocyanidins. Extended maceration also led to significantly lower gallocatechin concentration irrespective of the level of grape maturity in Pinot noir wine, likely due to polymerisation or oxidation reactions. On the other hand, Cabernet-Sauvignon wine (Figure 2B) showed no significant difference in prodelphinidin concentration between 7 d and 14 d maceration treatments. Significantly higher gallocatechin and epigallocatechin concentrations were observed with increasing grape maturity for Cabernet-Sauvignon wine. Extended maceration led to significantly lower concentrations of gallocatechin and epigallocatechin. In Cabernet-Sauvignon wine, the parameters gallocatechin and epigallocatechin had higher contributions to PC2, which segregated the wine by grape maturity, than to PC1, which segregated the wine by maceration time. Gallocatechin and epigallocatechin are found in grape skins suggesting that the extractability of skin tannins into the wine increased during grape ripening due to de-pectination (del Llaudy *et al.,* 2008; Garrido-Bañuelos *et al.,* 2019).

The stronger influence of maceration time on late-harvest wines, as seen in the sensory data (Figure 1), was not evident in phenolic composition (Figure 2). Most of the sensory descriptors that contributed to a shift on the PC2 axis were aroma descriptors such as herbaceous, spices or berries (Figure 1A), and eucalyptus/ethereal or dark fruit (Figure 1B).

Figures 3A and 3B show the anthocyanin concentrations of Pinot noir and Cabernet-Sauvignon wines. In general, anthocyanin concentrations increased with progressing grape maturity and decreased with extending maceration time in both grape varieties. The difference in anthocyanin

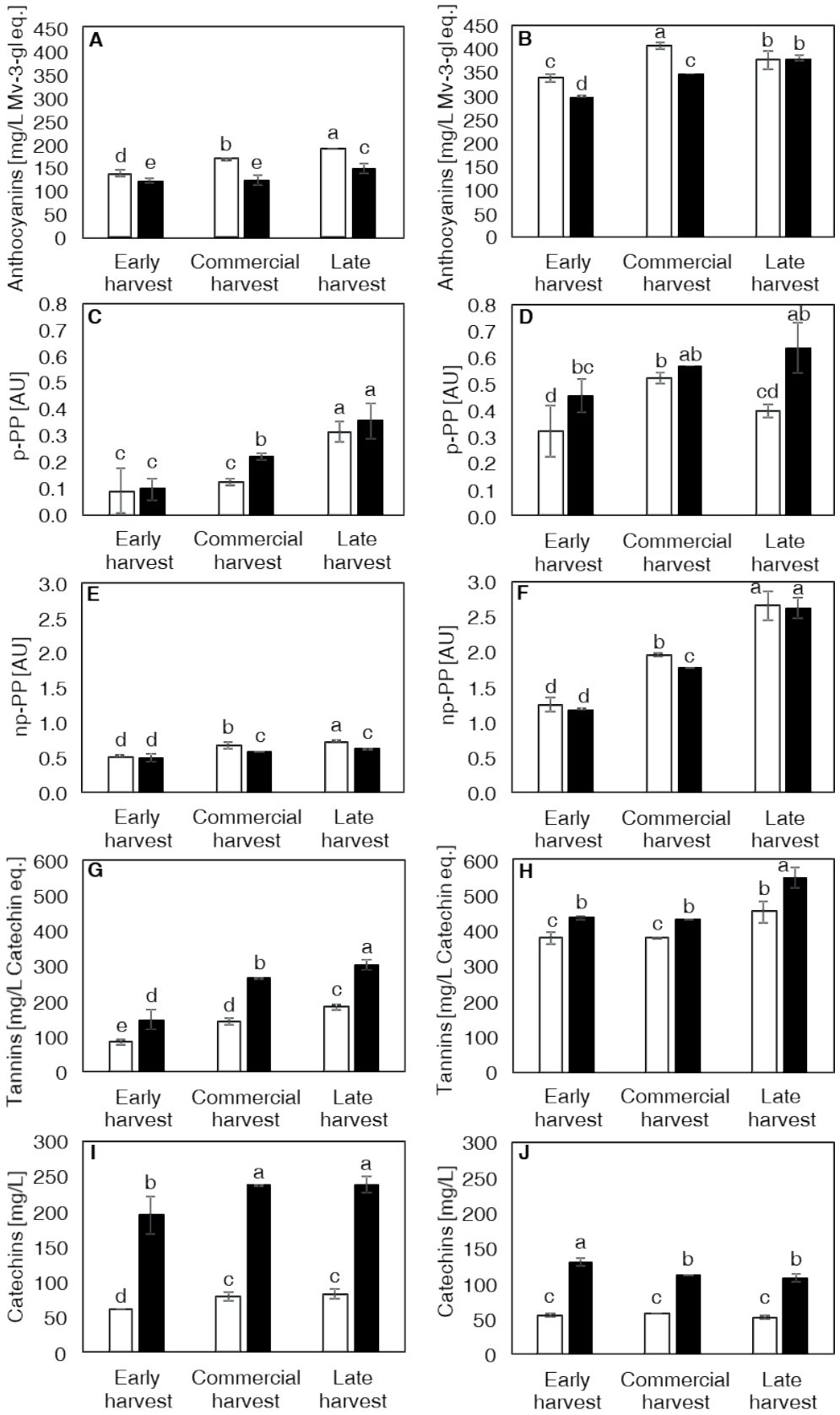


FIGURE 3. Polyphenol concentrations in Pinot noir (A, C, E, G, I) and Cabernet-Sauvignon (B, D, F, H, J) wines produced from grapes of different maturity levels and with 7 d maceration (white bars) and 14 d maceration (black bars). (A, B) Anthocyanins [mg/L Mv-3-gl eq.]; (C, D) p-PP [AU]; (E, F) np-PP [AU]; (G, H) Tannins [mg/L Catechin eq.]; (I, J) Catechins [mg/L]. The data presented are the mean (± SD) of the experimental replicates (n = 2); values sharing the same letter are not significantly different at $p \leq 0.05$.

concentrations between Point noir and Cabernet-Sauvignon outweighed the effects of grape maturity and maceration time. The increase of anthocyanins with progressing grape maturity was most pronounced for 7 d maceration in Pinot noir and 14 d maceration in Cabernet-Sauvignon. Although Pinot noir and Cabernet-Sauvignon differ in their absolute anthocyanin concentrations, the de-pectination process with progressing grape maturity (Garrido-Bañuelos *et al.,* 2019) might explain why anthocyanins are more readily extracted during winemaking for both varieties. Remarkably, 7 d maceration of Cabernet-Sauvignon reached a maximum in anthocyanins at commercial harvest and slightly decreased towards late-harvest. The peak of anthocyanin concentration of Cabernet-Sauvignon at commercial harvest indicates that anthocyanins can be broken down if the grapes become overripe (Ribéreau-Gayon *et al.,* 2006). Another explanation could be an increased adsorption of anthocyanins on the cell wall material as the surface of the cell walls increases with progressing maturity (Bindon *et al.,* 2014b).

When extending maceration time, a significant decrease in anthocyanins was observed irrespective of grape maturity for both varieties. This is in agreement with the study by Casassa *et al.* (2013b) and with the sensory results described earlier showing that purple hue decreased when extending maceration. Extended maceration promotes polymerisation reactions of monomeric anthocyanins and therefore decreases anthocyanins. Casassa *et al.* (2013a) observed a significant relationship between the decrease in anthocyanins and the increase of precipitable polymeric pigments in extended maceration wines.

Globally, p-PP increased with progressing grape maturity (Figures 3C and 3D) and with extended maceration in both grape varieties. This observation is in agreement with the findings of Casassa *et al.* (2013b). Harbertson *et al.* (2009) suggested that higher tannin concentrations due to extended maceration favour p-PP formation. However, 7 d maceration of Cabernet-Sauvignon reached a maximum in p-PP at commercial harvest and slightly decreased towards late-harvest. The same observation was made with anthocyanin concentration. It is thought that p-PP formation is dependent on anthocyanin concentration. Therefore, the assumed anthocyanin breakdown in overripe grapes (Ribéreau-Gayon *et al.,* 2006) is also visible in p-PP.

Increasing np-PP concentrations can be observed with progressing grape maturity, especially in Cabernet-Sauvignon (Figure 3F). In contrast, the influence of grape maturity in Pinot noir was very little (Figure 3E). The effect of maceration time was less distinct than the influence of grape maturity. This was also indicated in Figure 2 where np-PP had a high contribution to PC2 which segregated the wines by grape maturity. In both grape varieties extended maceration led to significantly lower np-PP. This observation is in agreement with the observations made by Casassa *et al.* (2013b). Studies by Adams *et al.* (2004) and Casassa *et al.* (2013b) assumed that np-PP is a heterogeneous mixture of anthocyanin-derived products such as acetaldehyde cross-linked oligomers or cycloaddition products, which are unable to precipitate with proteins. On the other hand, p-PP were assumed to be pigmented tannin-anthocyanin polymers. A shorter maceration time, indicating lower tannin concentrations would, therefore, favour the formation of np-PP as the anthocyanin to tannin ratio is higher.

Figures 3G and 3H show the tannin concentrations in the wines. Tannin concentrations were significantly higher with increasing grape maturity as well as with extended maceration time, irrespective of the grape variety. These observations support the theory discussed earlier with p-PP data that higher tannin concentrations with increasing grape maturity and extending maceration time might enhance p-PP formation. It is assumed that higher tannin concentrations with increased grape maturity and extended maceration time led to higher ratings of dry astringency in the 14 d late-harvest wines of both grape varieties. Casassa *et al.* (2013b) suggested that an increased tannin concentration in late-harvest Merlot wines resulted from higher tannin extractability from seeds.

Monomeric catechins were highest in Pinot noir wine (Figure 3I). A significantly higher concentration of catechins was observed for extended maceration time and—to a smaller extent—progressing grape maturity. An enhanced seed extraction when extending maceration time was also observed by others (del Llaudy *et al.,* 2008; Gil *et al.,* 2012). Similar, but less pronounced than in Pinot noir, extending maceration time also increased monomeric catechins in Cabernet-Sauvignon (Figure 3J). No effect of grape maturity was observed in the 7 d maceration wine of Cabernet-Sauvignon. The 14 d maceration wine showed even a negative trend with progressing grape maturity. For both grape varieties, the effect of maceration time on the catechin concentrations was more distinct than the effect of grape maturity. Monomeric catechins are not suitable to indicate grape maturity because of the contrasting behaviour of different grape varieties. *Vice versa*, catechins can exhibit high resolution for the effect of maceration time.

CONCLUSION

Maceration time affected sensory characteristics and phenolic composition of Pinot noir and Cabernet-Sauvignon wine differently than grape maturity. Extended maceration neither compensated for grape immaturity nor enhanced the effects of immaturity. Changes in the phenolic composition with progressing grape maturity and extending maceration time were reflected in the wine colour as well as in taste and tactile ratings in the sensory evaluation of the wines. Skin-associated phenolics such as anthocyanins and polymeric pigments correlated with grape maturity, while extended maceration enhanced the extraction of seed-associated phenolics such as monomeric catechins, procyanidins and procyanidin gallates. Concentrations of anthocyanins and polymeric pigments are suggested as suitable indicators for grape maturity in wine. Concentrations of monomeric catechins and procyanidins are good indicators for maceration time.

ACKNOWLEDGEMENTS

This research project was supported by the German Federal Ministry of Economic Affairs and Climate Action (*via* AiF) and the FEI (Forschungskreis der Ernährungsindustrie e.V., Bonn) project AiF 20024N and internal funding of the University of Applied Sciences Kaiserslautern. The authors would like to thank Daniel Munder for his support in producing the wines. Participation in the sensory panel is gratefully acknowledged.

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