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Research Article

Investigating Winemaking Potential of Enchantment, a New *Vitis* Hybrid Teinturier Cultivar

Sarah E. Mayfield,[1] Renee T. Threlfall,[1]* Dorothea Leis,[2] Luke R. Howard,[1] Erich Leitner,[2] and John R. Clark[3]

[1]Department of Food Science, University of Arkansas, 2650 N. Young Ave., Fayetteville, AR 72704; [2]Institute of Analytical Chemistry and Food Chemistry, Graz University of Technology, Streymayrgasse 9, 8010 Graz, Austria; and [3]Department of Horticulture, University of Arkansas, 316 Plant Sciences Building, Fayetteville, AR 72701.

*Corresponding author (rthrelf@uark.edu; tel: 479-575-4677; fax: 479-575-6936)

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Abstract: Enchantment is a *Vitis* hybrid released from the University of Arkansas System Division of Agriculture (UA System) wine-grape breeding program in 2016. This new teinturier cultivar has potential for producing high-quality wines. The effects of oak addition (no oak, American oak, and French oak) and storage on Enchantment wine attributes were evaluated in 2017 and 2018. Enchantment grapes were harvested in August of both years for wine production. The 2017 and 2018 wines were analyzed initially (0-months) for basic chemistry, anthocyanin, color, and aroma attributes, and 2017 wines were analyzed during storage (0, 6, and 12 months at 15°C) for basic chemistry, anthocyanin, and color attributes. Regardless of oak additions, initial chemistries of wines in both years were typical for dry wines and remained stable during storage. In both years,

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malvidin-3-glucoside was the predominant anthocyanin in Enchantment wine, and malvidin-3-glucoside, petunidin-3-glucoside, and delphinidin-3-glucoside composed over 80% of total anthocyanin content. Although anthocyanins decreased during storage, the deep, red color of the wine remained stable. In 2018, wines had a deeper red, darker color than 2017 wines, and this corresponded with higher anthocyanin levels in 2018. There were about 50 volatile aroma compounds identified in Enchantment wines. There was minimal impact of oak treatment on basic chemistry and anthocyanin, but some impact on color attributes. However, oak addition greatly impacted aroma attributes, resulting in wines with oaky, roasted, and caramelized aroma compounds in both years. These results demonstrated the potential of Enchantment wine grapes for producing deeply red-colored single varietal wines and blends with oaking and storage potential.

Key words: anthocyanins, color, oak, teinturier, volatile aroma compounds

Introduction

Vitis vinifera grapevines are highly vulnerable to pests, diseases, and extreme temperatures and are difficult to grow in much of the United States. Hybrids (crosses of two or more *Vitis* species) are generally better adapted to surviving stressors that devastate *V. vinifera* grapes (Reisch et al. 2012). The University of Arkansas System Division of Agriculture (UA System) has a fruit breeding program that was established in 1964. This program began breeding wine grapes over 40 years ago, with a goal to develop new hybrid wine grape cultivars that grow well in Arkansas and similar regions, have unique and desirable attributes, and are suitable for winemaking. In 2016,

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the first hybrid wine grape cultivars, Opportunity (white-wine cultivar) and Enchantment (red-wine cultivar) were released from the UA System.

The Enchantment grapevine produces teinturier berries with a dark purple color in the skin, flesh, and juice of the grape and shows potential for regions that have limited productivity of red-wine cultivars. Clark et al. (2018) discussed the breeding background as well as plant, grape, and wine attributes of Enchantment in a release publication. The female parent of Enchantment, Ark. 1628, was a cross between *V. vinifera* cultivars Petite Sirah and Alicante Bouschet, and the male parent, Ark. 1481, was a cross between *V. vinifera*-derived cultivars Bouschet Petite and Salvador. Alicante Bouschet, Bouschet Petite, and Salvador are also teinturier cultivars. In evaluations from 1998-2015, Enchantment grapevines displayed hardiness for growth in the Arkansas climate, the potential to withstand disease pressures of the region, acceptable fruit yield for commercial production, and berries with good composition for winemaking. Wines have been produced from Enchantment grapes at the UA System Department of Food Science since 1998 using small-scale winemaking techniques. In these preliminary trials, wines showed acceptable composition for a red table wine and a deep-red color.

The primary anthocyanin in Enchantment grapes and wine was malvidin-3-glucoside, which is also the primary anthocyanin in *V. vinifera* cultivars (Clark et al. 2018). Malvidin-3-glucoside, and other monoglucoside anthocyanins, are more stable than the diglucoside anthocyanins typically found in hybrid grapes and wine (Cheynier et al. 2006, He et al. 2012, Zhu et al. 2012). Although the color of young red wine is due to monomeric flavylium anthocyanins and their associated copigment complexes, the color contribution from monomeric anthocyanins decreases over time (de Freitas et al. 2017). During aging, anthocyanins participate in three major

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reactions that can influence wine color: direct polymerization between anthocyanins and tannins, indirect polymerization between anthocyanins and tannins via acetaldehyde, and formation of pyranoanthocyanins (Li and Duan 2019). These reactions create compounds/adducts that are more resistant to hydration and sulfite bleaching and less sensitive to degradation. Therefore, such "polymeric pigments" are important for color of aged red wines (Escribano-Bailón and Santos-Buelga 2012, de Freitas et al. 2017). Unlike monoglucoside anthocyanins, diglucoside anthocyanins are unable to form such polymeric pigments, and thus tend to produce wines with less stable color (Cheynier et al. 2006, He et al. 2012; Zhu et al. 2012). Because of its intense color and *vinifera*-like anthocyanin composition, Enchantment shows potential to be used in blending to improve wine color quality. Other teinturier cultivars, including Alicante Bouschet, a parent of Enchantment, are commonly used in blending to increase color of wine produced from lighter-colored cultivars (Revilla et al. 2016).

In sensory evaluations, Enchantment wines were described as having a fruity aroma similar to that of Syrah and some vegetal characteristics (Clark et al. 2018). It was proposed that Enchantment wines could benefit from addition of oak during wine production. Aging wine in contact with oak can increase complexity through extraction of woody, smoky, spicy, and vanilla aromas (Singleton 1995, Alencar et al. 2019). Oak staves and chips can be used as alternatives to oak barrels, as they are less expensive and more suitable for production of smaller volumes. These "barrel alternatives" can give wines similar complexity and aromatic character as barrel aging (Eiriz et al. 2007). Cano-López et al. (2008) evaluated the impact of barrel alternatives (oak powder, shavings, and cubes) on sensory attributes of red wines aged in stainless steel tanks. In general, oak aging improved quality of wines and increased fruity, vanilla, woody, spicy, and

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smoky aromas. Panelists were able to distinguish between control wines and wines with oak shavings or cubes, and wines aged with oak shavings had the highest overall aroma quality. American oak (*Quercus alba*) and French oak (*Q. alba* and *Q. petraea*) are the species most commonly used for wine production (Singleton 1995). American oak typically has higher concentrations of oak lactones and possesses more noticeable woody character than French oak (Masson et al. 1995). Alencar et al. (2019) evaluated the impact of American and French oak chips on Syrah wine sensory attributes. Wines produced with American oak had greater woody characteristics, whereas wines produced with French oak had more vanilla characteristics.

While the most noticeable effect of maturing wine in contact with oak is the extraction of aroma compounds, oak contact can also impact wine pigments and color (Li and Duan 2019). The primary non-volatile components extracted into wine from oak are ellagitannins. Chassaing et al. (2009) demonstrated that oak ellagitannins interact with wine anthocyanins to produce purple-colored ellagitannin-anthocyanin complexes, which were proposed to cause a red-to-purple shift during oak aging. Ellagitannins can be degraded and hydrolyzed to ellagic acid, which can enhance wine copigmentation and protect phenolic compounds from oxidation (Cadahía et al. 2001, Jordão et al. 2006, Zhang et al. 2017). In addition, certain volatile compounds extracted into wine from oak can react with wine phenolics to produce pigment complexes that alter wine color. This could include the brick-red oaklin pigments from oak cinnamic aldehydes and wine flavanols (de Freitas et al. 2004, Sousa et al. 2012) and the orange-red pyranoanthocyanins from oak 4-vinylguaiacol and wine anthocyanins (Fulcrand et al. 1996, Schwarz et al. 2003). Multiple studies have evaluated the impact of oak barrel aging and barrel alternatives on wine color, measured through spectrophotometric techniques. Del Álamo Sanza et al. (2004) determined that red wines aged with

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barrel alternatives had higher yellow-to-red color ratios than wines aged in traditional oak barrels, and wines aged with French oak had higher yellow color than American-oaked wines. In general, wine lost color due to oak aging, relative to unoaked wines, in particular the red color component, while the yellow color component increased. Similarly, del Alamo et al. (2000) observed a decrease in red color and an increase in yellow color of red wines with increasing barrel aging times. Although the aforementioned studies showed a loss in color quality of red wines due to oak aging, sensory studies have shown that such color differences were not perceivable (Cano-López et al. 2008, Alencar et al. 2019).

Although Enchantment grapes and wine have been preliminarily evaluated in viticultural and winemaking trials for over 20 years, there has been no published research on the impact of winemaking techniques, such as oak additions, on wine attributes. Since Enchantment grows well in Arkansas and similar regions, the objective of this study was to investigate winemaking potential of Enchantment, a *Vitis* hybrid teinturier cultivar.

Materials and Methods

Grape harvest.

Enchantment grapes were grown in an experimental vineyard at the UA System Fruit Research Station in Clarksville, AR (USDA hardiness zone 7b) in the Ozark Mountain American Viticultural Area. The soil type was Linker fine sandy loam (fine-loamy, siliceous, semi-active, thermic Typic Hapludult). The grapes were grown on a high-wire bilateral cordon system on own-rooted, variable-age vines. Approximately 50 kg of Enchantment wine grapes were hand harvested from 10 vines in August 2017 and 2018 for small-scale (approximately 23 L) wine production.

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Harvest date was determined based on ideal composition attributes for Arkansas red-wine grapes, as well as past harvest data, weather, and quality of fruit. Average daily temperature and rainfall for January-August 2017 and 2018 were recorded in Clarksville, AR. The grapes were taken to the UA System Food Science Department in Fayetteville, AR and stored at 4°C overnight for wine production the following day.

Wine production.

In 2017 and 2018, Enchantment wines were produced in a traditional red-wine style prior to oak addition and bottling. A single batch of wine was produced each year and was split later for oak treatments in duplicate. Winemaking procedures were kept as similar as possible for both years. Grapes were crushed/destemmed, and 30 mg/L sulfur dioxide (SO_2) as potassium metabisulfite (KBMS) was added at crush. In 2017, grapes were harvested on August 17 and had 14.6% soluble solids (SS), pH 3.14, and 0.84% w/v (g tartaric acid/100 mL juice) titratable acidity (TA). In 2018, grapes were harvested on August 8 and had 17.3% SS, pH 3.81, and 0.70% TA. The SS (expressed as %) of the must was determined using a Bausch & Lomb Abbe Mark II refractometer (Scientific Instruments, Keene, NH), and the pH and TA of musts were measured using a Metrohm 862 Compact Titrosampler (Metrohm AG, Herisau, Switzerland) fitted with a pH meter. Adjustments were made to the musts to ensure complete fermentation. SS levels of musts were adjusted to 21% using table sugar (sucrose) in both years, and in 2018 the TA of must was adjusted through tartaric acid additions to 0.9% to reduce the pH below 3.6 for fermentation.

Musts were inoculated with Lalvin ICV D254® wine yeast (Lallemand, Inc., Montreal, Canada) at a rate of 0.26 g/L and fermented on the skins for four days at 15°C. At the onset of fermentation, 20 g/hL Fermaid® O yeast nutrient (Lallemand, Inc.) was added to musts. Four days

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of skin contact time was used for this study based on previous winemaking experience with Enchantment. This allowed extraction of compounds from skins without over-extracting tannins and phenolics. After four days, musts were pressed with a 70-L Enoagricola Rossi Hydropress (Calzolaro, Italy) using three 10-minute press cycles and a pressure of 207 kPa. The wine was collected in a 22.7-L glass carboy fitted with a fermentation lock. Fermentation continued at 15°C for approximately six months. Wines were racked several times during fermentation. After fermentation was complete, free SO_2 content of wines was determined using the aeration-oxidation method (Iland et al. 1993) and adjusted to 60 mg/L. No further additions of tartaric acid were needed since the pH of the wine was below 3.6.

The wine was split into six 3.8-L glass jars for oak treatment, with two replications for each treatment. The oak additions included a control (no oak), French oak, and American oak. Innerstave medium-toast French oak and American oak staves (38.3 x 1.5 x 1.5 cm; Innerstave, LLC, Sonoma, CA) were placed in the wines, and wines were aged on oak for two months at 15°C. Prior to bottling, free SO_2 levels were again measured and adjusted to 60 mg/L. Wines were bottled into 125-mL glass bottles, sealed with plastisol-lined lug caps, and stored at 15°C until analysis. Wines were stored at 15°C for one week prior to the initial (month 0) analysis to account for any bottle shock effects.

In 2017 and 2018, wines were analyzed at 0-months storage for basic chemistry, anthocyanin, color, and aroma attributes, and the 2017 wines were analyzed during storage (0, 6, and 12 months at 15°C) for basic chemistry, anthocyanin, and color attributes. Basic chemistry attributes of wines included pH, TA, glycerol, ethanol, individual and total residual sugars, and individual and total organic acids. Anthocyanin attributes included individual and total

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anthocyanins. Color attributes included L*, a*, b*, red color (abs 520 nm), yellow/brown color (abs 420 nm), and color density (abs 520 nm + abs 420 nm). Basic chemistry, anthocyanin, and color attributes for each sample were analyzed in duplicate. Aroma attributes included identification of volatile compounds and determination of relative peak areas. Aroma attributes for each sample were analyzed in triplicate. The composition, anthocyanin, and color attributes were evaluated at the UA System Food Science Department (Fayetteville, AR), and the aroma attributes were evaluated at the Graz Technical University Institute of Analytical Chemistry and Food Chemistry (Graz, Austria).

Composition attributes analysis.

pH and titratable acidity. The pH and TA of Enchantment wines were measured using a Metrohm 862 Compact Titrosampler fitted with a pH meter. The probe was left in samples for two minutes to equilibrate before recording the pH value. The TA of wines were expressed as % w/v (g/100 mL) tartaric acid. Six grams of sample was weighed, then 50 mL degassed, deionized water was added to the sample, and the sample was titrated with 0.1 N sodium hydroxide to an endpoint of pH 8.2. Wine was degassed prior to analysis.

Glycerol, ethanol, residual sugars, and organic acids. The glycerol, ethanol, residual sugars, and organic acids in Enchantment wines were identified and quantified according to the HPLC procedure of Walker et al. (2003). Samples were passed through a 0.45 μm polytetrafluoroethylene (PTFE) syringe filter (Varian, Inc., Palo Alto, CA, USA) before injection onto an HPLC system consisting of a Waters 515 HPLC pump, a Waters 717 plus autosampler, and a Waters 410 differential refractometer detector connected in series with a Waters 996 photodiode array (PDA) detector (Water Corporation, Milford, MA, USA). Analytes were

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separated with a Bio-Rad HPLC Organic Acids Analysis Aminex HPX-87H ion exclusion column (300 x 7.8 mm) connected in series with a Bio-Rad HPLC column for fermentation monitoring (150 x 7.8 mm; Bio-Rad Laboratories, Hercules, CA). A Bio-Rad Micro-Guard Cation-H refill cartridge (30 x 4.5 mm) was used as a guard column. Columns were maintained at a temperature of 65 ± 0.1°C by a temperature control unit. The isocratic mobile phase consisted of pH 2.28 aqueous sulfuric acid at a flow rate of 0.45 mL/min. Injection volumes of both 10 µL (for analysis of organic acids and sugars), and 5 µL (for ethanol and glycerol) were used to avoid overloading the detector. The total run time per sample was 60 minutes. Citric, tartaric, malic, lactic, and succinic acids were detected at 210 nm by the PDA detector, and glucose, fructose, ethanol, and glycerol were detected at 410 nm by the differential refractometer detector.

Analytes in samples were identified and quantified using external calibration curves based on peak area estimation with baseline integration. Results were expressed as mg analyte per 100 mL wine for organic acids and sugars, grams per liter wine for glycerol, and % v/v for ethanol. Total residual sugars was calculated as the sum of glucose and fructose, and total organic acids was calculated as the sum of tartaric, malic, lactic, citric, and succinic acids.

Anthocyanin attributes analysis.

Anthocyanin quantification. Anthocyanins in Enchantment wines were quantified using the HPLC-PDA method of Cho et al. (2004). Samples were passed through a 0.45 µm PTFE syringe filter before injection onto a Waters Alliance HPLC system equipped with a Waters model 996 PDA detector and Millennium version 3.2 software. A 4.6 x 250 mm Symmetry® C_{18} column (Waters Corporation) preceded by a 3.9 mm x 20 mm Symmetry® C_{18} guard column was used to separate analytes. The mobile phase consisted of a binary gradient with 5% (v/v) formic acid in

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water (solvent A) and methanol (solvent B) at a flow rate of 1.0 mL/min. A gradient was used with 2% to 60% B from 0-60 minutes, 60% to 2% B from 60-65 minutes, then holding at 2% B from 65-80 minutes. A 50 µL injection volume was used, and total run time per sample was 80 minutes. Anthocyanins were detected at 510 nm.

Anthocyanins were quantified as anthocyanidin-3-glucoside equivalents of their major aglycone (cyanidin, delphinidin, peonidin, petunidin, or malvidin) using external calibration curves based on peak area estimation with baseline integration. Results were expressed as mg/100 mL wine. Total anthocyanins were determined by summing concentrations of individual anthocyanin compounds.

Anthocyanin identification. Anthocyanins in Enchantment wines were identified according to the HPLC-electrospray ionization (ESI)-mass spectrometry (MS) method of Cho et al. (2004). An HPLC-ESI-MS system equipped with an analytical Hewlett Packard 1100 series HPLC instrument (Hewlett-Packard Enterprise Company, Palo Alto, CA), an autosampler, a binary HPLC pump, and a UV/VIS detector interfaced to a Bruker Esquire LC/MS ion trap mass spectrometer (Bruker Corporation, Billerica, MA) was used to identify anthocyanins. Reverse-phase separation of anthocyanins was conducted using the same HPLC conditions previously described for anthocyanin quantification, and absorption was recorded at 510 nm. Mass spectral analysis was operated in positive ion electrospray mode with a capillary voltage of 4000 V, a nebulizing pressure of 30.0 psi, a drying gas flow of 9.0 mL/min, and a temperature of 300°C. Data was collected with Bruker software in full scan mode over a range of *m/z* 50-1000 at 1.0 seconds per cycle. Characteristic ions were used for peak assignment.

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Color attributes analysis.

L, a*, and b*.* Enchantment wine L*, a*, and b* color analysis was conducted using a ColorFlex system (HunterLab, Reston, VA). This system had a ring and disk set (to control liquid levels and light interactions) for measuring translucent liquids in a 63.5-mm glass sample cup with an opaque cover to determine Commission Internationale de l'Eclairage (CIE) Lab transmission values of L*, a*, and b* (Commission Internationale de l'Eclairage 1986). The vertical axis L* measured lightness from completely opaque (0) to completely transparent (100), while on the hue-circle, +a* red, -a* green, +b* yellow, and -b* blue were measured.

Red color, yellow/brown color, and color density. Red color of Enchantment wines was measured spectrophotometrically as absorbance at 520 nm, and yellow/brown color was measured as absorbance at 420 nm. Color density was calculated as red color + yellow/brown color (Iland et al. 1993). Absorbance values were measured using a Hewlett-Packard 8452A Diode Array spectrophotometer equipped with UV-Visible ChemStation software (Agilent Technologies, Inc., Santa Clara, CA). Samples were diluted 10 times with deionized water prior to analysis and were measured against a blank sample of deionized water. A 1-cm cell was used for all spectrophotometer measurements.

Aroma attributes analysis.

Volatile aroma profiles of wines were determined according to the headspace (HS)-solid-phase microextraction (SPME)-gas chromatography (GC)-MS method of Kraujalytė et al. (2012). Volatile compounds were extracted from 1 mL of wine in a 20-mL glass vial using SPME with a 2-cm stable flex divinylbenzene/carboxen/polydimethylsiloxane (DVB/CAR/PDMS) fiber for 30 minutes at 40°C. The samples were thermostated at 40°C for 10 minutes before exposing the fiber

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for enrichment of the volatiles. A GC-MS system equipped with a Shimadzu GC 2010 (Shimadzu Corporation, Kyoto, Japan), Shimadzu QP 2010 MS, and a PAL HTX autosampler (CTC Analytics AG, Zwingen, Switzerland) was used to separate and identify volatile compounds. Samples were extracted/injected in analytical triplicate. Volatiles were separated on a nonpolar Restek Rxi 5MS column (30 m x 0.25 mm x 1 μm; Restek, Bellefonte, PA) with a temperature gradient program: 30°C (hold 1 min) to 230°C at 5°C/min then to 280°C (hold 1 min) at 20°C/min in constant flow mode with a linear velocity of 35 cm/min. Data was recorded in the scan mode (*m/z* 35-350) with a 9.8 minute solvent cut time and a detector voltage relative to the tuning result.

Data was analyzed using the Shimadzu GCMS Solution Analysis software (Version 4.45). Compounds were identified using comparison of mass spectra with NIST14 (National Institute of Standards and Technology, Gaithersburg, MD), Flavors and Fragrances of Natural and Synthetic Compounds (FFNSC3, John Wiley & Sons, Inc., Hoboken, NJ), and Adam's Essential Oils (Adams 2007) mass spectral libraries. A series of n-alkanes from C8 to C20 were measured under identical conditions to calculate Kovats retention indices (Kováts 1958) of volatile compounds in wine samples. The identities of compounds were confirmed by comparison of calculated retention indices with values reported in the Flavornet (Acree and Arn 2004) and Pherobase (Sayed 2003) databases. A matching library result and a retention index within ±20 of previously reported values was considered a positive identification. Total ion chromatogram (TIC) peak areas were used to determine the relative peak areas (%) for each compound.

Experimental design and statistical analysis.

In both years, a single batch of wine was fermented, and after fermentation wines were split into three oak treatments (no oak, American oak, and French oak) in two replications.

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Duplicate treatments were used in this study because fruit was obtained from the UA System Fruit Research Station experimental vineyard, and there was not enough fruit to produce more wines while maintaining reasonable fermentation volumes. There were six samples (3 oak treatments x 2 replications) when wines were analyzed at 0-months storage, and there were 18 samples in 2017 when wines were analyzed during storage (0-, 3-, and 6-months). At each storage time for basic chemistry, anthocyanin, color, and aroma attributes, samples were taken from one 125-mL bottle. Statistical analyses were conducted using JMP® Pro statistical software (version 15.0.0, SAS Institute, Cary, NC).

Basic chemistry, anthocyanin, and color attributes. For 2017 and 2018 wines at 0-months storage, a univariate analysis of variance (ANOVA) was used to determine the significance of the main factors, year and oak treatment, and their interaction. Tukey's honest significant difference (HSD) was used to detect differences among means ($p<0.05$). For the 2017 wines during storage, a univariate mixed-model with a first-order autoregressive (AR1) covariance structure was used to conduct a repeated measures in time analysis, with individual experimental units (wines) as the subjects in a repeated structure for storage time. For the fixed effects (storage and oak), an ANOVA was used to determine significance of the main factors and their interaction. All factors were treated as categorical. Tukey's HSD was used to detect differences among means ($p<0.05$) for the fixed effects.

Aroma attributes. Relative peak areas (%) for each positively identified compound in 2017 and 2018 Enchantment wines at 0-months storage were used for principal components analysis (PCA). Each compound was assigned a chemical compound class and a general aroma category based on aroma descriptors reported in the Flavornet (Acree and Arn 2004) and Pherobase (Sayed

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2003) databases. The relative peak areas of compounds within each compound class and aroma category were summed to create general variables. This was done so that the model did not overfit to noise, which occurs when the number of parameters is greater than the number of variables. PCAs were conducted based on the compound class and aroma category variables and were used to explore the relationship between oak treatments and volatile aroma profiles.

Results and Discussion

The 2017 and 2018 wine grape production seasons in Clarksville, AR were relatively mild in terms of temperature and rainfall. The high and low temperatures were similar from January to August in both years with higher rainfall in 2017 than 2018 from April (budbreak on grapevines) to July prior to harvest. In August of 2017 and 2018, the average daily high temperature was 28.6°C and 30.0°C, respectively. In August, there was less cumulative monthly rainfall in 2017 (198.5 mm) than 2018 (281.7 mm).

The grapes were harvested in August of both years for wine production. After about eight months of fermentation and aging on oak for two months, the wines were bottled in May and stored at 15°C. In 2017 and 2018 Enchantment wines, the impacts of year and oak addition on all attributes (basic chemistry, anthocyanin, color, and aroma) were evaluated at 0-months storage. In 2017 Enchantment wines, the basic chemistry, anthocyanin, and color attributes were evaluated during storage (0-, 6-, and 12-months storage at 15°C).

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Basic chemistry, anthocyanin, color, and aroma attributes at 0-months storage (2017 and 2018).

The impact of oak treatment on basic chemistry, anthocyanin, color, and aroma attributes was mostly consistent between the two years in which the study was replicated. The year had a major impact on most attributes, whereas oak addition mainly impacted color and aroma attributes.

Basic chemistry attributes. Enchantment wines were analyzed for pH, TA, glycerol, ethanol, glucose, fructose, total residual sugars, tartaric acid, malic acid, citric acid, succinic acid, lactic acid, and total organic acids (Table 1). Of the basic chemistry attributes, the year x oak interaction was only significant for citric acid. The year impacted all basic chemistry attributes except glycerol and ethanol. The 2018 wines had a lower pH and higher TA than 2017 wines. Oak treatment was also significant for pH, although there was very little variation in pH values among oak treatments. Glycerol and ethanol contents of Enchantment wines fell within the ranges of 7-10 g/L glycerol and 11-14% ethanol reported for dry table wines (Liu and Davis 1994, Alston et al. 2011).

There was no impact of oak treatment on residual sugar concentrations of Enchantment wines. Wines from 2017 had higher glucose, fructose, and total residual sugar levels than 2018 wines. The residual sugar levels in all wines were less than 1% and were similar to concentrations of 50-100 mg/100 mL glucose and 20-400 mg/100 mL fructose reported by Liu and Davis (1994) for dry table wines.

Wine from 2017 had higher concentrations of each individual acid and total organic acids than 2018 wines. For the year x oak interaction, there was no difference among oak treatments for citric acid levels of 2018 wines. In 2017, French-oaked wines had higher citric acid than unoaked

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or American-oaked wines, and 2017 wines had higher citric acid than all 2018 wines. In general, concentrations of tartaric, malic, and lactic acids in Enchantment wines were within reported ranges of 200-600 mg/100 mL tartaric acid, 200-700 mg/100 mL malic acid, and 0-300 mg/100 mL lactic acid for dry table wines (Fowles 1992, Sowalsky and Noble 1998, Da Conceicao Neta et al. 2007). However, concentrations of citric and succinic acids were higher than reported ranges of 10-70 mg/100 mL citric acid and 50-100 mg/100 mL succinic acid for dry table wines (Fowles 1992, Sowalsky and Noble 1998, Da Conceicao Neta et al. 2007).

Anthocyanin attributes. Enchantment wines were analyzed for individual and total anthocyanins. Table 2 shows the anthocyanins identified in Enchantment wines, including the monoglucosides and their acetyl and coumaryl derivatives. It was of note that only anthocyanin monoglucosides, and not their diglucoside counterparts, were detected in Enchantment wines. The native and hybrid wines that typically grow well in Arkansas and the mid-South United States contain significant amounts of diglucoside anthocyanins (Pastrana-Bonilla et al. 2003, Zhu et al. 2012). Unlike monoglucosides, diglucosides are unable to form copigment and acylated complexes and are thus more susceptible to bisulfite bleaching or hydration (Cheynier et al. 2006, He et al. 2012, Zhu et al. 2012). In both years, malvidin-3-glucoside was the predominant anthocyanin in Enchantment wines, followed by petunidin-3-glucoside and delphinidin-3-glucoside. García-Beneytez et al. (2003) and Revilla et al. (2016) evaluated anthocyanin distribution in young red wines from the teinturier grape Alicante Bouschet and found that while malvidin-3-glucoside was the predominant anthocyanin, peonidin-3-glucoside was the second-most prevalent, followed by petunidin-3-glucoside. Alicante Bouschet is a parent of Enchantment, which also had malvidin-3-glucoside as the predominant anthocyanin.

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The concentrations of anthocyanin compounds in Enchantment wines are shown in Supplemental Table 1 and Figure 1. Total anthocyanin levels were similar to the levels of 44-164 mg/100 mL reported by Revilla et al. (2016) for young Alicante Bouschet wines. There have been multiple studies evaluating the anthocyanin profile of Syrah wines. Syrah is a parent of Petite Sirah (Syrah x Peloursin), and Petite Sirah is a parent of Enchantment (Meredith et al. 1999). Gómez-Míguez and Heredia (2004), Gutiérrez et al. (2005), and Gómez-Míguez et al. (2007) reported 53 mg/100 mL, 65 mg/100 mL, and 22 mg/100 mL total anthocyanins, respectively, in young Spanish Syrah wines. The lower anthocyanin levels in Syrah wines compared to Enchantment wines in the present study are logical, as Enchantment is a teinturier grape and thus produces wines with high anthocyanins and deeper color (Santiago et al. 2008).

The year x oak interaction was not significant for anthocyanin attributes, but year was significant for all anthocyanin attributes except peonidin-3-glucoside (Figure 1). Enchantment wines from 2018 had higher concentrations of malvidin-3-glucoside, petunidin-3-glucoside, delphinidin-3-glucoside, total anthocyanins, total acylated anthocyanins, and total coumaryl anthocyanins, and 2017 wines had higher concentrations of cyanidin-3-glucoside, though levels were low. The generally higher anthocyanin levels in 2018 wines could have been due to the 2018 grapes being riper at harvest, as evidenced by higher SS and pH values. In addition, environmental factors, such as temperature, pests, or rain, could have caused the difference in anthocyanin levels between the two years (Kliewer 1977, Spayd et al. 2002).

Oak treatment did not impact anthocyanin levels of Enchantment wines, which contrasted previous studies. Del Alamo-Sanza et al. (2006) evaluated the anthocyanin content of Spanish red wines aged in oak barrels or with oak chips and staves. There was a quicker loss of monomeric

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anthocyanins in the wines aged with oak alternatives than in wines aged in barrels, and French-oaked wines had slightly higher anthocyanin levels at the end of oak aging than American-oaked wines. Similarly, del Álamo Sanza et al. (2004) observed lower anthocyanin concentrations in Spanish red wines aged with oak alternatives than those aged in oak barrels, but no difference among oak species was reported.

Color attributes. Enchantment wines were evaluated for L*, a*, b*, red color (abs 520 nm), brown/yellow color (abs 420 nm), and color density (red color + yellow/brown color) (Supplemental Table 2 and Figure 2). The year x oak interaction was significant for L* (Figure 2a). All 2018 wines had lower L* (darker color) than 2017 wines. In 2018, French-oaked wine had a darker color than American-oaked or unoaked wines. There was no difference among oak treatments for L* in 2017 wines. The year and oak treatment impacted a* and b*. Enchantment wines from 2018 had higher a* (higher red color) and higher b* (higher yellow color) than 2017 wines, indicating a higher overall color intensity. French-oaked wines had higher a* and b* than unoaked wines, and unoaked wines had higher values than American-oaked wines. This was consistent with results of Alencar et al. (2019), who found that wines aged with French oak chips displayed an 18% increase in a* relative to wines with American oak chips and unoaked wines, and a 25-29% increase in b*. The year x oak interaction was also significant for red color (Figure 2b). All 2018 wines had higher red color than 2017 wines, but there were no differences among oak treatments within either year. The year main effect was significant for brown/yellow color and color density, and 2018 wines had lower brown/yellow color and higher color density than 2017 wines. The higher red color and color density and lower brown/yellow color of 2018 wines could indicate that these wines had a more desirable color, consistent with their higher anthocyanin

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levels. The color density values for both 2017 and 2018 Enchantment wines in this study were higher than the average color density of 19.1 reported by Revilla et al. (2016) for young Alicante Bouschet wines.

There were only slight differences among oak treatments for color attributes of Enchantment wines. Previous studies have reported an impact of oak exposure on red wine color. Del Álamo Sanza et al. (2004) observed that French-oaked wines had higher yellow color than American-oaked wines. This was consistent with higher b* values of French-oaked Enchantment wine in the present study. Jindra and Gallander (1987) and Revilla and González-SanJosé (2001) also concluded that impact of oak contact on wine color can depend on species of oak. Del Álamo Sanza et al. (2004) observed an increase in the yellow-to-red color ratio of wines aged with barrel alternatives, relative to wines aged in traditional oak barrels, and concluded that barrel alternatives can alter chromatic characteristics of red wine more rapidly than barrels. However, Cano-López et al. (2008) determined that sensory panelists could not detect a difference in color among red wines aged with barrel alternatives and those aged in oak barrels. Similarly, Alencar et al. (2019) saw no effect of oak chip addition on perceived color of Syrah wines, despite slight impacts of oak addition on spectrophotometric measurements.

Teinturier wines, such as Alicante Bouschet, are often used in wine blends to increase color of wines made from lighter-colored cultivars (Revilla et al. 2016). Li et al. (2020) evaluated effects of blending wines with less desirable color with varieties that had more ideal color attributes. All blended wines had higher color intensity and red color than control wines. As anthocyanin content and color of Enchantment wines were similar to those reported for Alicante Bouschet wines by Revilla et al. (2016), Enchantment could potentially be used in wine blends to improve color. This

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would be especially significant for wines produced from grapes grown in the mid-South United States, where Enchantment grapevines have been shown to grow well (Clark et al. 2018). The grape cultivars typically produced in this region have less stable anthocyanins than *V. vinifera* grapes, and therefore struggle with color loss during aging (Cheynier et al. 2006, He et al. 2012, Zhu et al. 2012).

There have been multiple studies evaluating impact of wine blending on wine sensory attributes. García-Carpintero et al. (2010) produced blends from three Spanish red varieties and performed descriptive analysis. All blends were rated higher for desirable sensory attributes and complexity than single varietal wines. Similarly, Singleton and Ough (1962) evaluated the effect of blending on perceived complexity of 34 blends of two similar wines. All blends were rated higher than the lower-scoring wine of each pair on its own, and higher ratings were attributed to increases in complexity of blended wines. Other studies have shown that adding 10% of either Graciano or Cabernet Sauvignon to Tempranillo wines lead to a visual color difference, and that blends had higher overall ratings than single varietal Graciano, Cabernet Sauvignon, and Tempranillo wines (Monagas et al. 2006a, 2006b). Therefore, using Enchantment wine in blends with less-intensely-colored varieties may increase overall complexity of wines, along with improving color.

Aroma attributes. There were 52 volatile aroma compounds identified in 2017 Enchantment wines and 50 compounds identified in 2018 wines. Table 3 shows the compounds identified in wines, their compound class, measured retention index, retention indices previously reported for each compound, aroma category each was grouped into, more detailed aroma descriptors, and TIC peak area of each compound in wines within each oak treatment and year.

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Compounds included chemical, floral, fruity, green/fat, roasted/caramelized, and vegetal alcohols, floral, green/fat, and roasted/caramelized aldehydes, vegetal alkyl sulfides, chemical benzothiazoles, fruity, green/fat, and unpleasant carboxylic acids, floral and fruity esters, chemical ethers, roasted/caramelized furans, fruity glycols, green/fat and vegetal ketones, oaked lactones, and floral, fruity, and herbal/spicy terpenes.

The esters were the largest class of compounds in all wines. Esters are characteristic byproducts of alcoholic fermentation and are critical for aroma of most wines. While some esters, such as ethyl esters, are relatively stable in wines during storage, acetate esters in particular decrease with time (Ramey and Ough 1980, Waterhouse et al. 2016) As Enchantment wines were analyzed at 0-months storage for aroma attributes, it is rational that esters were predominant. Oak lactone, an aliphatic γ-lactone extracted into wine during contact with oak, was only identified in 2017 American-oaked wines, and not in 2017 French-oaked wines or 2018 wines.

PCA was used to reduce dimensionality of the data and to elucidate relationships between compound classes and aroma categories and oak treatments. The relative TIC peak areas (%) were summed for compounds within each compound class and aroma category. The PCAs showed distinctions among oak treatments in 2017 and 2018 for compound classes and aroma categories.

When a PCA was conducted on compound class variables (Figure 3a), two components explained 83% of the variation in the data. PC1 (69.6%) had positive loadings for benzothiazoles, alkyl sulfides, glycols, alcohols, terpenes, lactones, aldehydes, furans, and all 2017 wines, regardless of oak treatment. Ethers, esters, ketones, carboxylic acids, and all 2018 wines loaded negatively on PC1. This indicated that there was a difference between 2017 and 2018 wines based on relative abundance of different classes of compounds. It was likely that 2018 wines had a greater

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amount of esters. PC2 (13.5%) had positive loadings for carboxylic acids, terpenes, alcohols, and 2017 and 2018 unoaked wines. Aldehydes, lactones, and 2017 and 2018 American- and French-oaked wines loaded negatively on PC2. Therefore, there was a clear separation between oaked and unoaked wines based on compound class variables.

When a PCA was conducted on aroma category variables (Figure 3b), two components explained 89% of the variation in the data. PC1 (66.3%) had positive loadings for vegetal, chemical, floral, herbal/spicy, roasted/caramelized, unpleasant, and oaked aroma categories, and all 2017 wines, regardless of oak treatment. Fruity and green/fat aroma categories and all 2018 wines loaded negatively on PC1. This indicated that there was a clear distinction between 2017 and 2018 wines based on distribution of their volatile compounds among different aroma categories. The association of 2018 wines with fruity aromas was consistent with their association with esters in the compound class PCA. Esters are characteristic byproducts of yeast during alcoholic fermentation, and their production is influenced by factors such as must composition, oxygen availability, and temperature (Waterhouse et al. 2016). Although must composition and fermentation conditions were kept consistent among years, slight variations in such factors could explain the difference in relative ester content between 2017 and 2018 Enchantment wines.

In Figure 3b, PC2 (22.5%) had positive loadings for unpleasant and herbal/spicy aroma categories and 2017 and 2018 unoaked wines. Roasted/caramelized and oaked aroma categories and 2017 and 2018 American- and French-oaked wines loaded negatively on PC2. The association of unoaked wines with unpleasant and herbal/spicy aromas was consistent with their association with carboxylic acids and terpenes, respectively, in the compound class PCA. The association of oaked wines with roasted/caramelized and oaked aromas was expected, as oak addition is known

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to impart such aromas to wines. In 2017, American-oaked wines had a very strong association with roasted/caramelized and oaked aromas, whereas 2017 French-oaked wines only had a weak association with these aroma categories. This correlation of American-oaked wines with traditional woody characteristics was supported by the results of Alencar et al. (2019), who evaluated the impact of American and French oak chip addition on sensory attributes of Syrah wines. Oak-aged wines had higher overall aromatic intensity compared to control wines, and wines produced with American oak chips had higher coffee, woody, and sweet/caramelized aroma than French-oaked wines. In a consumer test, wines produced with American oak chips were associated with “woody” characteristics, whereas wines produced with French oak chips were associated with “vanilla” characteristics. In 2018 Enchantment wines, there was no visible difference in the PCA plot between American- and French-oaked wines for aroma categories. Overall, these results suggested that oak addition could give Enchantment wines more complex, roasted, and “oaky” aromas than unoaked wines.

Basic chemistry, anthocyanin, and color attributes during storage (2017).

Storage had a major impact on basic chemistry, anthocyanins, and color attributes, whereas oak was not very influential. In most cases, the impact of storage did not depend on the oak treatment.

Basic chemistry attributes. The storage x oak interaction was not significant for any basic chemistry attributes, except malic acid, and the oak main effect did not impact any attributes (Supplemental Table 3). Storage impacted pH and TA of Enchantment wine, with pH increasing from 0- to 12-months storage, and TA decreasing from 6- to 12-months storage. However, all pH and TA values remained within the ranges of 3.3-3.7 pH and 0.5-0.65% TA for dry-red table wines

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(Waterhouse et al. 2016). Storage time had an effect on tartaric and citric acid. Tartaric acid concentration decreased from 0- to 6-months storage, consistent with the increase in pH. There was no difference among storage times for citric acid concentration.

Anthocyanin attributes. The storage x oak interaction and oak main effect were not significant for any anthocyanin attributes (Supplemental Table 4). Storage impacted all anthocyanin attributes (Figure 4). Individual and total anthocyanin concentrations decreased from 0- to 12-months storage, with the exception of total acylated and total coumaryl anthocyanins, which increased from 0- to 6-months storage and then decreased from 6- to 12-months storage. The malvidin-3-glucoside concentration decreased 64% and total anthocyanins decreased 61% over 12-months storage. This was likely due to the formation of compounds/adducts from monomeric anthocyanins that can influence and stabilize wine color during storage (Escribano-Bailón and Santos-Buelga 2012, de Freitas et al. 2017, Li and Duan 2019).

Color attributes. The storage x oak interaction was not significant for any color attributes except b*, but there were no differences among treatments (Supplemental Table 5). Storage impacted all color attributes except b*. There was no impact of oak treatment any color attributes except L*. Enchantment wines became darker during storage (decreasing L*), and French-oaked wines had a darker color than unoaked wines (Figure 5). Storage time was significant for a*, and the red color of wines increased (increasing a*) from 0- to 12-months storage. The red color and color density of Enchantment wines decreased from 0- to 6-months storage but had a slight (although insignificant) increase from 6- to 12-months storage (Figure 6). This was in contrast to the a* measurements, which showed red color increasing during storage. Brown/yellow color decreased from 0- to 12-months storage.

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Conclusions

In both 2017 and 2018, Enchantment wines had basic chemistry within acceptable ranges for a dry, red table wine, remaining mostly stable during one year of storage at 15°C. Only anthocyanin-3-glucosides, and not their diglucoside counterparts, were identified in Enchantment wines, with malvidin-3-glucoside as the predominant anthocyanin. Although red color and color density decreased slightly during 12-months storage, Enchantment wines maintained a deep red/purple color. There was minimal impact of oak treatment on basic chemistry and anthocyanins, but some impact on color attributes. The volatile aroma profiles of Enchantment wines were clearly distinguished by year and oak treatment, and oaked wines in both years were associated with higher amounts of oaky, roasted, and caramelized aroma compounds. Enchantment can be used to produce high-quality, deeply red-colored wines that can benefit from oak additions but also retain quality during storage. Enchantment shows potential as a teinturier wine grape for the mid-South United States as a single varietal or to enhance wine blends.

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Table 1 Effect of year (2017 and 2018) and oak treatment (no oak, American oak, or French oak staves) on basic chemistry attributes at 0-months storage of wines produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR.

Effects	**pH**	**Titratable acidity (%)[a]**	**Glycerol (g/L)**	**Ethanol (% v/v)**	**Glucose (mg/100 mL)**	**Fructose (mg/100 mL)**	**Total residual sugars (mg/100 mL)**	**Tartaric acid (mg/100 mL)**	**Malic acid (mg/100 mL)**	**Citric acid (mg/100 mL)**	**Succinic acid (mg/100 mL)**	**Lactic acid (mg/100 mL)**	**Total organic acids (mg/100 mL)**
Year													
2017	3.44 a[b]	0.62 b	7.85	11.15	53.46 a	184.93 a	238.39 a	580.50 a	458.96 a	233.37 a	715.46 a	303.41 a	2291.71 a
2018	3.25 b	0.70 a	7.82	11.17	39.03 b	100.67 b	139.70 b	412.92 b	218.39 b	172.37 b	361.74 b	95.50 b	1260.92 b
P value	***<0.0001***	***<0.0001***	*0.7732*	*0.8314*	***0.0019***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***0.0002***	***0.0107***	***<0.0001***
Oak													
No oak	3.34 b	0.66	7.76	11.03	41.78	124.50	166.28	478.56	351.78	192.94 b	573.51	245.71	1842.50
American oak	3.35 a	0.66	7.82	11.17	49.44	140.40	189.83	519.58	363.16	196.30 b	602.90	232.29	1914.23
French oak	3.34 ab	0.66	7.92	11.29	47.51	163.51	211.02	492.00	301.10	219.38 a	439.38	120.35	1572.22
P value	***0.0030***	*0.6703*	*0.2557*	*0.1212*	*0.2860*	*0.1469*	*0.1864*	*0.4786*	*0.0995*	***0.0056***	*0.1962*	*0.3287*	*0.3056*
Year x Oak													
2017 No oak	3.44	0.62	7.78	11.01	46.84	149.80	196.64	548.89	492.52	215.51 b	782.62	391.34	2430.87
2017 American oak	3.44	0.62	7.83	11.12	55.44	173.53	228.97	624.08	504.26	219.48 b	842.57	366.67	2557.06
2017 French oak	3.44	0.62	7.94	11.33	58.10	231.47	289.57	568.54	380.12	265.13 a	521.18	152.23	1887.19
2018 No oak	3.24	0.70	7.75	11.05	36.73	99.20	135.92	408.22	211.04	170.38 c	364.41	100.09	1254.13
2018 American oak	3.25	0.70	7.82	11.22	43.43	107.27	150.70	415.08	222.05	173.11 c	363.23	97.92	1271.39
2018 French oak	3.25	0.70	7.91	11.26	36.92	95.55	132.47	415.46	222.08	173.63 c	357.59	88.48	1257.25
P value	*0.0751*	*0.8734*	*0.9902*	*0.7842*	*0.4897*	*0.0832*	*0.1164*	*0.5691*	*0.0708*	***0.0106***	*0.2203*	*0.3937*	*0.3234*

[a] Expressed as % w/v (g/100 mL) tartaric acid.
[b] Connecting letters are only shown for attributes with significant differences among treatments. Means with different letters for each attribute within effects are significantly different ($p<0.05$) according to Tukey's Honest Significant Difference (HSD) test.

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Table 2 Anthocyanins identified in Enchantment wines at 0-months storage produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR (2018 and 2018).

Compound	**Molecular ion (*m/z*)**	**Characteristic fragment peak (*m/z*)**	**Relative composition (%)[a] 2017**	**2018**
Malvidin-3-O-glucoside	493	331	45.7	37.2
Petunidin-3-O-glucoside	479	317	20.4	14.8
Delphinidin-3-O-glucoside	465	303	14.7	11.7
Peonidin-3-O-glucoside	463	301	11.9	7.1
Cyanidin-3-O-glucoside	449	287	1.8	0.5
Malvidin-3-O-(6-O-acetyl)-glucoside	535	331	0.9	8.7
Petunidin-3-O-(6-O-acetyl)-glucoside	521	317	0.6	3.9
Delphinidin-3-O-(6-O-acetyl)-glucoside	507	303	0.8	1.7
Peonidin-3-O-(6-O-acetyl)-glucoside	505	301	0.2	2.1
Cyanidin-3-O-(6-O-acetyl)-glucoside	491	287	0.1	0.4
Malvidin-3-O-(6-O-*p*-coumaryl)-glucoside	639	331	1.8	6.3
Petunidin-3-O-(6-O-*p*-coumaryl)-glucoside	625	317	0.8	1.7
Delphinidin-3-O-(6-O-*p*-coumaryl)-glucoside	611	303	0.8	1.7
Cyanidin-3-O-(6-O-*p*-coumaryl)-glucoside	595	287	0.2	0.3

[a] Average relative composition (%) across oak treatments (no oak, American oak and French oak staves).

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Table 3 Volatile aroma compounds identified in unoaked, American-, and French-oaked wines at 0-months storage produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR (2017 and 2018).

						Relative peak area (%)[f]					
Compound[a]	**Compound class**	**Measured retention index[b]**	**Previously reported retention index[c]**	**Aroma category[d]**	**Aroma description[e]**	**2017- No oak**	**2017- American oak**	**2017- French oak**	**2018- No oak**	**2018- American oak**	**2018- French oak**
1-Pentanol	Alcohol	768	766	Fruity	Balsamic, fruit	1.05 ± 0.04	1.01 ± 0.05	0.98 ± 0.02	0.30 ± 0.03	0.28 ± 0.01	0.30 ± 0.01
4-Methyl-2-pentanol	Alcohol	835	807	Green/fat	Oil, green, wine	0.52 ± 0.06	0.48 ± 0.05	0.45 ± 0.07	0.24 ± 0.03	0.21 ± 0.02	0.23 ± 0.03
3-Methyl-1-pentanol	Alcohol	844	854	Fruity	Wine, cognac	12.72 ± 0.51	12.31 ± 0.64	11.90 ± 0.42	8.88 ± 0.28	8.29 ± 0.16	8.75 ± 0.19
Furfuryl alcohol	Alcohol	855	851; 866	Roasted/caramelized	Caramel	0.41 ± 0.03	0.41 ± 0.01	0.39 ± 0.02	0.07 ± 0.00	0.07 ± 0.01	0.07 ± 0.00
cis-3-Hexen-1-ol	Alcohol	856	857; 858	Green/fat	Grass, leaf	0.03 ± 0.01	0.03 ± 0.00	---	0.01 ± 0.01	0.00 ± 0.01	0.01 ± 0.01
1-Hexanol	Alcohol	867	851; 867	Green/fat	Green, herbal	0.03 ± 0.01	0.02 ± 0.02	0.03 ± 0.01	---	---	---
1-Heptanol	Alcohol	868	851; 867	Green/fat	Chemical, green, fresh	0.42 ± 0.01	0.31 ± 0.08	0.39 ± 0.02	0.54 ± 0.09	0.53 ± 0.02	0.57 ± 0.02
2-Heptanol	Alcohol	898	898; 925	Vegetal	Mushroom, herbal	0.15 ± 0.02	0.14 ± 0.01	0.12 ± 0.01	---	---	---
2-Ethylhexanol	Alcohol	1028	1032; 1037	Floral	Rose, citrus	0.07 ± 0.03	0.06 ± 0.01	0.06 ± 0.02	0.03 ± 0.01	0.03 ± 0.01	0.03 ± 0.01
Benzyl alcohol	Alcohol	1039	1039; 1043	Floral	Floral, fruit	---	---	---	1.43 ± 0.49	1.02 ± 0.14	0.99 ± 0.13
Octanol	Alcohol	1069	1070; 1072	Chemical	Chemical, metal	6.03 ± 0.13	5.83 ± 0.22	5.76 ± 0.11	6.08 ± 0.21	5.68 ± 0.14	6.06 ± 0.10
2-Phenylethanol	Alcohol	1122	1118; 1122	Floral	Honey, rose	0.09 ± 0.02	0.09 ± 0.01	0.02 ± 0.03	---	---	---
1-Nonanol	Alcohol	1171	1154; 1171	Green/fat	Fat, green	0.14 ± 0.04	---	---	0.11 ± 0.03	---	---
1-Decanol	Alcohol	1272	1263; 1272	Green/fat	Fat	0.02 ± 0.02	---	0.05 ± 0.02	0.07 ± 0.01	0.06 ± 0.01	0.07 ± 0.01
1-Undecanol	Alcohol	1374	1371; 1372	Fruity	Mandarin	---	0.22 ± 0.03	---	---	---	---
1-Dodecanol	Alcohol	1476	1473	Green/fat	Fat, wax	0.14 ± 0.01	0.13 ± 0.02	0.14 ± 0.00	---	---	---
Furfural	Aldehyde	834	829; 830	Roasted/caramelized	Almond, caramel	---	0.01 ± 0.02	---	---	---	---
5-Methylfurfural	Aldehyde	966	962; 978	Roasted/caramelized	Bread, almond	0.23 ± 0.02	0.22 ± 0.03	0.19 ± 0.03	0.13 ± 0.01	0.13 ± 0.02	0.11 ± 0.01
Benzaldehyde	Aldehyde	967	960; 961	Roasted/caramelized	Almond, caramel	0.29 ± 0.01	0.24 ± 0.03	0.26 ± 0.03	0.22 ± 0.04	0.21 ± 0.06	0.20 ± 0.04
Octanal	Aldehyde	1003	1004; 1006	Green/fat	Fat, soap, green	0.04 ± 0.01	0.04 ± 0.00	0.05 ± 0.01	---	0.06 ± 0.02	0.06 ± 0.01
Phenylacetaldehyde	Aldehyde	1052	1049	Floral	Floral, honey, rose	---	---	---	---	0.25 ± 0.02	0.34 ± 0.05
4-Methylbenzaldehyde	Aldehyde	1092	1079	Roasted/caramelized	Almond, caramel	---	---	---	---	0.77 ± 0.32	---
Nonanal	Aldehyde	1106	1104	Green/fat	Fat, citrus, green	2.32 ± 0.57	2.90 ± 0.55	2.84 ± 0.52	---	---	---
Decanal	Aldehyde	1208	1209	Green/fat	Soap, orange peel	---	1.77 ± 0.22	3.26 ± 0.27	---	3.65 ± 1.15	3.05 ± 0.23
Methionol	Alkyl sulfide	980	978	Vegetal	Cooked potato	0.60 ± 0.08	0.58 ± 0.05	0.57 ± 0.07	0.39 ± 0.04	0.39 ± 0.04	0.37 ± 0.07
Benzothiazole	Benzothiazole	1247	1240; 1243	Chemical	Gasoline, rubber	0.05 ± 0.01	0.06 ± 0.01	0.05 ± 0.01	---	---	---
Isovaleric acid	Carboxylic acid	832	834	Unpleasant	Sweat, cheese	0.11 ± 0.01	0.11 ± 0.00	0.11 ± 0.00	---	---	---
Octanoic acid	Carboxylic acid	1164	1179	Unpleasant	Sweat, cheese, fat	0.19 ± 0.10	0.26 ± 0.06	0.24 ± 0.08	0.69 ± 0.11	0.66 ± 0.07	0.80 ± 0.04
Decanoic acid	Carboxylic acid	1357	1373	Green/fat	Fat, soap	0.24 ± 0.03	0.23 ± 0.06	0.20 ± 0.04	---	---	---
Octanoic acid, 3-methylbutyl ester	Carboxylic acid	1447	1450	Fruity	Fruit, pineapple	0.50 ± 0.29	0.15 ± 0.17	0.30 ± 0.16	0.12 ± 0.01	0.13 ± 0.01	---
Ethyl isobutyrate	Ester	760	756; 762	Fruity	Strawberry	1.37 ± 0.12	1.36 ± 0.06	1.39 ± 0.14	1.34 ± 0.11	1.35 ± 0.21	1.28 ± 0.08
Isobutyl acetate	Ester	774	767; 776	Fruity	Apple, banana	0.28 ± 0.11	---	---	0.23 ± 0.05	---	---
Ethyl butanoate	Ester	800	800; 804	Fruity	Apple, strawberry, bubblegum	3.38 ± 0.45	3.60 ± 0.28	3.73 ± 0.33	3.92 ± 0.13	3.86 ± 0.35	3.94 ± 0.15
Ethyl 2-methylbutyrate	Ester	850	846	Fruity	Apple, strawberry	---	---	---	0.50 ± 0.02	0.45 ± 0.02	0.46 ± 0.01
Ethyl isovalerate	Ester	853	849; 854	Fruity	Anise, apple, black currant	1.12 ± 0.08	1.09 ± 0.04	1.07 ± 0.04	1.26 ± 0.04	1.16 ± 0.02	1.20 ± 0.04
Isoamyl acetate	Ester	876	876	Fruity	Banana, pear	2.20 ± 0.16	2.12 ± 0.15	2.08 ± 0.13	3.08 ± 0.10	2.95 ± 0.07	3.03 ± 0.07

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2-Methylbutyl acetate	Ester	878	880	Fruity	Fermented fruit, banana, rum	---	---	---	0.11 ± 0.00	0.11 ± 0.00	0.11 ± 0.00
Ethyl pentanoate	Ester	899	898; 900	Fruity	Fruit, yeast	0.08 ± 0.01	0.08 ± 0.00	0.08 ± 0.00	0.13 ± 0.01	0.12 ± 0.00	0.13 ± 0.00
Methyl hexanoate	Ester	924	934	Fruity	Fruit, fresh, paint thinner	0.18 ± 0.01	0.17 ± 0.01	0.18 ± 0.01	0.28 ± 0.01	0.26 ± 0.01	0.28 ± 0.01
Ethyl 3-hydroxybutyrate	Ester	934	935; 945	Fruity	Grape, coconut, marshmallow	0.08 ± 0.01	0.08 ± 0.01	0.08 ± 0.01	0.04 ± 0.00	0.04 ± 0.00	0.04 ± 0.00
Ethyl hexanoate	Ester	997	997; 1002	Fruity	Apple peel, strawberry, anise	5.87 ± 0.18	5.76 ± 0.26	5.95 ± 0.14	2.32 ± 0.10	2.23 ± 0.07	2.30 ± 0.06
Hexyl acetate	Ester	1011	1008; 1014	Fruity	Fruit, herb, wine	5.34 ± 0.85	5.47 ± 0.67	5.35 ± 0.67	9.51 ± 0.46	9.73 ± 0.53	9.60 ± 0.31
Ethyl 2-hexenoate	Ester	1043	1025	Fruity	Fruit	0.05 ± 0.01	0.05 ± 0.01	0.06 ± 0.01	0.50 ± 0.03	0.56 ± 0.07	0.48 ± 0.06
Ethyl 2-furoate	Ester	1054	1056	Fruity	Fruit, floral	0.10 ± 0.01	0.11 ± 0.01	0.10 ± 0.01	0.16 ± 0.02	0.17 ± 0.01	0.15 ± 0.01
Ethyl heptanoate	Ester	1096	1097	Fruity	Fruit	14.34 ± 0.62	13.67 ± 0.12	13.41 ± 0.27	16.36 ± 0.36	15.51 ± 0.18	15.72 ± 0.21
Diethyl succinate	Ester	1176	1167; 1179	Fruity	Wine, fruit, watermelon	0.42 ± 0.03	0.41 ± 0.04	0.43 ± 0.03	0.76 ± 0.05	0.69 ± 0.04	0.76 ± 0.04
Ethyl octanoate	Ester	1196	1195; 1198	Fruity	Fruit, floral	0.46 ± 0.02	0.45 ± 0.03	0.46 ± 0.01	0.60 ± 0.01	0.56 ± 0.02	0.60 ± 0.02
Isopentyl hexanoate	Ester	1250	1254	Fruity	Fruit	0.17 ± 0.05	0.16 ± 0.03	0.14 ± 0.01	0.15 ± 0.01	0.18 ± 0.01	0.15 ± 0.02
2-Phenylethyl acetate	Ester	1265	1260; 1265	Floral	Honey, floral, rose	25.45 ± 1.35	24.78 ± 0.53	25.13 ± 1.04	23.79 ± 0.40	23.35 ± 0.71	22.86 ± 0.32
Ethyl nonanoate	Ester	1294	1297	Fruity	Tropical fruit, rose	---	---	---	0.06 ± 0.01	0.05 ± 0.00	0.06 ± 0.00
Methyl decanoate	Ester	1324	1324; 1326	Fruity	Wine, fruit	0.10 ± 0.01	0.11 ± 0.00	0.10 ± 0.00	1.12 ± 0.03	1.03 ± 0.01	1.05 ± 0.02
Ethyl decanoate	Ester	1394	1394; 1398	Fruity	Grape	9.60 ± 0.38	9.44 ± 0.24	9.16 ± 0.32	12.27 ± 0.17	11.29 ± 0.25	11.85 ± 0.07
Isopentyl octanoate	Ester	1448	1444	Fruity	Fruit, pineapple	0.32 ± 0.02	0.32 ± 0.02	0.32 ± 0.02	0.28 ± 0.03	0.26 ± 0.01	0.28 ± 0.02
Ethyl dodecanoate	Ester	1594	1595	Fruity	Mango, leaf	---	---	---	0.28 ± 0.01	0.28 ± 0.01	0.27 ± 0.01
2,5-Diethyltetrahydrofuran	Furan	901	884	Roasted/caramelized	Caramel	---	---	---	0.13 ± 0.01	0.13 ± 0.01	0.12 ± 0.01
2,3-Butanediol	Glycol	781	769	Fruity	Fruit, onion	---	---	---	0.01 ± 0.01	0.03 ± 0.00	0.01 ± 0.01
2,3-Hexanedione	Ketone	784	786	Green/fat	Butter, cream, caramel	0.05 ± 0.00	0.05 ± 0.00	0.05 ± 0.01	0.05 ± 0.01	0.05 ± 0.00	0.05 ± 0.00
6-Methyl-5-hepten-2-one	Ketone	987	985	Vegetal	Mushroom, earthy	---	---	---	0.05 ± 0.00	0.05 ± 0.00	0.05 ± 0.00
Oak lactone	Lactone	1336	1321	Oaked	Coconut, floral	---	---	0.05 ± 0.01	---	---	---
p-Cymene	Terpene	1032	1026; 1027	Herbal/spicy	Herbal, spicy	2.26 ± 0.73	2.33 ± 0.49	2.05 ± 0.62	1.17 ± 0.26	0.90 ± 0.07	0.99 ± 0.08
Linalool	Terpene	1102	1100; 1103	Floral	Floral, lavender, Earl Grey tea	---	---	---	0.02 ± 0.02	0.03 ± 0.00	0.03 ± 0.01
alpha-Terpineol	Terpene	1204	1195; 1207	Herbal/spicy	Anise, mint, toothpaste	0.02 ± 0.00	---	---	---	---	---
Citronellol	Terpene	1230	1228; 1233	Floral	Rose, citrus, clove	---	0.51 ± 0.03	---	---	---	---
β-damascenone	Terpene	1402	1386; 1391	Fruity	Apple, rose, honey	0.14 ± 0.02	0.13 ± 0.02	0.13 ± 0.02	0.03 ± 0.00	0.03 ± 0.00	---

[a]Compounds were identified by comparison of mass spectra with NIST14 (National Institute of Standards and Technology, Gaithersburg, MD, USA), Flavors and Fragrances of Natural and Synthetic Compounds (FFNSC3, John Wiley & Sons, Inc., Hoboken, NJ, USA), and Adam's Essential Oils (Adams 2007) mass spectral libraries and comparison of calculated Kovats retention indices (Kováts 1958) with previously reported values.
[b]Retention indices were calculated as Kovats retention indices (Kováts 1958).
[c] Reported retention indices were obtained from the Flavornet (Acree and Arn 2004) and Pherobase (Sayed 2003) databases.
[d] Compounds were grouped into aroma categories based on aroma descriptors reported in the Flavornet (Acree and Arn 2004) and Pherobase (Sayed 2003) databases.
[e] Aroma descriptors were obtained from the Flavornet (Acree and Arn 2004) and Pherobase (Sayed 2003) databases.
[f] Peak areas were obtained from the total ion chromatogram (TIC). Error term represents standard deviation.

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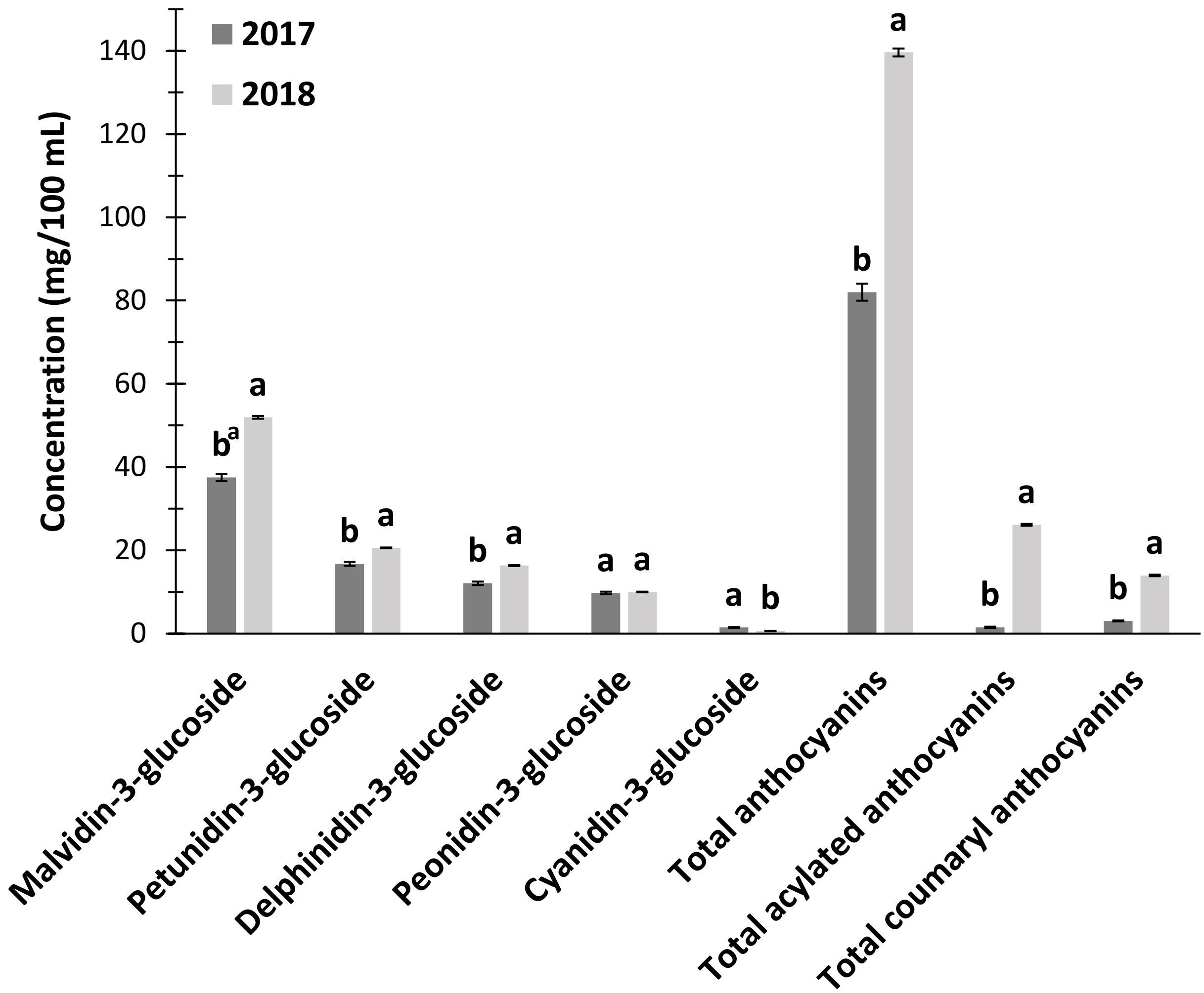

Figure 1 Effect of year (2017 and 2018) on anthocyanin attributes at 0-months storage of wines produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR.
[a] Error bars represent standard error. Means with different letters for each attribute are significantly different ($p<0.05$) according to student's t-test.

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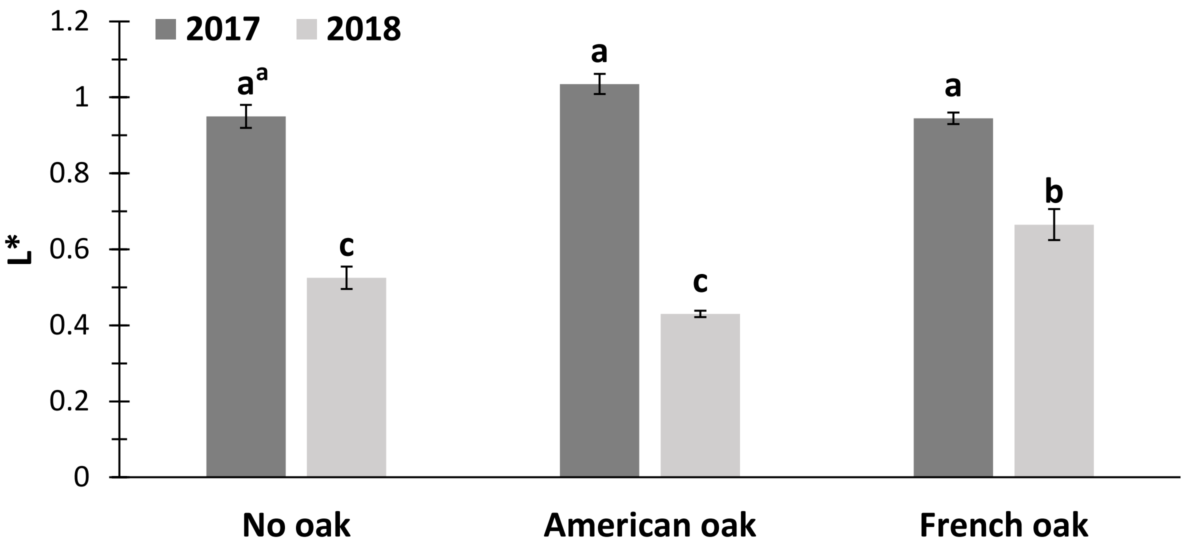
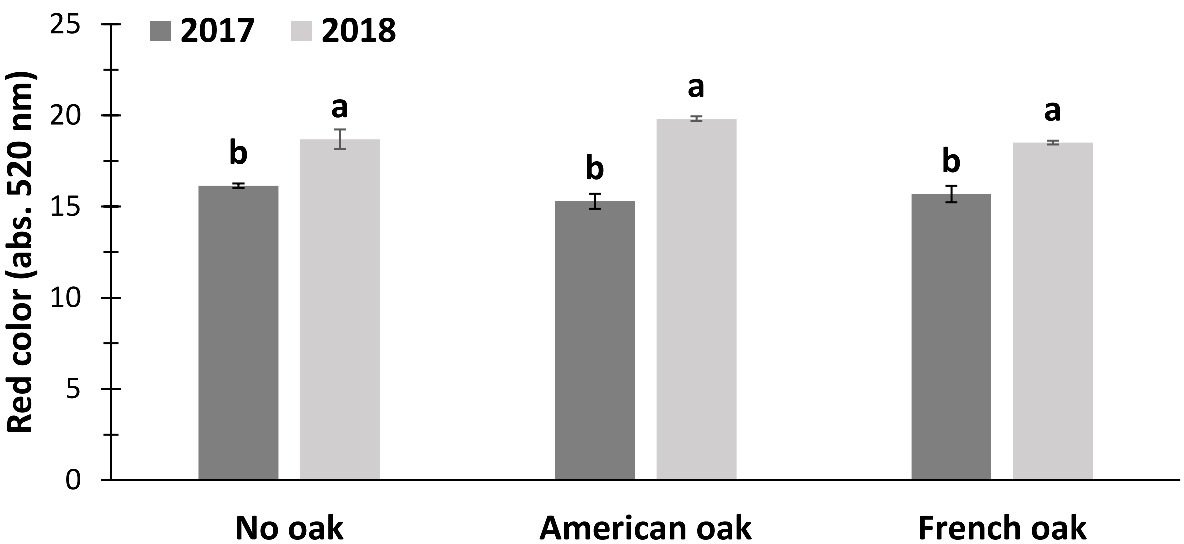


(a)



(b)

Figure 2 Effect of year (2017 and 2018) and oak treatment (no oak, American oak, or French oak staves) on L* (a) and red color (b) at 0-months storage of wines produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR.

[a] Error bars represent standard error. Means with different letters for each attribute are significantly different ($p<0.05$) according to Tukey's honest significant difference (HSD) test.

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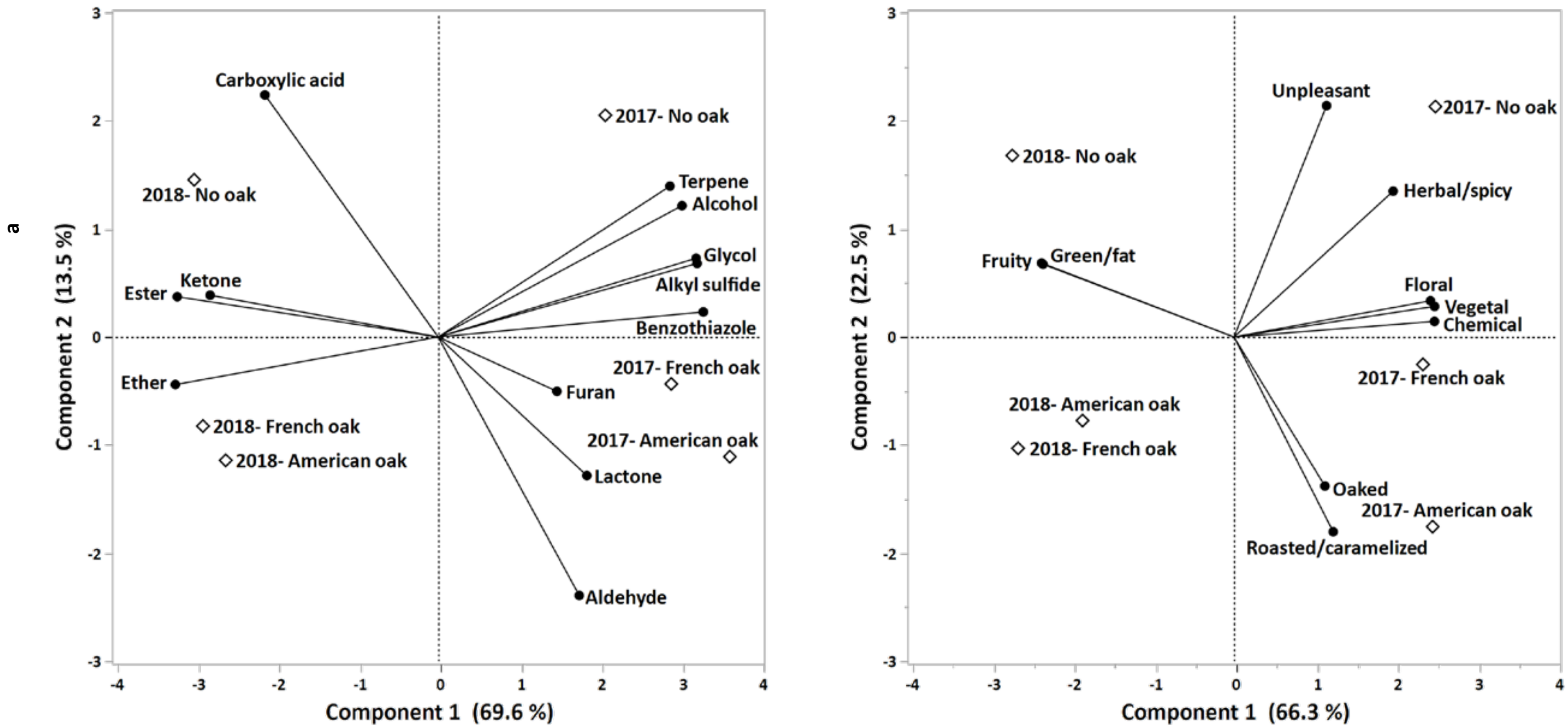

(a) (b)

Figure 3 Biplots from principal components analysis on volatile aroma compound classes[b] (a) and aroma categories[c] (b) in wines at 0-months storage at 15°C produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR (2017 and 2018).

[a] Percent of variation in data explained by each component.

[b] Compound class variables represent the sum of the total ion chromatogram (TIC) relative peak areas (%) of positively identified compounds within each compound class (Table 5).

[c] Aroma category variables represent the sum of the total ion chromatogram (TIC) relative peak areas (%) of positively identified compounds within each aroma category (Table 5).

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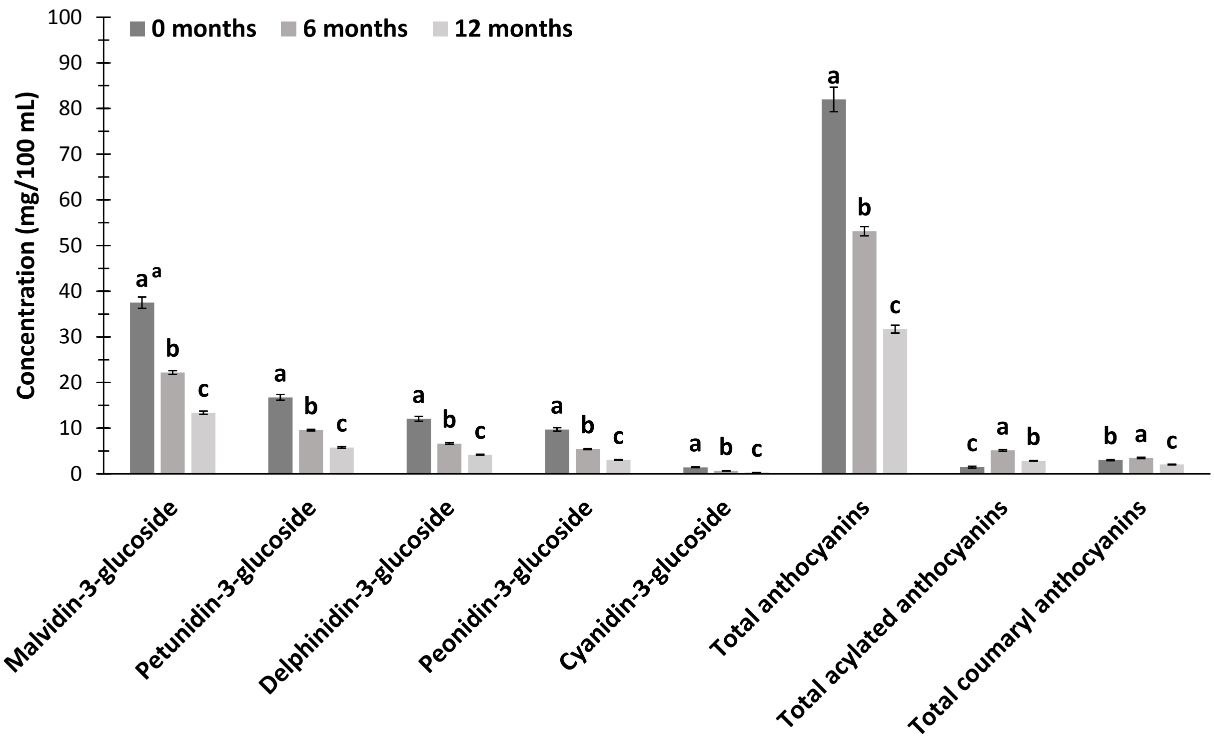

Figure 4 Effect of storage (0, 6, and 12 months at 15°C) on anthocyanin attributes of wines produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR (2017).
[a] Error bars represent standard error. Means with different letters for each attribute are significantly different (p<0.05) according to Tukey's honest significant difference (HSD) test.

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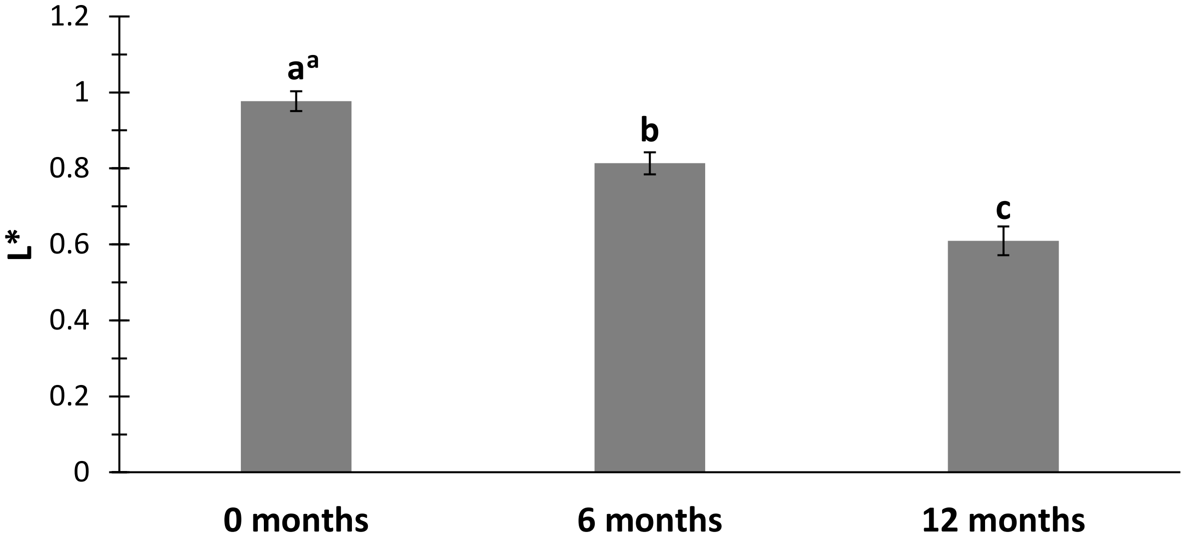
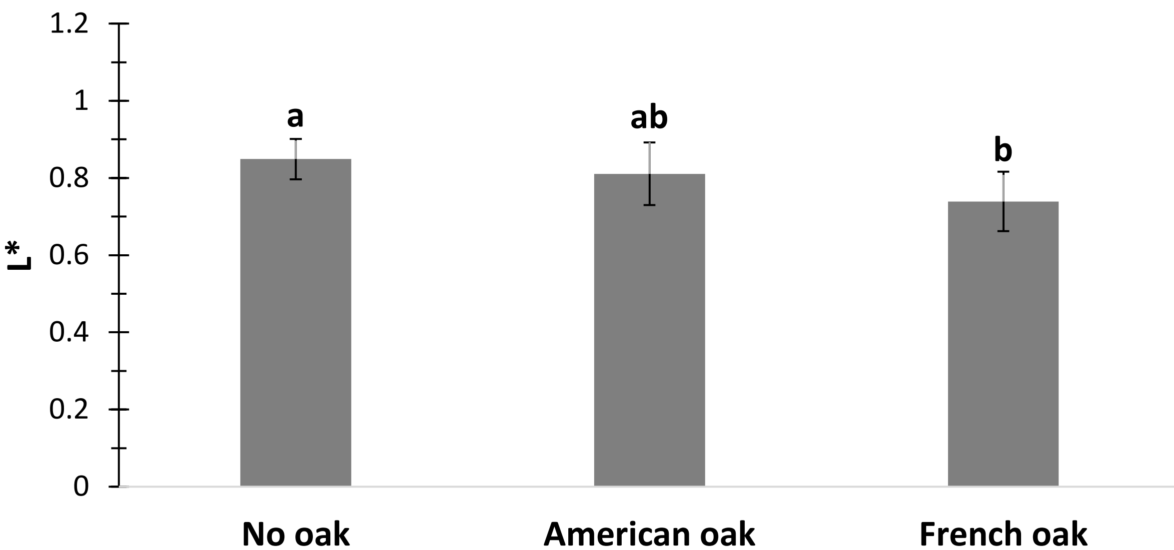


(a)



(b)

Figure 5 Effect of storage (0, 6, and 12 months at 15°C) (a) and oak treatment (no oak, American oak, or French oak staves) (b) on L* of wines produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR.
[a] Error bars represent standard error. Means with different letters within each effect are significantly different ($p<0.05$) according to Tukey's honest significant difference (HSD) test.

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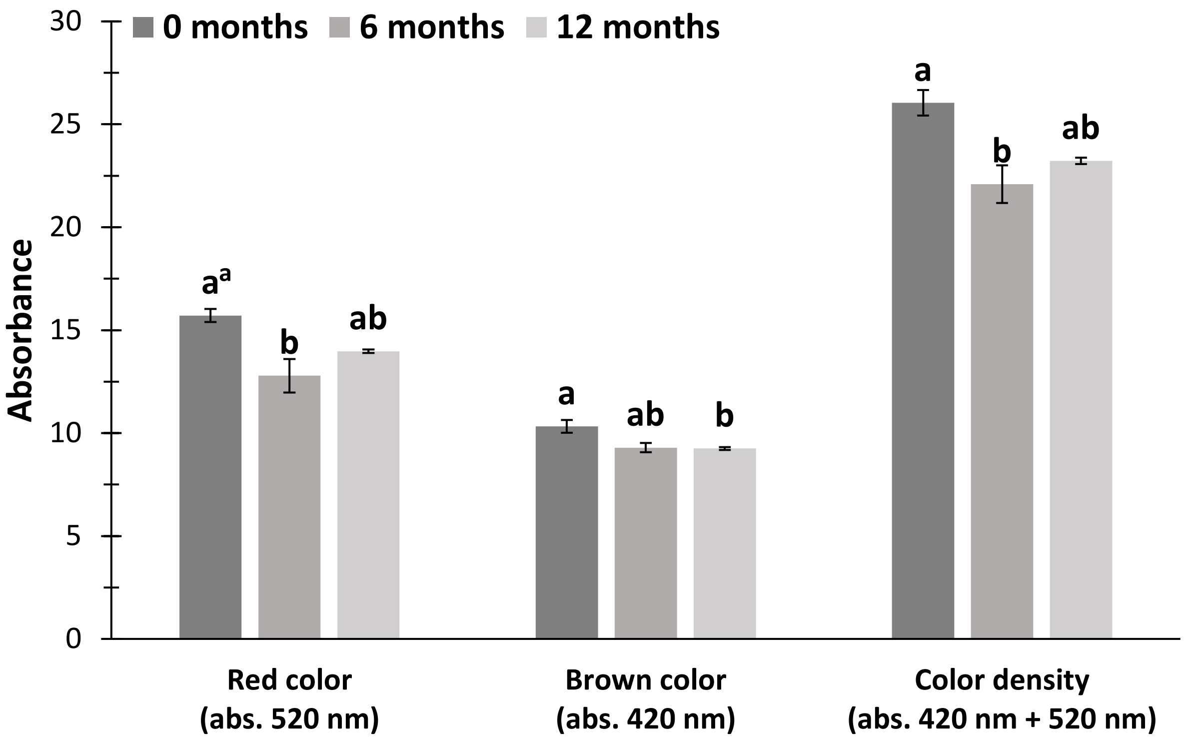

Figure 6 Effect of storage (0, 6, and 12 months at 15°C) on red color, brown/yellow color, and color density of wines produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR.

[a] Error bars represent standard error. Means with different letters for each attribute are significantly different ($p<0.05$) according to Tukey's honest significant difference (HSD) test.

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or edited or formatted, but may be cited by DOI. The final version may contain substantive or nonsubstantive changes.

Supplemental Table 1 Effect of year (2017 and 2018) and oak treatment (no oak, American oak, or French oak staves) on anthocyanin attributes at 0-months storage of wines produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR.

Effects	Malvidin-3-glucoside (mg/100 mL)	Petunidin-3-glucoside (mg/100 mL)	Delphinidin-3-glucoside (mg/100 mL)	Peonidin-3-glucoside (mg/100 mL)	Cyanidin-3-glucoside (mg/100 mL)	Total anthocyanins (mg/100 mL)	Total acylated anthocyanins (mg/100 mL)	Total coumaryl anthocyanins (mg/100 mL)
Year								
2017	37.49 b[a]	16.75 b	12.06 b	9.73	1.45 a	81.98 b	1.49 b	3.02 b
2018	51.95 a	20.60 a	16.32 a	9.98	0.67 b	139.60 a	26.13 a	13.95 a
P value	***<0.0001***	***<0.0001***	***<0.0001***	*0.4583*	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***
Oak								
No oak	44.74	18.52	14.05	9.73	1.00	111.04	14.22	8.78
American oak	44.44	18.66	14.19	9.97	1.10	110.29	13.48	8.47
French oak	44.97	18.84	14.35	9.87	1.07	111.04	13.73	8.21
P value	*0.9069*	*0.8865*	*0.8798*	*0.8465*	*0.7600*	*0.9557*	*0.0814*	*0.1149*
Year x Oak								
2017 No oak	36.79	16.27	11.59	9.30	1.34	80.20	1.82	3.09
2017 American oak	38.02	16.99	12.34	10.17	1.55	83.72	1.50	3.17
2017 French oak	37.65	16.99	12.27	9.72	1.45	82.04	1.15	2.81
2018 No oak	52.69	20.78	16.51	10.16	0.66	141.87	26.62	14.47
2018 American oak	50.86	20.33	16.04	9.76	0.66	136.87	25.45	13.76
2018 French oak	52.29	20.69	16.42	10.02	0.70	140.05	26.31	13.62
P value	*0.4612*	*0.6580*	*0.5856*	*0.3167*	*0.7694*	*0.3481*	*0.1749*	*0.3078*

[a] Connecting letters are only shown for attributes with significant differences among treatments. Means with different letters for each attribute within effects are significantly different (p<0.05) according to Tukey's Honest Significant Difference (HSD) test.

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Supplemental Table 2 Effect of year (2017 and 2018) and oak treatment (no oak, American oak, or French oak staves) on color attributes at 0-months storage of wines produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR.

Effects	**L***	**a***	**b***	**Red color (abs 520 nm)**	**Brown/yellow color (abs 420 nm)**	**Color density[a]**
Year						
2017	0.98 a[b]	1.35 b	0.37 b	15.71 b	10.33 a	26.04 b
2018	0.54 b	2.41 a	0.47 a	19.01 a	8.98 b	27.99 a
P value	***<0.0001***	***<0.0001***	***0.0206***	***<0.0001***	***<0.0001***	***0.0010***
Oak						
No oak	0.74 ab	1.85 b	0.43 b	17.42	9.77	27.18
American oak	0.73 b	1.45 c	0.25 c	17.56	9.66	27.21
French oak	0.81 a	2.33 a	0.58 a	17.10	9.55	26.65
P value	***0.0277***	***<0.0001***	***<0.0001***	*0.4136*	*0.7488*	*0.5935*
Year x Oak						
2017 No oak	0.95 a	1.32	0.35	16.14 b	10.71	26.85
2017 American oak	1.04 a	1.07	0.26	15.30 b	10.05	25.35
2017 French oak	0.95 a	1.67	0.50	15.69 b	10.25	25.94
2018 No oak	0.53 c	2.39	0.52	18.70 a	8.83	27.52
2018 American oak	0.43 c	1.84	0.24	19.82 a	9.27	29.08
2018 French oak	0.67 b	2.99	0.65	18.51 a	8.86	27.37
P value	***<0.0001***	*0.2209*	*0.1575*	***0.0214***	*0.1719*	*0.0556*

[a] Color density was calculated as red color (abs 520 nm) + brown/yellow color (absorbance 420 nm).

[b] Connecting letters are only shown for attributes with significant differences among treatments. Means with different letters for each attribute within effects are significantly different ($p<0.05$) according to Tukey's Honest Significant Difference (HSD) test.

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Supplemental Table 3 Effect of storage (0, 6, and 12 months at 15°C) and oak treatment (no oak, American oak, or French oak staves) on basic chemistry attributes of wines produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR (2017).

Effects	**pH**	**Titratable acidity (%)[a]**	**Glycerol (g/L)**	**Ethanol (% v/v)**	**Glucose (mg/100 mL)**	**Fructose (mg/100 mL)**	**Total residual sugars (mg/100 mL)**	**Tartaric acid (mg/100 mL)**	**Malic acid (mg/100 mL)**	**Citric acid (mg/100 mL)**	**Succinic acid (mg/100 mL)**	**Lactic acid (mg/100 mL)**	**Total organic acids (mg/100 mL)**
Storage													
0 months	3.44 c	0.62 a	7.85	11.15	53.46	184.93	238.39	580.50 a	458.96	233.37 a	715.46	303.41	2291.71
6 months	3.49 b	0.62 a	7.88	11.06	52.18	155.63	207.81	461.67 b	413.16	195.65 a	605.11	172.04	1847.63
12 months	3.53 a	0.59 b	8.01	11.35	47.48	147.43	194.91	483.62 ab	458.45	193.23 a	687.74	189.03	2012.08
P value	***<0.0001***	***0.0025***	*0.3255*	*0.2014*	*0.8776*	*0.4084*	*0.5434*	***0.0309***	*0.1159*	***0.0430***	*0.3455*	*0.1956*	*0.1117*
Oak													
No oak	3.49	0.62	7.86	11.13	46.80	148.30	195.11	469.92	431.36	192.38	640.22	217.48	1951.36
American oak	3.49	0.61	7.93	11.16	50.34	155.26	205.59	555.89	471.36	213.83	732.80	252.32	2226.20
French oak	3.49	0.60	7.94	11.28	55.97	184.43	240.41	499.99	427.86	216.05	635.29	194.68	1973.86
P value	*0.9594*	*0.1898*	*0.7364*	*0.5685*	*0.7578*	*0.4269*	*0.5056*	*0.1373*	*0.1525*	*0.2668*	*0.3744*	*0.7309*	*0.3179*
Storage x Oak													
0 months No oak	3.44	0.62	7.78	11.01	46.84	149.80	196.64	548.89	492.52 a	215.51	782.62	391.34	2430.87
0 months American oak	3.44	0.62	7.83	11.12	55.44	173.53	228.97	624.08	504.26 a	219.48	842.57	366.67	2557.06
0 months French oak	3.44	0.61	7.94	11.33	58.10	231.47	289.57	568.54	380.12 a	265.13	521.18	152.23	1887.19
6 months No oak	3.50	0.64	7.91	11.07	46.62	148.59	195.21	399.88	357.99 a	172.00	480.72	114.62	1525.22
6 months American oak	3.49	0.62	7.76	10.86	43.86	138.76	182.62	542.08	434.59 a	223.09	647.61	202.14	2049.50
6 months French oak	3.49	0.62	7.96	11.27	66.05	179.55	245.60	443.05	446.91 a	191.88	687.01	199.35	1968.19
12 months No oak	3.53	0.60	7.90	11.30	46.96	146.52	193.47	460.98	443.58 a	189.64	657.31	146.48	1897.98
12 months American oak	3.54	0.59	8.21	11.50	51.71	153.48	205.19	501.52	475.23 a	198.91	708.22	188.15	2072.04
12 months French oak	3.54	0.58	7.92	11.25	43.77	142.29	186.06	488.37	456.55 a	191.14	697.68	232.46	2066.21
P value	*0.1718*	*0.5823*	*0.3694*	*0.4702*	*0.8736*	*0.7453*	*0.8175*	*0.8449*	***0.0485***	*0.3084*	*0.1792*	*0.3655*	*0.3193*

[a] Expressed as % w/v (g/100 mL) tartaric acid.
[b] Connecting letters are only shown for attributes with significant differences among treatments. Means with different letters for each attribute within effects are significantly different (p<0.05) according to Tukey's Honest Significant Difference (HSD) test.

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Supplemental Table 4 Effect of storage (0, 6, and 12 months at 15°C) and oak treatment (no oak, American oak, or French oak staves) on anthocyanin attributes of wines produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR (2017).

Effects	Malvidin-3-glucoside (mg/100 mL)	Petunidin-3-glucoside (mg/100 mL)	Delphinidin-3-glucoside (mg/100 mL)	Peonidin-3-glucoside (mg/100 mL)	Cyanidin-3-glucoside (mg/100 mL)	Total anthocyanins (mg/100 mL)	Total acylated anthocyanins (mg/100 mL)	Total coumaryl anthocyanins (mg/100 mL)
Storage								
0 months	37.49 a	16.75 a	12.06 a	9.73 a	1.45 a	81.99 a	1.49 c	3.02 b
6 months	22.20 b	9.58 b	6.65 b	5.42 b	0.65 b	53.11 b	5.14 a	3.48 a
12 months	13.42 c	5.79 c	4.21 c	3.07 c	0.28 c	31.69 c	2.85 b	2.07 c
P value	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***
Oak								
No oak	24.43	10.66	7.59	5.99	0.76	55.64	3.30	2.91
American oak	23.97	10.53	7.51	6.11	0.82	54.75	3.10	2.72
French oak	24.71	10.92	7.83	6.12	0.80	56.40	3.07	2.95
P value	*0.8555*	*0.8374*	*0.8513*	*0.9192*	*0.7042*	*0.8498*	*0.6125*	*0.2437*
Storage x Oak								
0 months No oak	36.79	16.27	11.59	9.30	1.34	80.20	1.82	3.09
0 months American oak	38.02	16.99	12.34	10.17	1.55	83.72	1.50	3.17
0 months French oak	37.65	16.99	12.27	9.72	1.45	82.04	1.15	2.80
6 months No oak	22.65	9.73	6.82	5.45	0.64	53.95	5.10	3.56
6 months American oak	20.99	9.05	6.11	5.22	0.64	50.10	5.06	3.17
6 months French oak	22.97	9.96	7.02	5.59	0.66	55.29	5.26	3.85
12 months No oak	13.86	5.99	4.37	3.22	0.29	32.78	1.82	2.07
12 months American oak	12.89	5.56	4.08	2.94	0.27	30.44	2.75	1.94
12 months French oak	13.51	5.82	4.19	3.06	0.29	31.87	2.81	2.19
P value	*0.9012*	*0.9028*	*0.8439*	*0.6825*	*0.7296*	*0.8081*	*0.7369*	*0.0656*

[a] Connecting letters are only shown for attributes with significant differences among treatments. Means with different letters for each attribute within effects are significantly different ($p<0.05$) according to Tukey's Honest Significant Difference (HSD) test.

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Supplemental Table 5 Effect of storage (0, 6, and 12 months at 15°C) and oak treatment (no oak, American oak, or French oak staves) on color attributes of wines produced from Enchantment grapes grown at the University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR (2017).

Effects	**L***	**a***	**b***	**Red color (abs 520 nm)**	**Brown/yellow color (abs 420 nm)**	**Color density[a]**
Storage						
0 months	0.98 a	1.36 b	0.37	15.71 a	10.33 a	26.04 a
6 months	0.81 b	1.86 ab	0.35	12.79 b	9.30 ab	22.09 b
12 months	0.61 c	2.29 a	0.36	13.98 ab	9.25 b	23.23 ab
P value	***<0.0001***	***0.0069***	*0.9494*	***0.0188***	***0.0297***	***0.0145***
Oak						
No oak	0.85 a	2.11	0.42	14.29	9.66	23.94
American oak	0.81 ab	1.58	0.33	13.70	9.61	23.11
French oak	0.74 b	1.81	0.34	14.49	9.61	24.10
P value	***0.0151***	*0.1020*	*0.3210*	*0.6250*	*0.9920*	*0.7519*
Storage x Oak						
0 months No oak	0.95	1.32	0.35 a	16.14	10.71	26.85
0 months American oak	1.04	1.07	0.26 a	15.30	10.05	25.35
0 months French oak	0.95	1.67	0.50 a	15.69	10.25	25.94
6 months No oak	0.90	1.92	0.38 a	12.88	9.11	21.99
6 months American oak	0.80	1.61	0.33 a	11.75	9.52	21.27
6 months French oak	0.75	2.06	0.34 a	13.74	9.27	23.00
12 months No oak	0.70	3.10	0.52 a	13.84	9.16	22.99
12 months American oak	0.60	2.07	0.40 a	14.06	9.27	23.32
12 months French oak	0.53	1.69	0.17 a	14.04	9.33	23.37
P value	*0.1158*	*0.0673*	***0.0487***	*0.8453*	*0.8117*	*0.9091*

[a] Color density was calculated as red color (abs 520 nm) + brown/yellow color (absorbance 420 nm).
[b] Connecting letters are only shown for attributes with significant differences among treatments. Means with different letters for each attribute within effects are significantly different (p<0.05) according to Tukey's Honest Significant Difference (HSD) test.