Southern Region Small Fruit Consortium

Progress Report Research

Title: Investigating use of alternative packaging on quality of *Vitis* hybrid wine during storage

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Public Abstract
Grapevines (*Vitis* species) are grown globally for wine production, but the sustainability of wine production is majorly impacted by costs and supply chain issues, primarily glass packaging.

Remainder of abstract will be finalized January 2024 after 12-months storage analysis of the wines.

Introduction
Grapevines (*Vitis* species) are grown globally for production of table grapes, juice grapes, dried grapes, and wine that substantially impact economies, with most of this production for wine. The United States is the world's fourth-largest wine producer by volume, with California, Washington, New York, Pennsylvania, and Oregon responsible for 95% of grape and wine production (USDA NASS 2019). Almost every U.S. state, including the southern region, has a grape and wine industry that benefits the economy, but acreage of grapes and volume of wine production varies by state.

One obstacle that impacts the sustainability of wine production is the costs and supply chain issues with glass, the primary packaging material used for wine. Glass is heavier when compared to other packaging materials in the marketplace, and this increases the overall transportation cost associated with shipping both empty and full glass bottles to wineries and consumers. In general, the heavier the packaging is, the higher the carbon footprint during the life cycle analysis, a method used to evaluate the environmental impact of a product through its life cycle from raw materials, manufacturing, distribution, use, recycling, and final disposal.

Recycling packaging can lower the carbon footprint of products over time. Reducing the packaging weight (light weighting) can also reduce cost and energy consumption, but the reduction of materials used in packaging is limited by the impact on the quality of the product in the package. For wine, plastics, especially those not constructed with a moisture and oxygen

barriers, may not maintain environments that protect the integrity of wines (Ghidossi et. al 2011). Reducing the carbon footprint, while important, must not compromise the quality of the wine that a consumer purchases.

Alternative packaging materials for wine can be used to minimize the carbon footprint associated with bottling and packaging, making wine production more sustainable. New packaging materials and technologies for food and beverage products have been created as alternatives for glass including polyethylene terephthalate (PET), aluminum, bag-in-box, and tetra pak's. Other packing options include glass/polyvinyl chloride, high density polyethylene, low density polyethylene, and polypropylene.

Glass is considered the premium package for wine from a quality and presentation. Glass is advantageous as a packaging material for wine because it is inert and impermeable to air and moisture. Glass can be used for aging wines in the bottle, but most wines commercially produced are consumed within the first year after bottling. Consumers purchase wine based on bottle quality, label quality and expression, and proper naming (Rocchi and Stefani 2005). When introduced to alternative wine packaging materials, a consumers first reaction could be to perceive the wine as lower quality. However, experienced wine consumers are more receptive towards alternative wine packaging (Kojic and Jabobek 2021; Mueller S. and Lockshin 2008; Mueller S. and Snolnoki 2008; Ruggero et. al 2022). Similar perception is consistent for wine packaged in PET and bag-in-box systems. One of the hurdles with alternative wine packaging is that the packaging is not as clear (see through) as glass, which consumers could perceive as a lower quality product.

This research from the University of Arkansas System Division of Agriculture (UA System) will **investigate the use of alternative packaging on quality of *Vitis* hybrid wine** by evaluating physicochemical and color attributes of the wine during storage. **This project is important because it will help establish the potential for the use alternative packaging for the grape and wine industry.**

Objectives:

1. Evaluate physicochemical attributes of wine bottled and stored in alternative packaging
Measure physicochemical attributes (composition and phenolics) of wine bottled and stored in alternative packaging

2. Evaluate color attributes of wine bottled and stored in alternative packaging
Measure color attributes (L*, hue, chroma, red color, brown color, color density, and polymeric color) of wine bottled and stored in alternative packaging

3. Develop recommendations for wine bottled and stored in alternative packaging
Develop recommendations for alternative packaging of wine based on data generated from Objectives 1 and 2

Materials and Methods

Grape cultivars and harvest

Vignoles and Chambourcin grapes were hand harvested from a commercial grower in Arkansas in Hindsville, AR in 2022. About 122 kg (270 lbs) of each cultivar were harvested (Vignoles in August and Chambourcin in September). After harvest, the grapes were taken to the UA System Food Science Department for wine production. Vignoles grapes at harvest had 20.0% soluble

solids, 3.43 pH, and 0.88% titratable acidity. Chambourcin grapes at harvest had 22.4% soluble solids, 3.37 pH, and 0.85% titratable acidity.

Wine production

The grapes from each cultivar were randomized, weighed, then crushed and destemmed. Sulfur dioxide (SO_2) was added at crush at a rate of 30 mg/L. The wines were processed in traditional red and white wine styles for wine production. The wines were bottled into the packaging treatments and stored at 15°C.

Chambourcin red wine production. The musts (seeds, pulp, and juice) were placed in 60-L plastic containers with food-grade polyethylene liners for fermentation. Initial juice composition was analyzed. The musts were inoculated with D254 yeast (0.26 g/L) and Fermaid yeast nutrient (0.26 g/L) (Lallemand, Montreal, Canada). The bags were partially sealed with tape to allow carbon dioxide to escape during fermentation. During fermentation, the must cap was punched down twice daily through the bag without exposing the must to air. The grapes were fermented at 15°C on the skins until dryness (0° Brix). The must was pressed in a 70-L Enrossi bladder-type press at 4 bar pressure (Enoagricol Rossi, Calzolaro, Italy), and the wine was collected into glass carboys with fermentation locks. The wines were racked three times to clarify and remove spent yeast cells.

Vignoles white wine production. The must (seeds, skins. and juice) were pressed in a 70-L Enrossi bladder-type press at 4 bar pressure (Enoagricol Rossi, Calzolaro, Italy), and the juice was collected into glass carboys and cold settled (4°C) overnight. The juice was racked into glass carboys. Initial juice composition was analyzed. The juice was inoculated with GRE23 (0.26 g/L), and Fermaid yeast nutrient (0.26 g/L) (Lallemand, Montreal, Canada) was added. The juice was fermented in glass carboys with fermentation locks. The wines were racked three times to clarify and remove spent yeast cells. After fermentation, wines were cold stabilized for 2 months at 2 °C. For bottling, wines from each variety were combined into a large container, sparged, and the SO_2 was adjusted to 0.8 molecular.

Wine packaging

Wine was bottled into seven types of packaging including three sizes of glass bottles (250 mL, 375 mL, and 750 mL) and 250 mL alternative packaging including polyethylene terephthalate (PET), high density polyethylene (HDPE), low density polyethylene (LDPE), polypropylene (PP), and aluminum with epoxy phenolic lining (Figure 1). Wines were bottled in triplicate in January 2023 and evaluated for physicochemical and color attributes at 0- (bottling), 6- and 12-months storage at 15°C.

Figure 1 – Packaging treatments for Chambourcin and Vignoles wines from left to right, 250 mL packaging for polyethylene terephthalate, high density polyethylene, low density polyethylene, polypropylene, aluminum with epoxy phenolic lining, and glass plus 375 mL and 750 mL glass bottles

Physicochemical and color analysis

Composition analysis

Soluble solids, pH, and titratable acidity. Soluble solids, pH, and titratable acidity were done on grape samples prior to fermentation and pH and titratable acidity was done on wine samples. Titratable acidity and pH was measured with an automated titrimeter and expressed as g/L tartaric acid. Total soluble solids (expressed as %) of the sample was measured using a refractometer.

Ethanol. Ethanol (%v/v) was measured using a Dujardin-Salleron ebulliometer (model 360; Paris, France).

Volatile acidity and free sulfur dioxide. The volatile acidity and free sulfur dioxide content of wines was determined using the aeration-oxidation method (Iland et al. 1993) and measured in mg/L of sample.

Dissolved oxygen. The dissolved oxygen of the wine was measured with a H12040-0, edge Multiparameter DO Meter (HANNA® Instruments, Woonsocket, RI).

Phenolic analysis

Total phenolics. The total phenolic concentration in the wine treatments was determined using the Folin-Ciocalteu assay (Slinkard and Singleton 1977), using gallic acid as the standard. The standard was made by mixing 10 mg gallic acid and 90 mL deionized water. Wine samples were diluted with deionized water prior to analysis and measured against a blank sample of deionized water. Serial dilutions were performed to provide the standard curve formula. A stock solution of Folin's reagent (sodium 1,2-naphthoquinone-4-sulfonate) was used and diluted to 0.2N with deionized water. A sodium carbonate ($Na2CO3$) stock solution was made by measuring 75 g of anhydrous $Na2CO3$ and bringing up to one liter with deionized water. 1000 uL of 0.2N Folin's reagent and 800 uL of $Na2CO3$ (75g/L) was added to the diluted wine samples, standard, and blank in 1-cm cells. Samples were incubated for two hrs before reading at an absorbance of 760 nm using a VWR Spectrophotometer UV-1600PC UV-VIS (VWR International, LLC, Radnow, PA). Results were expressed as mg/L gallic acid equivalents (GAE).

Total Monomeric Anthocyanins. The monomeric anthocyanin concentration were determined using the pH differential method of Giusti and Wrolstad (2001). This method is based on the reaction of anthocyanin pigments in their different forms at different pH values; specifically, the difference between the colored oxonium form at pH 1.0 and the colorless hemiketal form at pH 4.5. A 0.025 M potassium chloride buffer at pH 1.0 will be made by mixing 1.86 g potassium chloride and 980 ml of distilled water in a beaker, measuring the pH and adjusting to 1.0 with concentrated hydrochloric acid. The solution was transferred to a 1-liter volumetric flask and filled to 1-liter with distilled water. A 0.4 M sodium acetate buffer solution at pH 4.5 was made by mixing 54.43 g $CH3CO2Na·3\ H2O$ and ~960 ml distilled water in a beaker. The pH was measured and adjusted to 4.5 with concentrated HCl. The solution was transferred to a 1-liter volumetric flask and filled to 1-liter with distilled water. Samples were evaluated with a VWR Spectrophotometer UV-1600PC UV-VIS (VWR International, LLC, Radnow, PA). The appropriate dilution factor for the sample was determined by diluting with potassium chloride buffer, pH 1.0, until the absorbance of the sample at the λvis-max, 510 nm, which is based on the molar absorptivity (ε=26900) and molecular weight (MW=449.2) of cyanidin-3-glucoside, is within the linear range of the spectrophotometer, which will be less than 1.2. The final volume of the sample was divided by the initial volume to obtain the dilution factor. Two dilutions of the sample were prepared, one with potassium chloride buffer at pH 1.0, and the other with sodium acetate buffer at pH 4.5, diluting each by the previously determined dilution factor. The dilutions equilibrated for 15 min and not longer than 60 minutes. The absorbance of each diluted sample were measured in a 1-cm cell for all spectrophotometer measurements at 510 nm and at 700 nm (to correct for haze), against a blank cell filled with

distilled water. For a pathlength of 1 cm, the absorbance of the diluted samples (A) was calculated as follows: A = (Aʎvis-max – A700)pH1.0 – (Aʎvis-max – A700)pH4.5. The monomeric anthocyanin pigment concentration in the original sample was calculated using the following formula: Monomeric anthocyanin pigment (mg/L) = (A × MW × DF × 1000)/(ε × 1) where MW is the molecular weight DF is the dilution factor and ε is the molar absorptivity.

Color analysis

L*, hue and chroma. Wine color analyses was conducted using a ColorFlex system (HunterLab, Reston, VA). The ColorFlex system uses 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*=100, a*=0, and b*=0 (CIE 1986). Hue angle, calculated as tan^(-1)〖(b*)/(a*)〗, describes color in angles from 0 to 360°: 0° is red, 90° is yellow, 180° is green, 270° is blue, and 360° is red. Chroma, calculated as √(〖a*〗^2+〖b*〗^2), will identify color by which a wine appeared to differ from gray of the same lightness and corresponded to saturation (intensity/purity) of the perceived color.

Red color, brown color, and color density. Absorbance values of the wines were measured using a VWR Spectrophotometer UV-1600PC UV-VIS (VWR International, LLC, Radnow, PA). Red color of wines was measured as absorbance at 520 nm, brown color at 420 nm, and color density as red color + brown color (Iland et al. 1993). A 1-cm cell was used for all spectrophotometer measurements.

Statistical analysis

Analysis of physicochemical and color attributes will be conducted using JMP® (version 16.0; SAS Institute Inc., Cary, NC). The study will be analyzed as a completely randomized design with 2 cultivars x 7 packaging types x 3 storage times x 3 replications. Tukey's Honestly Significant Difference (HSD) will be used for mean separation at a p-value ≤ 0.05.

Results and Discussion

In progress

Tables 1-2 and Figures 1-4

Conclusions

In progress

Impact Statement

In progress

Table 1. Composition of Chambourcin and Vignoles wines at bottling (0 days storage) with different packaging treatments (2022).

Variety and packaging treatment [zy]	pH	Titratable acidity (% tartaric)
Chambourcin		
Aluminum	3.54	0.71
Glass 250	3.51	0.72
Glass 375	3.55	0.71
Glass 750	3.51	0.71
HDPE	3.48	0.72
LDPE	3.48	0.74
PET	3.48	0.72
PP	3.52	0.72
Vignoles		
Aluminum	3.57	0.76
Glass 250	3.59	0.76
Glass 375	3.53	0.74
Glass 750	3.53	0.73
HDPE	3.50	0.76
LDPE	3.41	0.76
PET	3.56	0.75
PP	3.51	0.76

[z] Genotypes were evaluated in triplicate.

[y] Wine was bottled into seven types of packaging including three sizes of glass bottles (250 mL, 375 mL, and 750 mL) and 250 mL packaging including polyethylene terephthalate (PET), high density polyethylene (HDPE, low density polyethylene (LDPE), polypropylene (PP), and aluminum with epoxy phenolic lining

Table 2. Color and phenolic attributes of Chambourcin and Vignoles wines at bottling (0 days storage) with different packaging treatments (2022).

Variety and packaging treatment [zy]	L*	Hue angle (°)[x]	Chroma	Red color[w]	Brown color[w]	Color density[w]	Total phenolics (mg/L)	Total anthocyanins (mg/L)
Chambourcin								
Aluminum	1.47	0.21	8.69	2.76	4.37	7.13	2007.42	352.46
Glass 250	1.50	0.23	8.80	2.74	4.35	7.10	2006.05	343.33
Glass 375	1.67	0.22	10.28	2.64	4.24	6.87	2030.79	345.78
Glass 750	1.73	0.22	10.33	2.63	4.19	6.80	2018.42	350.01
HDPE	1.32	0.21	7.80	2.91	4.48	7.40	1977.18	352.90
LDPE	1.21	0.22	6.84	3.14	4.58	7.72	1975.81	343.55
PET	1.54	0.22	9.26	2.71	4.32	7.03	1913.95	350.68
PP	1.30	0.22	7.76	2.83	4.48	7.31	1964.81	352.24
Vignoles								
Aluminum	65.11	178.53	15.67	N/A[v]	0.140	N/A	525.57	N/A
Glass 250	65.53	178.55	15.75	N/A	0.137	N/A	511.82	N/A
Glass 375	65.52	178.55	15.87	N/A	0.142	N/A	518.69	N/A
Glass 750	65.42	178.54	15.88	N/A	0.142	N/A	515.60	N/A
HDPE	64.93	178.50	14.89	N/A	0.135	N/A	493.95	N/A
LDPE	64.81	178.51	15.12	N/A	0.136	N/A	499.45	N/A
PET	65.28	178.53	15.28	N/A	0.137	N/A	503.23	N/A
PP	64.72	178.52	15.32	N/A	0.135	N/A	515.95	N/A

[z] Genotypes were evaluated in triplicate.

[y] Wine was bottled into seven types of packaging including three sizes of glass bottles (250 mL, 375 mL, and 750 mL) and 250 mL packaging including polyethylene terephthalate (PET), high density polyethylene (HDPE, low density polyethylene (LDPE), polypropylene (PP), and aluminum with epoxy phenolic lining

[x] Hue angles <90° were subjected to a 360° compensation to account for discrepancies between red samples near 0° and those near 360°.

[w] Red color calculated as absorbance of wine at 520 nm, Brown color at 420 nm, Color density at 520 nm + absorbance 420 nm.

[v] Data not applicable for white wines.

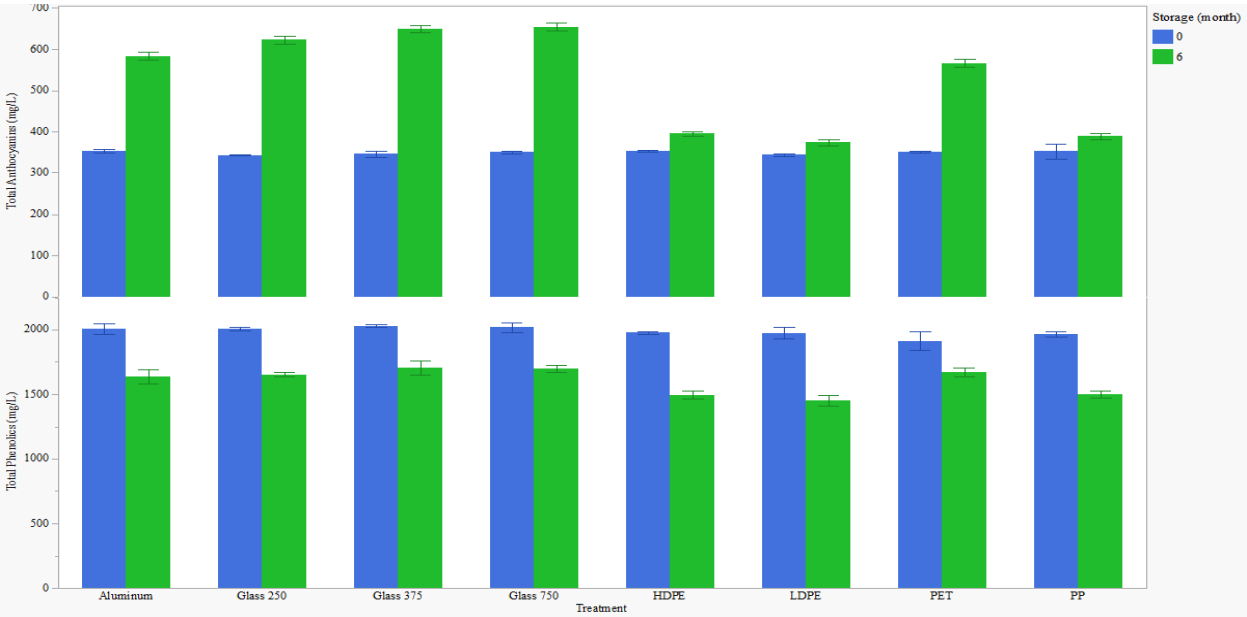

Figure 1. Total phenolics and total anthocyanins of Chambourcin wines at bottling (0 days storage) and 6-months storage at 15°C with different packaging treatments (2022).
Genotypes were evaluated in triplicate. Each error bar was constructed using 1 standard error from the mean. Wine was bottled into seven types of packaging including three sizes of glass bottles (250 mL, 375 mL, and 750 mL) and 250 mL packaging including polyethylene terephthalate (PET), high density polyethylene (HDPE, low density polyethylene (LDPE), polypropylene (PP), and aluminum with epoxy phenolic lining

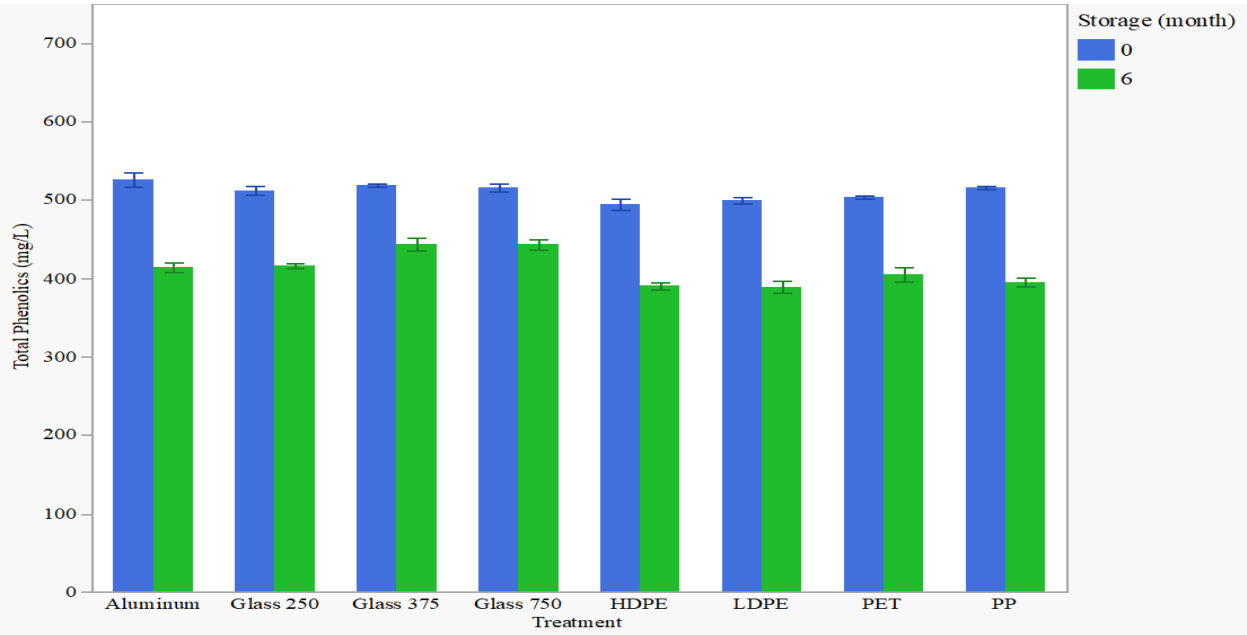

Figure 2. Total phenolics of Vignoles wines at bottling (0 days storage) and 6-months storage at 15°C with different packaging treatments (2022).

Genotypes were evaluated in triplicate. Each error bar was constructed using 1 standard error from the mean. Wine was bottled into seven types of packaging including three sizes of glass bottles (250 mL, 375 mL, and 750 mL) and 250 mL packaging including polyethylene terephthalate (PET), high density polyethylene (HDPE, low density polyethylene (LDPE), polypropylene (PP), and aluminum with epoxy phenolic lining

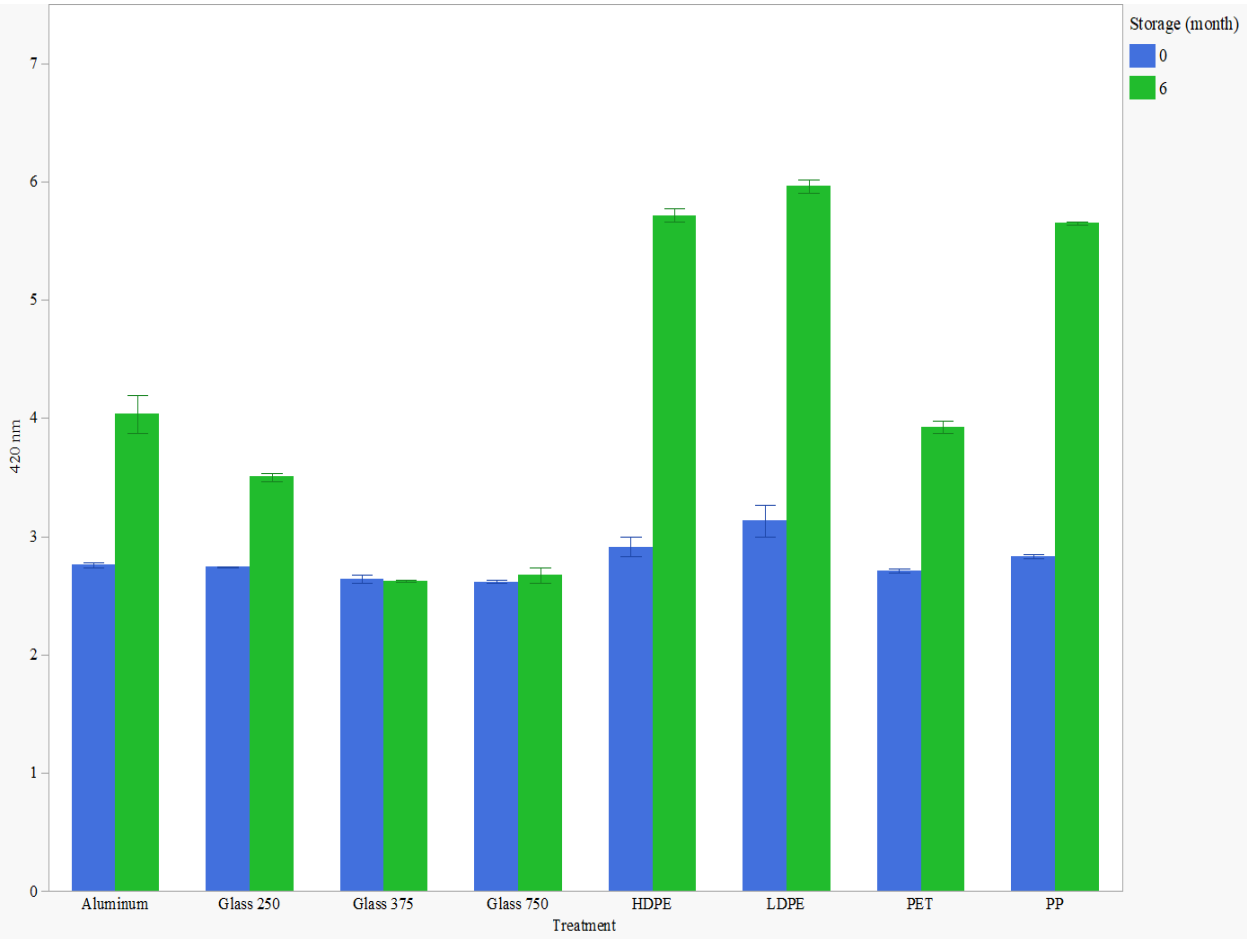

Figure 3. Brown color (420 nm) of Chambourcin wines at bottling (0 days storage) and 6-months storage at 15°C with different packaging treatments (2022).
Genotypes were evaluated in triplicate. Each error bar was constructed using 1 standard error from the mean. Wine was bottled into seven types of packaging including three sizes of glass bottles (250 mL, 375 mL, and 750 mL) and 250 mL packaging including polyethylene terephthalate (PET), high density polyethylene (HDPE, low density polyethylene (LDPE), polypropylene (PP), and aluminum with epoxy phenolic lining

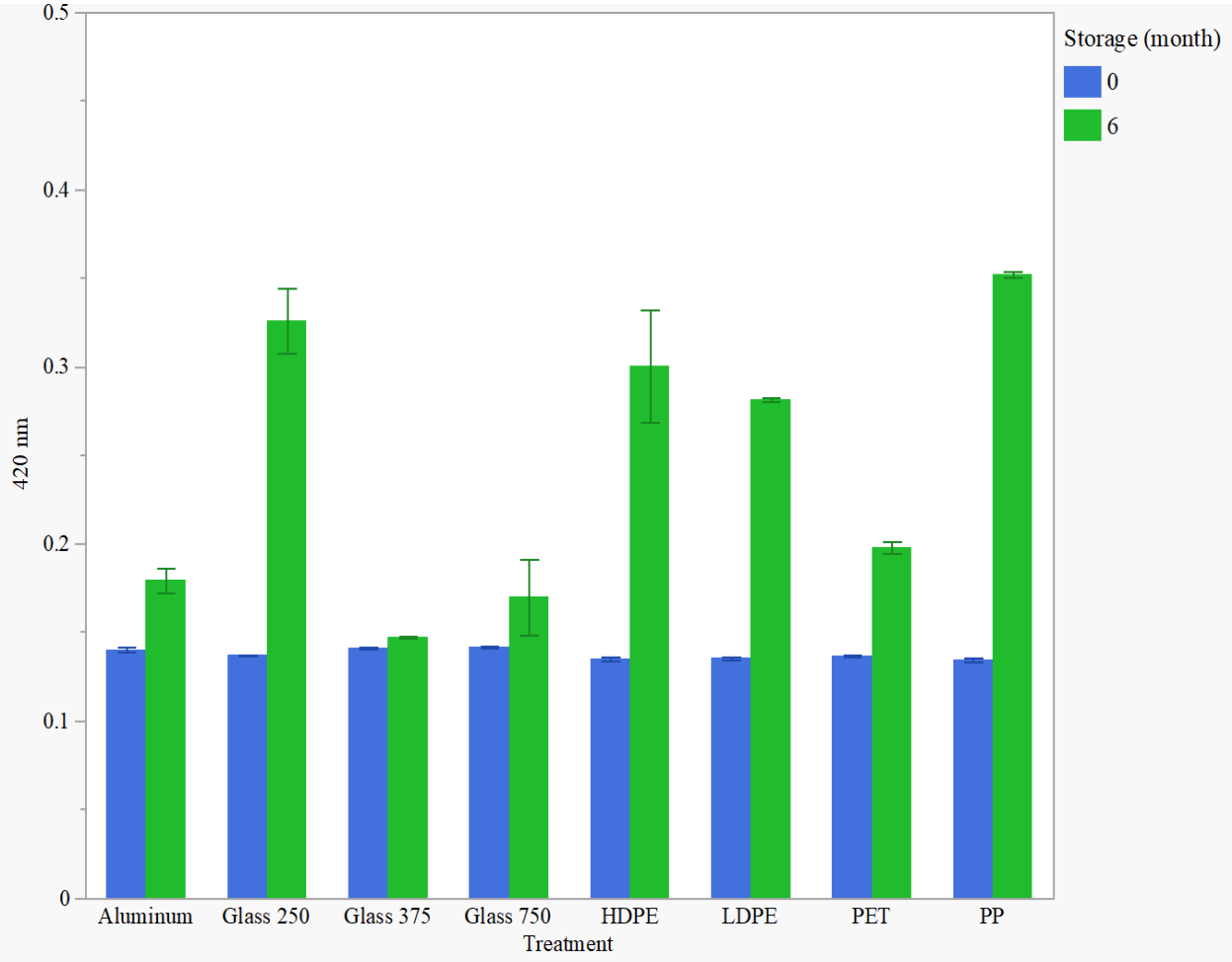

Figure 4. Brown color (420 nm) of Vignoles wines at bottling (0 days storage) and 6-months storage at 15°C with different packaging treatments (2022).
Genotypes were evaluated in triplicate. Each error bar was constructed using 1 standard error from the mean. Wine was bottled into seven types of packaging including three sizes of glass bottles (250 mL, 375 mL, and 750 mL) and 250 mL packaging including polyethylene terephthalate (PET), high density polyethylene (HDPE, low density polyethylene (LDPE), polypropylene (PP), and aluminum with epoxy phenolic lining

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