TECHNICAL PAPER

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MITIGATING SMOKE TAINT IN RED WINE USING OAK ELLAGIC AND CHERRY WOOD TANNINS

ABSTRACT

Background and Aims:

The aim of this research was to:

(i)investigate the impact of additions of untoasted American oak ellagitannins and cherry wood tannins in Cabernet Sauvignon wine grapes affected by wildfire, and

(ii)investigate the significance of the timing of additions at three stages of wine development; (a) addition before primary fermentation (b) addition before malolactic fermentation and (c) addition in finished wine/pre-bottling, and

(iii)evaluate the sensory effects of oak ellagitannins and cherry wood tannins in wine impacted by smoke taint after bottling.

Results: Smoke-affected wines were treated with a range of oak and cherry tannin additives. Treated wines contained a significantly lower level of perceived smoke attributes with enhanced overall quality in finished wine.

Conclusions: Oak or cherry tannin additives showed a significant impact on the sensorial quality of the wine. Timing of treatment was an important factor in improving the wine and reducing the perception of smoke-related attributes.

Significance of the Study: The results of this study will help winemakers make informed decisions in the use of enological oak ellagitannins and cherry wood tannins in helping mask or balance smoke characteristics when processing affected grapes.

INTRODUCTION

As seen in year 2020, wildfires in close proximity to grape growing regions in California and the Northwest have increased in frequency. Approximately 10 million acres were impacted by wildfires in the western United States. More than $680 million is expected in wine grape crop losses in three wine grape growing regions – California, Oregon, and Washington. The sensory characteristics of smoke taint have been well studied and are described as ortho-nasal with aromas such as smoky, dirty, band-aid, earthy, medicinal, burnt, charred, muddy, tar, smoked meat, and ashtray (Kennison et al. 2007) with a heavy carry-over ashtray palate.

Previous studies have proven that the intensity of smoke taint has been observed to increase during the fermentation of smoke-affected grapes. Kennison, et al. provided evidence that the accumulation of smoke-derived volatile phenols in glycoconjugate form was released during primary and malolactic fermentation. During wine processing, grapes that have been crushed quickly release volatile phenols associated with smoke taint. On day one up to 30% of volatile phenols are released in juice; by day 3 up to 50%; and by day 5 up to 80% (Kennison et al.). This is consistent with anecdotal evidence from the industry that smoky characters either appeared during fermentation of grapes that had not previously exhibited smoke taint or increased throughout the winemaking process.

While previous studies have focused on the effect of mitigation and amelioration techniques on smoke tainted wine grapes and finished wine, absolute successful applications have not been recorded. Our objective is to present a method to help mask or balance smoke characteristics in wine by introducing oak ellagitannins or cherry wood tannins at three different stages of the winemaking process. The wine industry is familiar with and has accepted that both free and bound (combined) smoke volatile phenols contribute to overall smoke taint. The selection of our products was carefully chosen to represent the tools suggested by industry leaders and academics to help reduce or mitigate the impact of smoke taint at harvest and to avoid costly amelioration techniques in finished wine. American oak chips and hydrolyzable tannins derived from untoasted American oak and cherry wood tannin were included in the trial and added at three different stages of the wine-making process to determine if they reduced smoke taint aromatics or the retro-nasal ashtray in finished wine.

MATERIALS AND METHODS

2.1 WINE GRAPES

The grapes used in this study were 2020 Cabernet Sauvignon from a vineyard located near Sonoma, California. The vineyard was harvested on October 10, 2020 and approximately 810 kg was processed on October 12, 2020. The main grape characteristics were: brix 26.00 degrees, pH 3.80.

2.2 VINEYARD AND JUICE CHEMICAL COMPOUNDS ASSOCIATED WITH SMOKE TAINT

Due to the impact of excessive heat, ash, and smoke caused by the 2020 Glass Fire in Sonoma County, the winegrower received a notice from the buyer (winery) that the grapes did not meet the applicable Quality Standards for wine processing. The buyer optimized sample preparation and extraction procedures to determine and measure the bound (glycosylated) form of the following compound markers: guaiacol, 4-methylguaiacol, o-, m- and p-cresol, syringol, and methyl syringol (Table 1). The markers showed elevated levels of guaiacol at 28 ppb (threshold 8 ppb) and the total value of all markers at 144 ppb (the acceptable baseline is 30 ppb).

A juice sample was collected on the day the grapes were crushed and sent to ETS Laboratory in St. Helena. ETS's Smoke Volatile Markers - Basic Panel measures guaiacol and 4-methylguaiacol, the primary markers of smoke impact (Table 1). Grape juice panel is recorded at guaiacol 0.9 ppb and 4-methyl guaiacol at <0.5 ppb.

Table 1: Smoke Volatile Markers – Vineyard and Grape Juice

STAGE	LABORATORY	ANALYSIS DESCRIPTION	EQUIPT	BATCH	guaiacol ppb	4-methylguaiacol ppb	o-cresol ppb	p-cresol ppb	m-cresol ppb	syringol ppb	4-methylsyringol ppb	sum
VINEYARD	Winery Results	bound glycosylated	GC/MS	Vyd	28	< 2	< 2	< 2	< 2	113	< 2	144
					guaiacol ppb	4-methylguaiacol ppb						
CRUSH	ETS	Smoke Volatile Markers - Basic Panel	GC/MS	Juice	0.9	< 0.5						

MATERIALS AND METHODS

2.3 OAK WOOD CHIP AND AQUEOUS TANNIN ADDITIVES

In this study, we used untoasted American oak chips from Eastern Pennsylvania (Quercus alba), particle size range of 2 – 5 mm. Aqueous oak ellagitannins extracted from untoasted American oak chips – Premiere E Fresh and Finissage E Fresh. Aqueous tannins extracted from seasoned untoasted cherry wood chips – Premiere Special Fruit. Analysis of each additive is listed in Table 2. AWRI's analysis of oak adjuncts dose rate and methodology is determined to ensure the maximum amount of relevant compounds is extracted at 10 g/L. ETS was instructed to measure the oak compounds in each aqueous additive without dilution. The technique used to measure each compound is gas chromatography-mass spectrometry (GC-MS).

Table 2: Laboratory Oak Panel Analysis For Each Additive

Product	LABORATORY	CHEMICAL ANALYSIS								
		furfural	5-methylfurfural	trans-lactone	cis-lactone	guaiacol	4-methylguaiacol	eugenol	isoeugenol	vanillin
American Untoasted Oak Chip (ppm)	AWRI	85	11	6	7	0	0	ND	NA	28
Premiere American E Fresh (ppb)	ETS	<100	<20	1091*	7172*	1481*	1428*	580*	2	<20
Finissage American E Fresh (ppb)	ETS	<100	<20	838*	2382*	159*	51	292*	<1	<20
Premiere Special Fruit (ppb)	ETS	803	76	18	70	53	24	10	2	1174

*Estimated value, out of calibration range

Figure 1: Treatments In Study: American Chips and Oak, Cherry Aqueous Tannins

MATERIALS AND METHODS

2.4 EXPERIMENTAL CONDITIONS

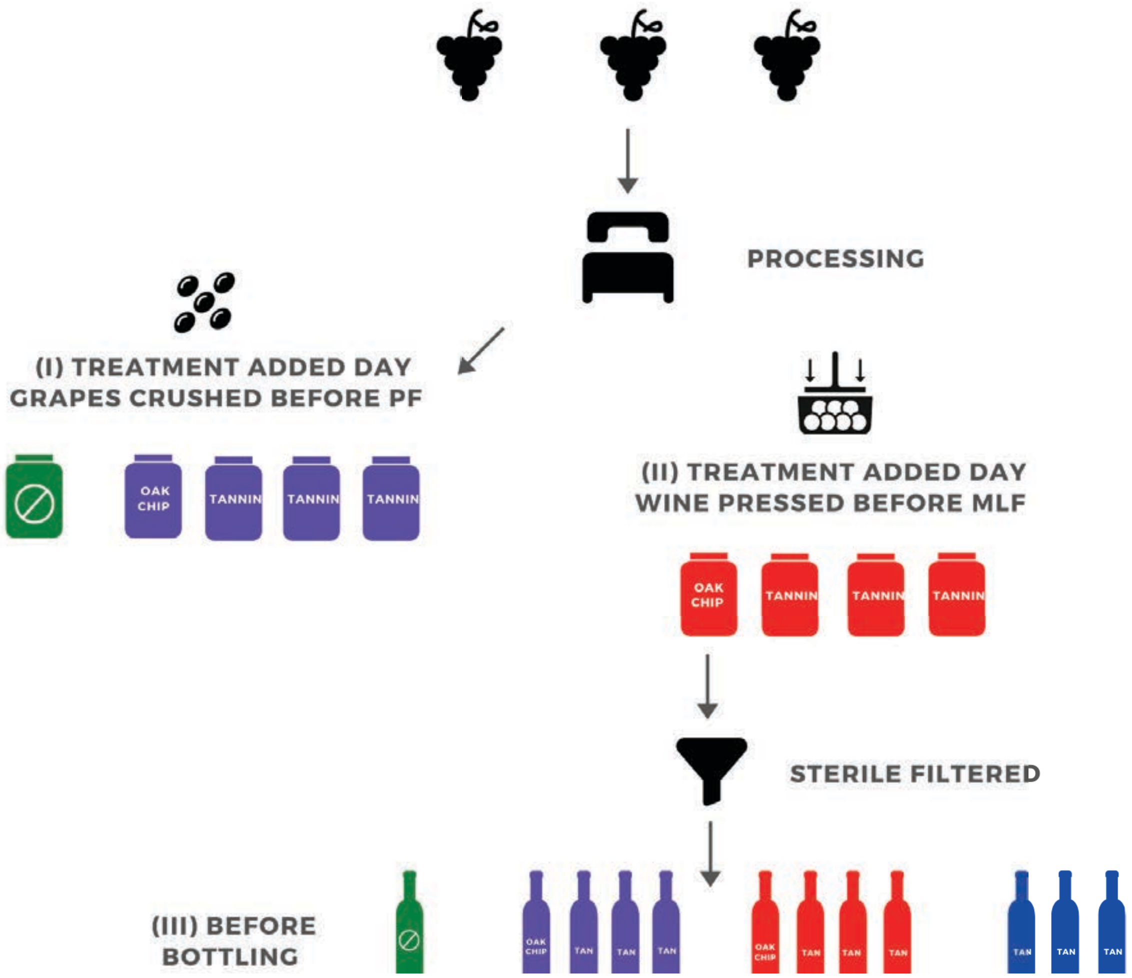
The fruit was de-stemmed and crushed, with the addition of 50 mg/L sulfur dioxide (added as potassium meta-bisulfite), then randomly sorted into 66-liter plastic pails each containing approximately 31 kg of crushed fruit. The five parcels included are; control, American oak untoasted chip, Premiere American E Fresh, Finissage American E Fresh, and Premiere Special Fruit. Starting Brix was 26.0 and tartaric acid was added to adjust the pH from 3.80 to 3.40 prior to inoculation with Lalvin Clos yeast (250 ppm).

The treatments were added at different intervals of the winemaking process: before primary fermentation yeast inoculation, post-primary fermentation before malolactic bacteria inoculation, and in finished wine pre-bottling (Figure 2). American oak chip addition rate 0.15 kg/hL (1.5 g/L). Premiere and Finissage tannin addition rate 3 mL/L. A combination of Microessential nutrients (Gusmer Enterprises), Superfood complex nutrient (BSG), and diammonium phosphate were added to supplement the low nitrogen level (150 mg/L). Cold soak was not conducted. Musts were fermented on skins with the cap plunged once per day. Where stuck fermentations occurred, yeast wall Reskue was added prior to a starter culture comprising of active dry Lallemand Uvaferm 43 (400 mg/L) and yeast nutrient Go Ferm Protect (Lallemand at 30 g/hL) and Fermaid O (Lallemand at 12 g/hL) was used to resume fermentation. Wines were pressed at a Brix level of <5 Brix and transferred into 19-liter glass carboys and held at 21 C until the residual sugar approached < 2.0 g/L. Malolactic fermentation was carried out as soon as primary fermentation was complete. Chr. Hansen direct inoculation Oenos was the bacteria strain used in each treatment and the manufacturer’s directions were followed. Not all wines completed secondary fermentation. Wines were racked once and filtered with course (DANMIL Absolute PP 1.0 **µ**m) and sterile membrane filters (DANMIL Absolute PES 0.45 **µ**m). Bottles (375 ml) were stored at 15 C until sensory analysis.

MATERIALS AND METHODS

2.4 EXPERIMENTAL CONDITIONS (continued)

Figure 2: Smoke Taint Trial and Stages-of-Treatment



MATERIALS AND METHODS

2.5 WINE CHEMICAL ANALYSIS

Latest studies show the best correlation with compounds associated with smoke taint as the sum of volatile phenols for smoke exposure of grapes. Once primary fermentation was complete, wine samples were sent to ETS Laboratory for Smoke Volatile Markers – Extended Panel which measures secondary markers of smoke impact: o-cresol, m-cresol, p-cresol, phenol, syringol, and 4-methylsyringol. ETS utilizes GC-MS/MS method for analyzing the smoke taint compounds in wine. Compound thresholds are listed in Table 3.

Wine Smoke Volatile Markers - Extended Panel data is listed in Table 4. Samples were collected the day each batch was pressed on October 21, 2020 and approximately five months after each batch was pressed.

Table 3: ETS Smoke Volatile Aroma Descriptors and Thresholds (De Vries et al. 2016)

Compound	Aroma Descriptor	Odor Threshold (ppb)
guaiacol	smoky, sweet, medicinal	7.5-23
4-methylguaiacol	ashy, toasted, vanilla-like	65
o-cresol	bandaid, medicinal, smoky	62
p-cresol	bandaid, phenol-like	64
m-cresol	dry, tar, medicnal-leathery	20
syringol	na	na
4-methylsyringol	na	na
phenols	sickeningly,sweet, irritating	7100

Table 4: ETS Smoke Volatile Markers – Extended Panel in Wine

STAGE-OF-TREATMENT	SAMPLE COLLECTED	BATCH	CHEMICAL ANALYSIS (ppb)								
			guaiacol	4-methylguaiacol	o-cresol	p-cresol	m-cresol	syringol	4-methylsyringol	sum cresol	phenols
PRIMARY FERMENTATION	PRESS	CONTROL	3.3	<1.0	2.5	1.2	1.8	< 10.0	< 10.0	5.5	8.6
PRIMARY FERMENTATION	PRESS	PREMIERE SPECIAL FRUIT PF	4.7	1.7	3.1	1.6	2.0	< 10.0	< 10.0	6.7	21.7
PRIMARY FERMENTATION	PRESS	PREMIERE E FRESH PF	16.1	11.4	2.0	1.6	1.1	< 10.0	< 10.0	4.7	7.5
PRIMARY FERMENTATION	PRESS	FINISSAGE E FRESH PF	5.4	1.0	2.3	< 1.0	1.5	< 10.0	< 10.0	3.8	9.7
PRIMARY FERMENTATION	PRESS	CHIP AMERICAN UNTOASTED PF	4.8	< 1.0	2.3	1.1	2.0	< 10.0	< 10.0	5.4	9.8
PRIMARY FERMENTATION	5 MONTHS AFTER PRESS	CONTROL	4.0	<1.0	3.4	1.5	2.0	21.9	<5.0	6.9	10.7
PRIMARY FERMENTATION	5 MONTHS AFTER PRESS	PREMIERE SPECIAL FRUIT PF	5.2	1.2	2.3	1.2	1.9	21.4	7.9	5.4	11.6
PRIMARY FERMENTATION	5 MONTHS AFTER PRESS	PREMIERE E FRESH PF	17.9	9.8	2.3	1.9	1.2	50.5	132.9*	5.4	9.9
PRIMARY FERMENTATION	5 MONTHS AFTER PRESS	FINISSAGE E FRESH PF	5.9	1.2	2.4	1.2	1.8	20.3	5.7	5.4	9.8
PRIMARY FERMENTATION	5 MONTHS AFTER PRESS	CHIP AMERICAN UNTOASTED PF	5.3	1.2	2.3	1.3	2.0	19.0	<5.0	5.6	9.8
MALOLACTIC FERMENTATION	5 MONTHS AFTER PRESS	PREMIERE SPECIAL FRUIT MLF	6.3	1.4	2.4	1.2	2.3	22.3	9.0	5.9	12.9
MALOLACTIC FERMENTATION	5 MONTHS AFTER PRESS	PREMIERE E FRESH MLF	32.8	19.9	2.3	1.2	1.8	74.6	248.7*	5.3	9.6
MALOLACTIC FERMENTATION	5 MONTHS AFTER PRESS	FINISSAGE E FRESH MLF	7.8	1.7	2.3	1.2	1.9	18.7	<5.0	5.4	9.7
MALOLACTIC FERMENTATION	5 MONTHS AFTER PRESS	CHIP AMERICAN UNTOASTED MLF	6.2	1.4	2.4	1.6	2.1	20.5	5.6	6.1	9.7

*Estimated value, out of calibration range

MATERIALS AND METHODS

2.6 SENSORY ASSESSMENT OF WINES

One month after bottling, the wine was submitted to Applied Sensory LLC for objective evaluation using the sensory method descriptive sensory analysis. The analysis was used to quantitatively characterize differences in the perceived aroma and flavor attributes of wines exposed to smoke taint (Table 5). Eight wine experts were used as judges. Six of the judges have made wine in the wine industry, one has worked in the sensory field at a Napa winery, and one is a sensory scientist.

One replication of the twelve Sonoma Cabernet Sauvignon wines was performed on May 4, 2021. A modified Latin square design was used to randomize the presentation of the wines among the eight panelists. The wines were served in clear, tulip-shaped wine glasses of 220-ml capacity which were coded with 3-digit random number codes (generated by SIMS 2000 sensory software). A 60-ml sample was poured into each glass and then covered with a 5.7 cm diameter plastic Petri dish cover at least 15 minutes prior to evaluation. The tests were conducted in a room illuminated with “daylight” fluorescent lighting. All wines were served at 20 - 24 C. The panelists were separated by dividers and were not allowed to communicate during the session. Panelists expectorated the wines and rinsed with bottled water between tastings. Each judge rated the intensity of the attributes for the different wines using structured 10-point scales anchored at the ends with terms “weak” and “strong”, “low” and “high”, or “none” and “9-10 seconds.”

Table 5: Applied Sensory’s Score Card for Panelist and Description

Aroma	Description
Overall Smoke Intensity	perception of smoke in wine
Fruity	the intensity of the overall fruit aroma, includes red fruit, red berry, dark berry, strawberry, raspberry, cherry, apple
Smoky	perception of any type of smoke aroma, whether it be hickory or artificial, maybe phenolic, includes charry, smoked meat, bacon
Acrid Smoky	liquid smoke, campfire
Ash	burnt aroma associated with ashes, includes ashtray, earthy, muddy, tarry
Burnt	burnt toast
Medicinal/Bandaid	aromatic characteristic of band-aids, disinfectant-like or phenols, includes cleaning product, disinfectant, phenols, band-aid
Phenolic	clove-like, spicy char
Oak/Woody	toasted sweet oak, cigar box
Palate	
Overall Smoke Intensity	perception of smoke in wine
Bitterness	Intensity of bitter taste, bitter aftertaste
Fruity Flavor	the intensity of the overall fruit flavor; includes red fruit, red berry, dark berry, strawberry, raspberry, cherry, apple
Oaky/Caramelized Flavor	flavors assocaited with oak
Astringency	perception in wine takes on many subtle forms, having broad subqualities of roughing, drying, and puckering
Burning in Mouth or Throat	burning or hot sensation
Duration of Ashy Aftertaste None; 4-5 seconds; 9-10 seconds	Length of taste associated with residue of ashtray perceived in the mouth after expectorating, includes coal ash, ashtray, tarry, acrid
Overall Impression	open to panelist comments

RESULTS AND DISCUSSION

3.1 SENSORY EFFECTS OF MITIGATION AND/OR AMELIORATION TREATMENTS

3.1.1 Principal Component Analysis (PCA)

Results obtained from sensory analysis of the wines are discussed in this section in terms of general sensory effects and then on per stage-of-treatment effects.

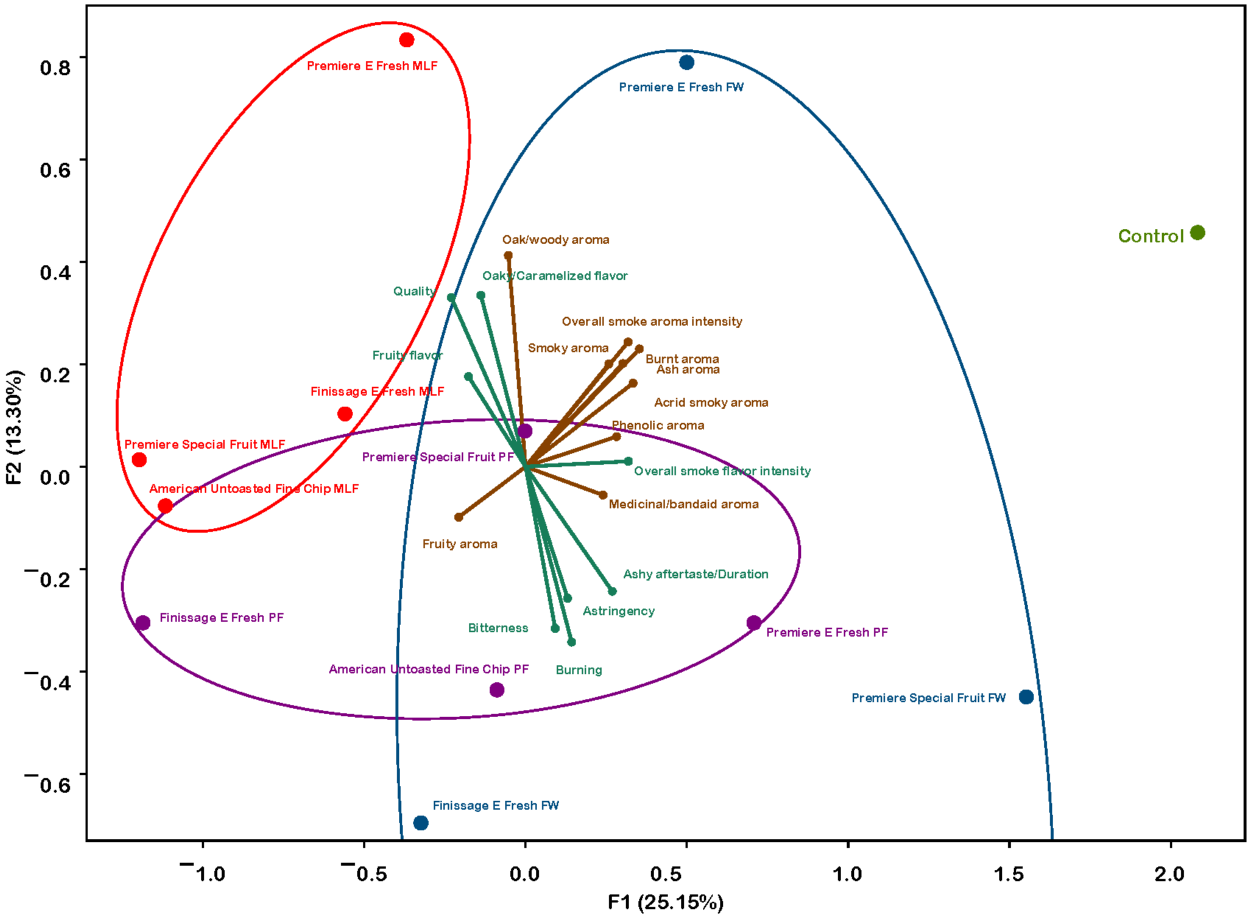
An advanced statistical method, principal component analysis, is often used to illustrate relationships and intuitively grasp a reduced set of variables. The most important use of PCA is to represent a multivariate data table as a smaller set of variables (summary indices) in order to observe trends, jumps, clusters, and outliers. This overview may uncover the relationships between observations and variables, and among the variables.

In Figure 3, each point represents the scores of each different sensory attribute. Points that are close together are wines that are sensorily similar and points that are far apart are wines that are different. Emanating from the central origin are vectors representing each attribute. The length of the vector may be interpreted as an indication of the influence of the sensory attribute in the PCA space. Short vectors indicate attributes of relatively low importance, long vectors indicate attributes of relatively high importance. Close alignment of a vector with the PC axis indicates a high correlation between the attribute represented by the axis and the variability explained by the principal component.

RESULTS AND DISCUSSION

3.1.1 Principal Component Analysis (PCA) (continued)

Figure 3: PCA of the Mean Ratings of the 12 Wines for 17 Sensory Attributes
Axis 1: 25.15%, Axis 2: 13.30%



In Figure 3, the aroma attributes are depicted in brown and palate attributes in green. Purple ellipse depicts addition before primary fermentation (PF), red ellipse depicts addition before malolactic fermentation (MLF), and blue ellipse depicts addition in finished wine/pre-bottling (FW). The control wine is characterized by the smoke-related attributes in the top right quadrant. Also displaying similar smoke-taint properties are a few wines in which the additives were added at stages - primary fermentation and in the finished wine. The additives added before malolactic fermentation (upper, left quadrant/red ellipse) display the most fruity aroma, lowest smoke-related attributes, and are of higher quality than the wines in which additives were added at primary fermentation and/or in finished wine.

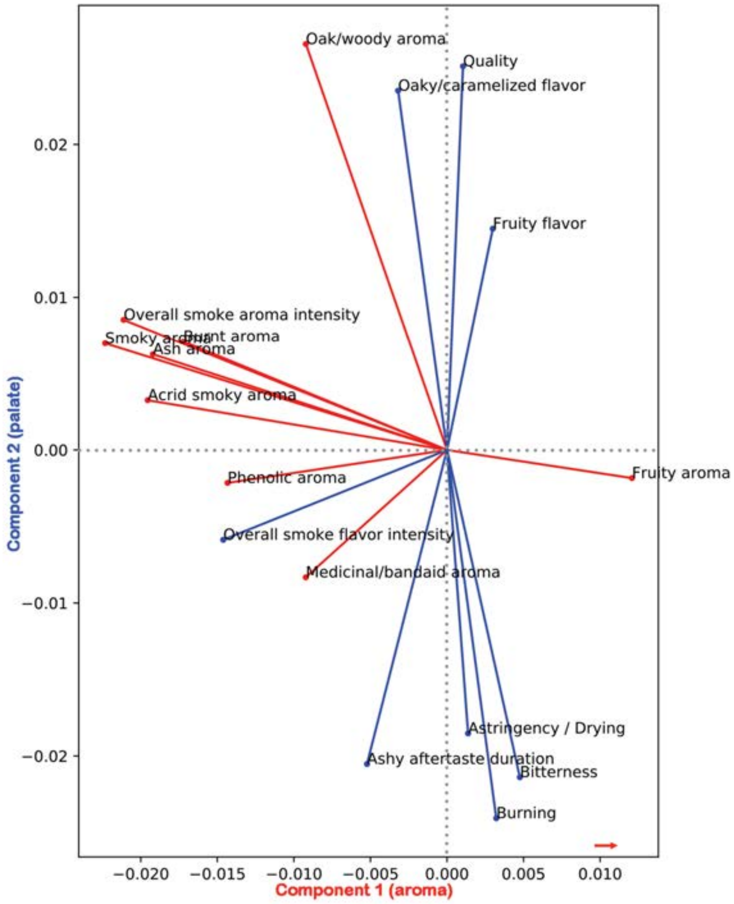
3.1.2 Independent Component Analysis (ICA)

A more recent method for data dimensionality-reduction is Independent Component Analysis (ICA, developed between 1984 and 1995 by the machine-learning community). In contrast to PCA, with ICA the components explain equal amounts of variance and are not required to be orthogonal. ICA, used for applications from cosmology to measuring the ripeness of tomatoes, has the capacity to identify dimensions of the data that are functionally salient even if not orthogonal.

In Figure 4 we see this concept in play. With a couple of exceptions, aroma (red) vectors project predominately along Component 1, whereas the non-aroma (blue) vectors (which reflect palate qualities) align predominately with Component 2. Thus, in the ICA analysis, the components have intuitive interpretations (aroma, palate) which facilitate analysis of wines we will project into this space.

The way the qualities vectors lay along the component axes is noteworthy. The fruity aroma vector points to the right, whereas characteristics associated with smoke taint, i.e. acrid smoky aroma and phenolic aroma, point to the left. Oaky/caramelized flavor and quality point up, whereas ashy aftertaste and astringency/drying point down. These results lend confidence that ICA is providing dimensionality reduction in a manner that is more intuitively satisfying than PCA.

Figure 4: ICA Vectors of the 17 Sensory Attributes Projections



3.1.3 Independent Component Analysis (ICA): Control, PF, MLF and FW

A smoke-affected control wine was treated with various oak and cherry tannin additives at different stages of the winemaking process listed below:

Stage-of-Treatment:

(i) before primary fermentation (PF)
(ii) before malolactic fermentation (MLF)
(iii) in finished wine/pre-bottling (FW)
(iv) none - control

Figure 5 shows how wines are grouped by stage-of-treatment project into the ICA component 1 vs component 2. The horizontal and vertical error bars represent the standard errors of the means of the judges' ratings. Hotelling’s two-sample t-tests were used to estimate the significance of difference between pairs of wines in this two-dimension space. The control wine is significantly different from the MLF group ($p < .002$) as well as the PF group ($p < .007$). Furthermore, the FW group is significantly different from the MLF group ($p < .038$).

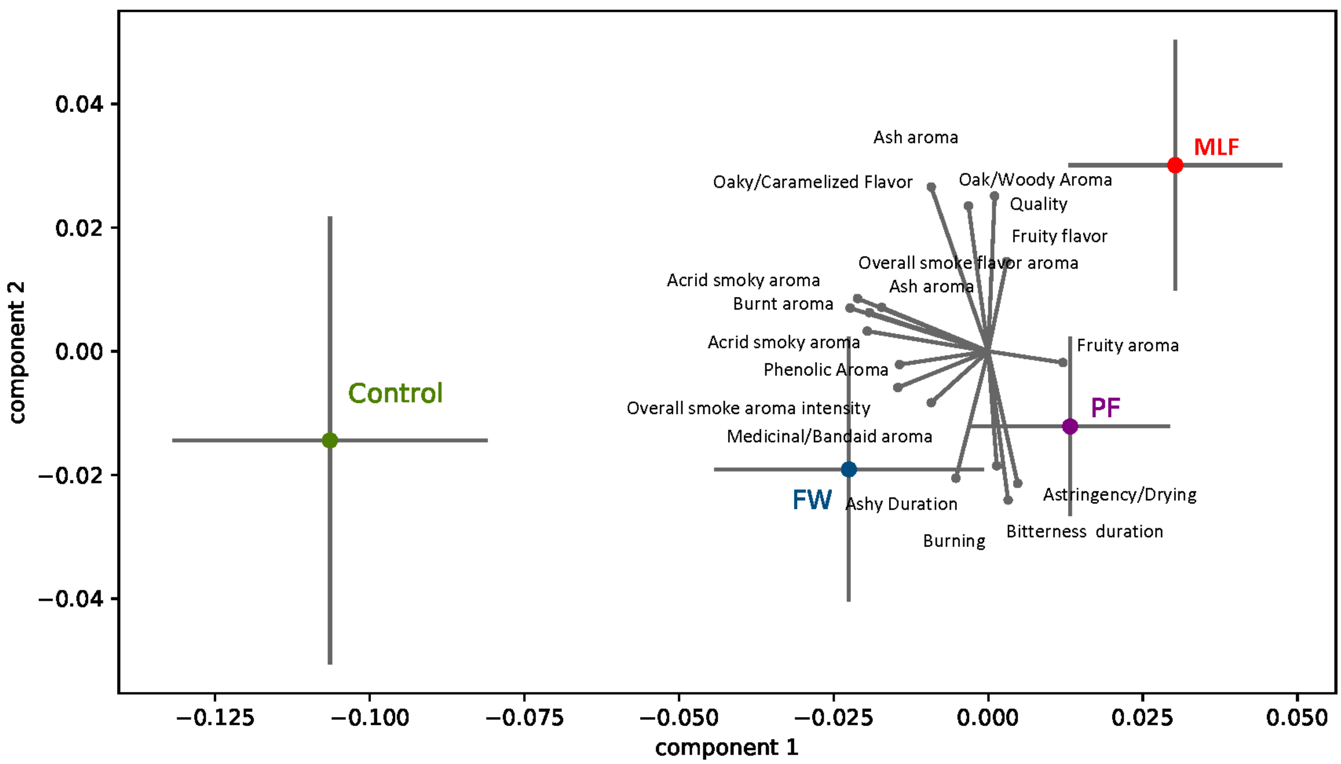
As we discussed component 1 relates to aromas, with smoke-affected characteristic aromas on the left and minimal-to-no smoke-effected characteristics to the right. With this in mind, we see that treatments at all three stages move the wine groups to the right of the control, improving aroma from, for example, acrid, smoky, and medicinal to fruity.

RESULTS AND DISCUSSION

3.1.3 Independent Component Analysis (ICA): Control, PF, MLF and FW (continued)

As we also discussed, Component 2 corresponds intuitively to palate, with lower values corresponding to ashy aftertaste, bitterness, and astringency, and higher values corresponding to fruity flavor, oak, and an overall improvement in quality. Viewing the groups, it is noteworthy that treatment at the primary fermentation state and in finished wine, while effective in improving aroma, do nothing obvious to improve the palate as compared to the control (at least when the various oak and cherry tannin additives are viewed collectively here). The malolactic stage treatment in contrast, indicates improvement in aroma and palate, elevating the MLF data point above the control.

Figure 5: ICA Vectors and Stage-of-Treatment Effects



RESULTS AND DISCUSSION

3.1.4 Independent Component Analysis (ICA): Control vs Individual Wines

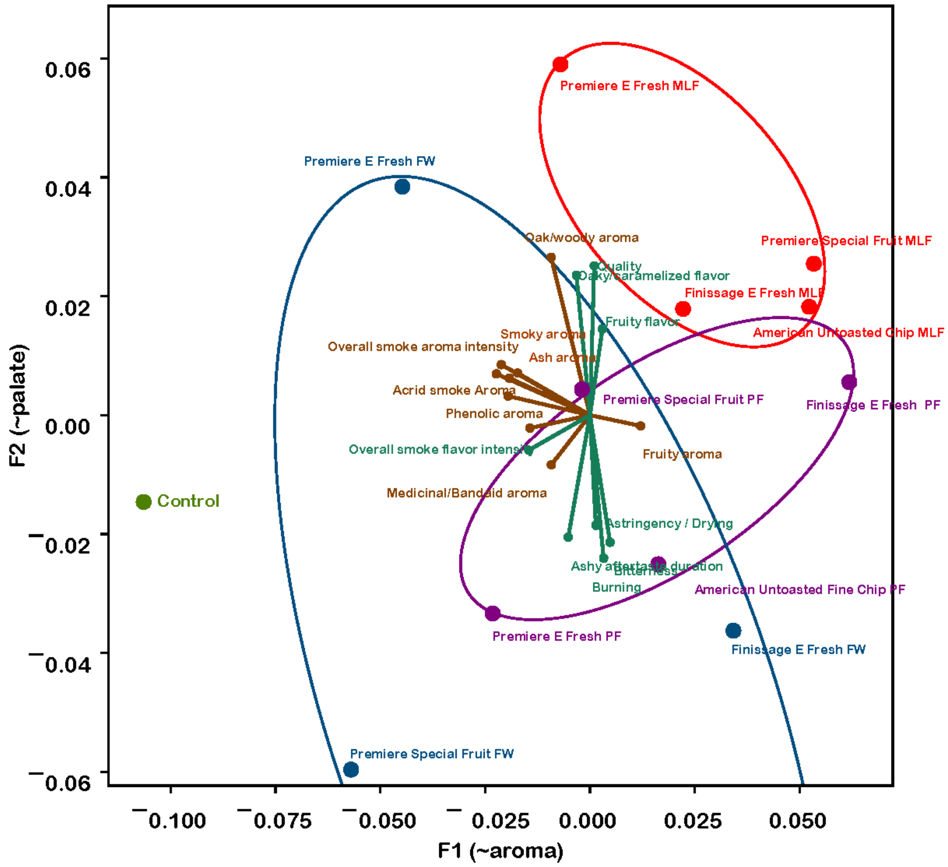
Above, we grouped various oak and cherry tannin additives together when considering stage-of-treatment effects. In fact, the American oak and cherry tannins are quite distinct products as listed below:

Oak Chip and Aqueous Tannin Products:

- American Untoasted Fine Chip
- Premiere E Fresh
- Finissage E Fresh
- Premiere Special Fruit

We now turn to investigate the effects of these various additives individually. With the exception of Premiere E Fresh in the finished Wine (FW) group, the individual wines stack neatly by stage-of-treatment along Component 2, with Premiere E Fresh MLF (red sphere) performing the best followed by the other treatments added before malolactic fermentation (upper right quadrant). The sensory results from the American untoasted oak ellagitannins and cherry tannins did not perform as well when added in finished wine compared to treatment before malolactic fermentation.

Figure 6: ICA Vectors and Individual Wine Effects



3.1.5 Ranking Freeform Appraisals

Up to this point, we have examined data from the judges' numerical scoring of various wine attributes through the lens of PCA and ICA dimensionality reduction. The results indicate various oak and cherry tannin additives can differentially affect and minimize the smoke-affected aroma and taste of wines, in some cases to positive effect. We are left wondering, what did the wines actually taste like? Did the differences in wine qualities amount to something that could turn the undrinkable control wine into a drinkable modified wine? Or, were the changes merely in the direction of drinkable without actually attaining this goal to a qualitatively meaningful degree?

Fortunately, in this study, the panel of expert judges recorded their freeform impressions of every wine they tasted, in addition to making the numerical scores we have considered thus far. From these written statements, we have a clear sense of the experiences of analyzing and interpreting the wines from the trial. The comments are highly individualistic and reflect the expertise of the judges. The comments convey the impression the judges were tasting entirely different wines, some worse and some far better than the control. This is readily apparent from their comments which ranged from (for example), "Very unpleasant 4EP aroma and flavor" to "Has great cedar/ash flavor characteristics that are not unpleasant; could drink this".

The panelists' comments can be helpful in interpreting the quality of the wines. In order to bring together the diverse comments into a condensed form, we sought to classify them into five qualitative categories. To do this, each individual comment was printed on a separate slip of paper (marked with identification number). Shuffled, the written appraisals could be read 'blind' without any way of knowing which statement corresponded to which judge or which wine. Two of the authors did this categorization process, with essentially similar results. Below we list three representative examples for each category. This set of comments indicate how dramatically the wines varied.

RESULTS AND DISCUSSION

3.1.5 Ranking Freeform Appraisals (continued)

Category 1
- Unpleasant aroma and mouthfeel.
- Canned vegetables/asparagus, bitter, and astringent finish.
- Very obviously flawed, high ashtray.

Category 2
- Could be fruity, just massively bitter and astringent and overpowering 4EP aroma.
- Low smoke aroma intensity, but rather strong medicinal aroma. Smokiness becomes more intense in the mouth.
- Smoky aromas dominate. Nice fruity flavor marred by searing astringency.

Category 3
- Very fruity and some ash. Seems a bit low in aroma characteristics.
- Slightly detectable medicinal and phenolic characteristics. Strong fruit component, with low bitterness and astringency.
- Not terribly tainted, just poor quality, thin.

Category 4
- Spicy, fruity.
- Low overall smoke impact. Some phenolic detectable on the nose and more in the mouth. Nice fruit component, low bitterness and astringency.
- No significant smoke aromas. Slightly phenolic in the mouth. Very good overall fruit intensity, low bitterness, and astringency.

Category 5
- Not too bad; sweet aroma and flavor but has some nice cedar aromas; drinkable.
- Lots going on flavor and mouth-feel, aroma too; seems a bit more balanced where everything works together.
- Very fruity wine that is pretty clean. I struggled to find any smoke characteristics.

RESULTS AND DISCUSSION

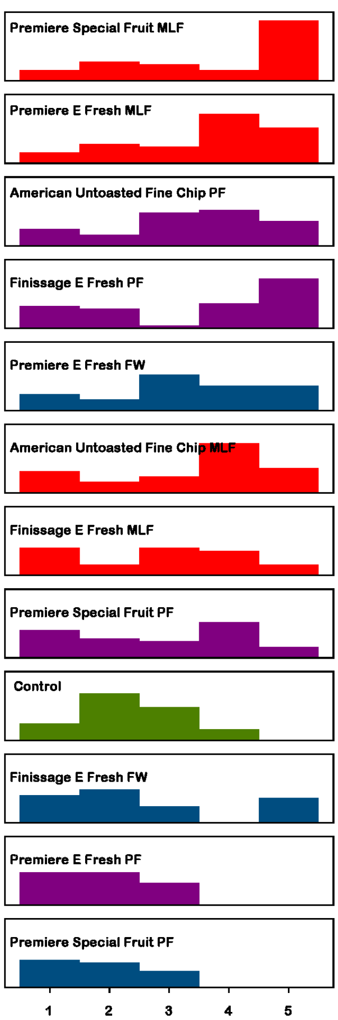
3.1.6 Histogram of Wine Ratings

Given the blind categorizing of the judges' freeform comments, we associated them with the twelve wines to which the comments referred.

We counted the total number of rankings in a given category, then calculated the proportion of those which a given wine received. Doing this for all five categories allowed us to create a histogram.

Looking at Premiere Special Fruit MLF (top histogram) we see that it had a higher proportion of category 5 ratings than any other wine, and a fairly low proportion of the ratings in the remaining four categories. Thus, Premiere Special Fruit MLF was favored by the judges in this analysis.

Figure 7: Histogram of Wine Ratings



Premiere E Fresh MLF was also rated highly. Although it received a smaller proportion of the Category 5 ratings, it had a substantial proportion of the Category 4 ratings. Neither of these two wines received high proportions of the lower Category ratings 1 through 3.

The control and the lowest-ranged wines received few rankings above Category 3. The three lowest ranged wines all received worse categorical rankings than the control. The control was mostly ranked into Categories 2 and 3. Some middling wines received a broad spectrum of rankings.

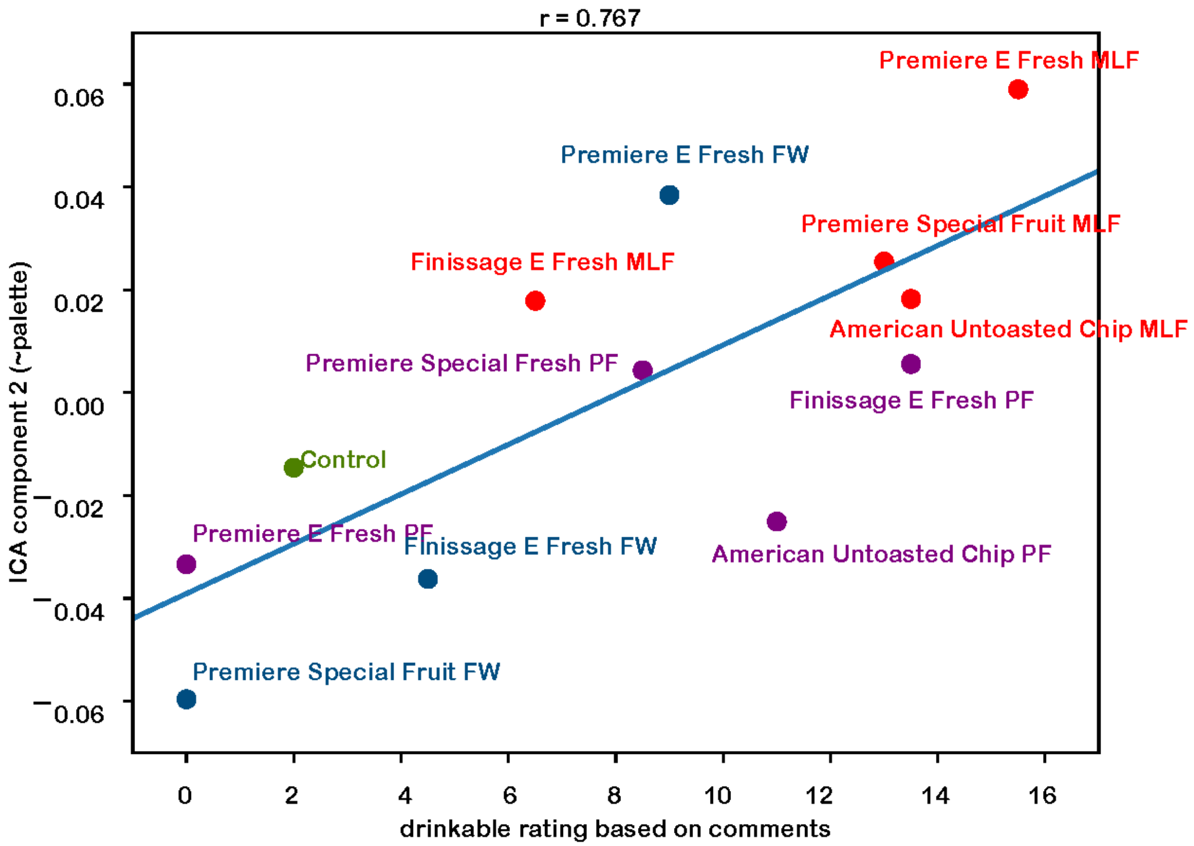
In contrast, the control wine had no category 5 ratings, but had a peak at category 2. Interestingly, three wines ranked even lower, with solid proportions of both Category 1 and Category 2 ratings.

RESULTS AND DISCUSSION

3.1.7 Comment Ratings vs ICA, Component 2

Earlier we discussed how ICA component 2 appears to correspond to wine taste qualities. We now can ask the question, how does ICA component 2 correspond to the categorical rankings of wine quality in Figure 7? We can examine this by plotting ICA component 2 values for each wine (y-axis, Figure 8) against a measure of wine quality taken from the judges' comments (x-axis). The value we use for the x-axis is, for a given wine, the percent of that wine's category 4 and 5 rankings out of the total number of 4 and 5 rankings. For example, Premiere E Fresh MLF has nearly 16% of all the category 4 and 5 rankings (the highest percentage), and also the highest ICA component 2 rating. In contrast, Premiere Special Fruit FW has 0% of the category 4 and 5 rankings and the lowest ICA component 2 score. These two independent measures of wine taste quality (ICA component 2 value and percent of category 4/5 rankings) are strongly correlated (*r* = 0.77).

Figure 8: x-axis label: 'Percent of category 4/5 rankings



CONCLUSION

4.1 Conclusion

The techniques evaluated as potential mitigation treatments for smoke-affected wine showed that oak and cherry tannin additives are most effective in improving wine aroma and taste when added before malolactic fermentation. There is variability in the effects of individual oak and cherry tannin treatments. With the wine tested here, Premiere Special Fruit was the most successful tannin when added.

The surprising divergence in quality rating for some tannin additives/stage-of-treatment combinations suggests that these perturbations may have highly individualistic results. From one and another standpoint, this suggests the necessity for testing wines with as large a panel of judges as possible, because a given individual, even an expert wine taster, may not be capable of detecting some objectionable characteristics of the modified wines. From one standpoint, these modified wines may be satisfactory to the typical non-expert wine taster.

Judges were instructed to rate each wine for each quality on a scale of one to ten. Each judge had a different interpretation of what the middle score should be (i.e. the mean) and the spread of scores (i.e., the variance). If the data are used in this raw form, the results are to a large degree driven by these individual differences which are irrelevant to the study but effectively add a great deal of noise to the data. By z-scoring each judge's wine ratings for each individual attribute (that is, setting the mean wine rating to zero and the standard deviation to one), the separate judge's scores for each attribute can be put on a comparable scale and meaningfully combined for analysis.

Amelioration methods utilizing toasted oak aqueous ellagitannins were not included in this study and should be evaluated at a later date. Providing alternative amelioration options to winemakers struggling with methods on the current market should be considered in future trials.

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Public repository: https://github.com/karlzipser/k3/tree/master/misc/wine

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