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Comparison of Sensory Qualities of Geographically Paired Organic and Conventional Red Wines from the Southwestern US with Differing Total Polyphenol Concentrations: A Randomized Pilot Study

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ABSTRACT

Dietary polyphenols, or phenolic compounds, are numerous, diverse, and ubiquitous phytochemicals occurring throughout the plant kingdom. They are important components of the human diet because of their capacity to reduce the risk of chronic diseases such as cardiovascular disease and cancer. In plants, polyphenols contribute to resistance to pathogens due to their potent astringency and function as phytoalexins. As a result, organic grapevines grown with reduced pesticides may be more stressed by pathogens than conventionally grown grapevines and presumably produce more polyphenols. Since polyphenols also play an important role in the sensory qualities of fruits and wines particularly involving astringency and bitterness, there may be differences that affect sensory perceptions of wine. This establishes a conundrum where dietary polyphenols are healthful but potentially unpalatable. We recruited and randomized 18 *female participants* (21 - 50 *y*) *to one of five groups* (3 - 4 *per group*). *Each group evaluated the sensory qualities of a geographically paired organic* (*OW*) *and conventional wine* (*CW*) *and an artificially colored white wine placebo* (*PW*) *with significantly differing total polyphenol concentrations* (*TP*). *Participants reported for three visits* (*one wine per visit*) *where they consumed* 5 *ounces* (150 *mL*) *of wine over* 15 *minutes while completing the sensory survey. Sensory evaluations based on a Likert-type scale included visual, aroma, and taste perceptions and overall impressions* (*scale* 0 - 10). *In two wine pairs, the OW contained significantly more TP* (3.49 *and* 5.86 *g/L*) *than the respective CW* (2.63 *and* 4.63 *g/L*). *In two other wine pairs both produced by sustainable viticulture, the CW* (5.23 *and* 8.38 *g/L*) *contained significantly more TP than OW* (4.55 *and* 3.70 *g/L*) *and in one set the amounts were equivalent* (4.10 *and* 4.17 *g/L*). *The five PW averaged* 1.26 ± 0.20 *g/L. Although there were significant differences in TP content of test wines, the results indicated that no significant differences in either intensity or quality for any of the sensory qualities were detected between paired OW and CW wines but both scored significantly higher than the PW, with significantly lower TP. We conclude in this pilot study that a subset of OW from the Southwestern US is perceived similarly to CW produced by the same vineyard even with significantly differing TP concentrations.*

Keywords: *Organic, Wine, Conventional, Polyphenols, Sensory Qualities*

1. Introduction

Polyphenols, or phenolic compounds, constitute one of most numerous and widely distributed groups of phytochemicals in the plant kingdom with more than 8000 distinct structures [1]. Polyphenols contribute significantly to plant physiology playing key roles in pigmentation, growth, reproduction, and resistance to pathogens and predators due to their potent astringency and function as phytoalexins [2]. Plant polyphenols are also important components of the human diet because of their demonstrated antioxidant activity and capacity to interrupt oxidative stress-induced elaboration and exacerbation of chronic diseases such as cardiovascular disease and cancer [3-5]. In addition, dietary polyphenols exert antibiotic, anti-diarrheal, anti-ulcer, and anti-inflammatory activities [2,6]. Thus, increased consumption of polyphenol-rich foods and beverages would seem to be an effective means of reducing the risk for chronic disease.

The polyphenol family of molecules has many subclasses based on chemical structures including the anthocyanins and flavanols. Anthocyanins are responsible for the red, blue and purple colors of many foods including fruits and vegetables while flavanols and high molecular weight tannins contribute to sensorial properties such as astringency and bitterness [7]. Astringency is a complex tactile sensation produced by the binding of dietary polyphenols with proline-rich proteins in saliva and eventual precipitation of these insoluble complexes, which would normally provide lubrication in the mouth [8-10]. While astringency is a natural and desirable part of the overall flavor of many foods, it can be strong enough along with bitterness to be unpleasant in some foods and beverages [7,11]. As a result, some functional foods that could be beneficial to health may not be well-accepted due to their astringency.

The concentration of polyphenols in fruit-based foods depends on a number of factors including species, varieties, geographical heritage, maturity, growing conditions, production area and yield of fruit as well as technological processes [12]. Plants, such as *Vitis vinifera*, used to make wine, produce many biomolecules, or naturally occurring chemicals, as defense against microbial pests. For example, levels of resveratrol, a polyphenolic stilbene, are increased significantly by grapevines after exposure, in large part, to fungus and bacteria [13]. As a result, organic grapevines grown with reduced pesticide treatment would be exposed more frequently to pathogens than conventionally grown grapevines and presumably produce more polyphenol [14-16]. Several have suggested that organic grapes and their products, *i.e.*, wines, would then be more healthful [13,17,18]. While this could potentially be more beneficial for humans, polyphenols, as well as other biomolecules including biogenic amines, ochratoxin A, etc., can exhibit adverse qualities, *i.e.*, bitterness, astringency, etc., which could markedly affect the perception and sensory quailties of organic wines [19-21].

The objectives of this blinded, placebo-controlled study using untrained panelists were 1) to determine if a subset of OW from the Southwestern US would contain higher concentrations of TP than their paired CW; and 2) to determine if relative sensory differences (visual, aroma, and taste) could be detected in wines with differing polyphenol concentrations [22]. In order to control for variables including cultivar, soil and climate, each wine of a particular agricultural process (organic vs. conventional) was paired with one or more wines of similar cultivar, region, and harvest year but grown using the alternate agricultural procedure. An artificially colored Pinot grigio was used as the PW for comparison. Participants evaluated the quality and intensity of visual, aroma, and taste perceptions of the test wines and commented on overall impressions.

2. Methods

2.1. Wines Analyzed

Sample wines (750 mL each) were obtained from five vineyards in the Southwestern US (California and Arizona). Each wine of a particular agricultural process (organic, sustainable and conventional) was paired with one or more wines of similar cultivar, region (to control for soil and climate), and harvest year but grown using alternate agricultural practices. Processing of grapes after harvest and subsequent procedures for wine production of respective wine pairs were similar. A total of five red wine pairs as well as a placebo wine for each pair were tested (**Table 1**). The conventionally produced placebo wines were purchased at local supermarkets in the greater Phoenix area and samples (150 mL) were artificially colored at each member visit with 5 drops of red food coloring (McCormick & Co., Inc., Hunt Valley, MD) prior to sampling by participants. The organic wines were produced by certified organic wineries and were third party-certified to conform to organic certification standards or those using sustainable agricultural practices. Although a universally accepted definition of sustainable viticulture is lacking, avoidance of chemicals such as pesticides is routinely employed and aligns with organic viticulture practices. The conventional wines were from wineries that did not specify or affirm use of organic and/or sustainable agricultural practices.

2.2. Subjects

Eighteen non-pregnant, non-smoking generally healthy females aged 21 - 50 years, who consumed wine twice or more each month, were recruited from Arizona State University to participate in the study. Inclusion criteria included absence of illness, disease or other medical condition, limited average alcohol consumption (≤7 servings/week with ≤2/day) and a body weight ≥50 kg. All participants reported a preference toward wine consumption, versus other alcoholic beverages, and for those at the upper limit of servings consumed no more than one glass per day. At the initial recruitment interview, participants reported no negative perceptions or specific

Table 1. Sources and descriptions of test wines.

Group	ID[1]	County	Type	Winery	Varietal	Vintage (year)
1	OQ1	Mendocino	Organic*	Barra	Pinot Noir	2006
1	CQ1	Mendocino	Conventional	Graziano	Pinot Noir	2004
1	PQ1	NE Italy	Placebo	Bella Sera	Pinot Grigio	2005
2	OQ2	Sonoma	Organic*	Preston	Zinfandel	2005
2	CQ2	Sonoma	Conventional	Francis Ford Coppola	Zinfandel	2005
2	PQ2	Italy	Placebo	Bolla	Pinot Grigio	2007
3	OQ3	Sonoma	Organic*	Adastra	Pinot Noir	2005
3	CQ3	Sonoma	Conventional	Kent Rasmussen	Pinot Noir	2004
3	PQ3	New South Wales	Placebo	Yellow Tail	Pinot Grigio	2007
4	OQ4	San Luis Obispo	Organic**	Halter Ranch	Syrah	2004
4	CQ4	San Luis Obispo	Conventional	Zenaida	Syrah	2004
4	PQ4	NE Italy	Placebo	Bella Sera	Pinot Grigio	2005
5	OQ5	Socorro	Organic**	Colibri	Syrah	2005
5	CQ5	Socorro	Conventional	Fort Bowie Winery	Syrah	2005
5	PQ5	NE Italy	Placebo	Bella Sera	Pinot Grigio	2005

*Certified organic; **Sustainable farming; [1]OQ1, organic quality group 1; CQ, conventional quality group 1; PQ1, placebo quality group.

preferences for organic versus conventional wines although red wines were consumed more than white wines. The study was approved by the Institutional Review Board of Arizona State University and informed consent was obtained from the subjects on the first visit.

2.3. Study Design

Subjects were randomly assigned to one of five groups (3 - 4 participants per group) and each group was assigned to a particular pair of wines (OW and CW) from the same region, vintage and varietal and a PW (artificially colored Pinot grigio) for a total of three samplings. The subjects were blinded regarding group assignment and wine sampled at each visit.

Each group of subjects reported for 3 independent visits to the Department of Nutrition with at least a 48-hour washout period between visits. During each visit (three total), the subjects consumed either a 150 mL (5 ounce) glass (one serving) of organic wine, its conventional counterpart or an artificially colored placebo wine poured in a secluded metabolic kitchen 15 min prior to serving at 25˚C in standard Bordeaux wine glasses. Wine samples were provided in random order over three visits and consumed over 15 min in a departmental lounge. Participants remained at the testing site for one hour post-consumption, were provided food and non-alcoholic beverages, and were interviewed prior to being released from the site.

2.4. Sensory Survey

During the consumption period, subjects completed a qualitative sensory evaluation survey based on a Likert-type scale for each wine as adapted from Vilanova [23]. Quantitative descriptive analysis of attributes including visual, aroma, and taste were determined (as shown in **Figure 1**) using an 11 point scale (range 0 - 10) for both quality and intensity for each attribute [24,25]. Participants were provided instruction on aspects of flavor as a combination of experiences from the senses of smell (noting specific aromas and/or sensations), taste (bitter, sweet, etc.), touch (mouth feel, astringency, etc.), and sight (color and depth), as well as familiarized with definitions and standards of astringency and bitterness and asked to focus on these endpoints. Participants, although untrained, were encouraged, but not required, to construct comments based on any additional observations or perceptions. The comments were categorized overall as either positive, negative, indifferent (both negative and positive), or non-responsive, and were assigned scores of 12, 13, 14 and 11, respectively.

Participant ID#:													Date: / /
Wine ID#:													
Point		0	1	2	3	4	5	6	7	8	9	10	Observations
Visual Expression	Intensity												
	Quality												
Smell Expression	Intensity												
	Quality												
Taste Expression	Intensity												
	Quality												
Overall Impression	Intensity												
	Quality												

Figure 1. Example of qualitative sensory survey.

2.5. Ethanol Concentration and Analysis of pH

The ethanol concentration was acquired from the product label as reported by each individual company. The pH of multiple aliquots of each wine (25˚C) was measured in triplicate using a pH meter calibrated with purchased standards.

2.6. Analysis of Total Polyphenols

The Folin-Ciocalteau method was used to quantify TP in wine samples as described previously [26]. Three milliliters of water, 200 uL Folin-Ciocalteau reagent and 200 uL of diluted sample or standard (gallic acid) were added to test tubes and mixed well by gentle vortexing (3 sec; low speed). Tubes were incubated at room temperature (25˚C) for 10 min followed by addition of 600 uL of 20% sodium carbonate. Tubes were then incubated in a water bath at 40˚C for 20 min followed by immediately cooling in an ice bath to room temperature 25˚C (30 min). After cooling, samples were analyzed at 755 nm. Purified gallic acid was used as the external standard and data expressed as mean gallic acid equivalents (GAE) from triplicate samples.

2.7. Statistics

Statistical analysis was performed using the SPSS Statistical Analysis system 15.0 using ANOVA and the Student's t test. Comparisons were made between responses for conventional, organic and placebo wines within each member group. Data for all five groups for each wine and attribute were pooled and also analyzed. All data are reported as means ± standard deviation. Differences were considered significant at $P < 0.05$.

3. Results

Sensory surveys were completed for all 15 organic, conventional and placebo wines in order to determine if significant differences in sensory qualities of OW and CW were perceived by study participants. The participants ranked the wines on a scale of 0 - 10, commented regarding the qualities, and evaluated the intensity and quality of each parameter to include visual, aroma, and taste impressions, as well as overall impression.

Since pH, ethanol concentration, and TP levels can have an impact on the sensory qualities of wines, we evaluated these first. The mean ethanol concentration was 13.7% ± 1.1% v/v and ranged from 12.5% - 15.7% v/v for all wines and was within the range expected for commercial wines (**Table 2**). By law, a tolerance of ±1.5% is allowed in reporting for wines with ≤14% ethanol by volume, and ±1% for wines with >14% ethanol. The pH ranges for organic and conventional wines were 3.23 - 3.56 and 3.28 - 3.61, respectively, and values were not significantly different from one another. The pH for the PW was significantly lower than the collective red wines, as expected, with a range of 2.82 - 2.92. TP ranged from 3.49 - 5.86 mg/mL for OW and 2.63 - 8.38 mg/mL for CW. The PW contained significantly less TP, as expected, with a

Table 2. Ethanol content, pH and total polyphenols in test wines.

Group	ID[1]	ALC[2] (%)	pH (x ± SD)	TPP[3] (mg/mL)
1	OQ1	13.5	3.53 ± 0.03	3.49 ± 0.16
1	CQ1	13.5	3.28 ± 0.02	2.63 ± 0.15*
1	PQ1	12.5	2.82 ± 0.02**	0.86 ± 0.09**
2	OQ2	14.3	3.23 ± 0.02	4.10 ± 0.19
2	CQ2	14.8	3.50 ± 0.01	4.17 ± 0.12
2	PQ2	12.5	2.92 ± 0.02**	1.52 ± 0.21**
3	OQ3	14.5	3.56 ± 0.02	5.86 ± 0.36
3	CQ3	14.6	3.58 ± 0.01	4.63 ± 0.26 *
3	PQ3	12.5	2.88 ± 0.02**	1.00 ± 0.21**
4	OQ4	15.4	3.36 ± 0.01	4.55 ± 0.14
4	CQ4	15.7	3.60 ± 0.10	5.24 ± 0.17 *
4	PQ4	12.5	2.80 ± 0.02**	1.86 ± 0.37**
5	OQ5	13.5	3.61 ± 0.02	3.70 ± 0.33
5	CQ5	13.5	3.49 ± 0.01	8.38 ± 0.65*
5	PQ5	12.5	2.89 ± 0.01**	1.52 ± 0.21**

[1]OQ1, organic quality group 1; CQ, conventional quality group 1; PQ1, placebo quality group; [2]ALC: alcohol (ethanol) concentration (%); [3]TPP: total polyphenol concentration; $^{*}P < 0.05$, CQ versus OQ within group; $^{**}P < 0.05$, OQ and CQ versus PQ.

range of 0.86 - 1.86 mg/mL.

Similar to the previous results, there were no significant differences between organic and conventional wines regarding visual qualities (**Table 3**). The mean pooled sensory scores for intensity for organic and conventional were 8.2 ± 0.3 and 8.0 ± 0.3, respectively. The mean sensory score for quality scores were 8.0 ± 0.3 and 7.7 ± 0.2 for organic and conventional wines, respectively. Both red wines differed significantly from the placebo white wine which had scores of 3.1 ± 0.7 and 3.1 ± 0.7 for intensity and quality, respectively.

There were no significant differences between organic and conventional wines regarding aroma qualities. The mean pooled aroma sensory score for intensity for organic and conventional were 6.3 ± 0.5 and 6.4 ± 0.4, respectively (**Table 4**). The mean sensory score for quality scores were 6.1 ± 0.4 and 6.9 ± 0.5 for organic and conventional wines, respectively. Both red wines scored significantly higher than the placebo white wine, which averaged 3.5 for intensity and quality. When all data were pooled to evaluate the overall impression of wines, the scores were not significantly different between organic and conventional wines, but were for both red wines

Table 3. Visual sensory quality scores for test wines[1].

Group	Wine	ID[2]	Quality	Intensity
1	Barra	OQ1	7.8 ± 1.3	7.8 ± 1.3
1	Graziano	CQ1	7.3 ± 1.0	7.3 ± 1.0
1	Bella Sera	PQ1	1.5 ± 1.7*	3.3 ± 1.0*
2	Preston	OQ2	8.3 ± 1.3	8.0 ± 0.8
2	Francis Ford Coppola	CQ2	7.0 ± 2.2	7.3 ± 1.0
2	Bolla	PQ2	5.5 ± 4.0*	1.8 ± 1.7*
3	Adastra	OQ3	9.5 ± 0.6	8.8 ± 1.9
3	Kent Rasmussen	CQ3	8.0 ± 2.6	8.0 ± 1.7
3	Yellow Tail	PQ3	3.0 ± 1.7*	7.0 ± 1.0*
4	Halter Ranch	OQ4	7.5 ± 1.3	7.5 ± 1.3
4	Zenaida	CQ4	8.0 ± 1.4	7.8 ± 0.5
4	Bella Sera	PQ4	1.0 ± 1.0*	2.3 ± 2.5*
5	Colibri	OQ5	7.7 ± 1.5	7.7 ± 1.5
5	Fort Bowie Winery	CQ5	8.0 ± 2.0	8.3 ± 0.6
5	Bella Sera	PQ2	5.5 ± 4.0*	1.8 ± 1.7*

[1]Data are expressed as means ± std dev from 3 - 4 participants; [2]OQ1, organic quality group 1; CQ, conventional quality group 1; PQ1, placebo quality group; $^{*}P < 0.05$, PQ versus OQ and CQ within group.

Table 4. Aroma sensory quality scores for test wines[1].

Group	Wine	ID[2]	Quality	Intensity
1	Barra	OQ1	5.0 ± 1.4	6.8 ± 0.5
1	Graziano	CQ1	6.8 ± 1.3	6.3 ± 1.5
1	Bella Sera	PQ1	3.3 ± 1.0*	3.3 ± 1.0*
2	Preston	OQ2	7.3 ± 1.3	6.5 ± 1.3
2	Francis Ford Coppola	CQ2	6.0 ± 2.6	7.0 ± 2.4
2	Bolla	PQ2	2.5 ± 0.6*	1.8 ± 1.7*
3	Adastra	OQ3	5.0 ± 2.7	4.5 ± 3.1
3	Kent Rasmussen	CQ3	4.7 ± 0.6	5.0 ± 2.6
3	Yellow Tail	PQ3	5.0 ± 2.6*	4.7 ± 1.2*
4	Halter Ranch	OQ4	6.3 ± 1.7	7.3 ± 1.3
4	Zenaida	CQ4	7.5 ± 1.3	8.0 ± 0.8
4	Bella Sera	PQ4	2.3 ± 2.5*	1.7 ± 1.2*
5	Colibri	OQ5	8.3 ± 0.6	5.3 ± 1.5
5	Fort Bowie Winery	CQ5	7.0 ± 1.7	8.3 ± 0.6
5	Bella Sera	PQ5	2.3 ± 2.5*	1.7 ± 1.2*

[1]Data are expressed as means ± std dev from 3 - 4 participants; [2]OQ1, organic quality group 1; CQ, conventional quality group 1; PQ1, placebo quality group; $^{*}P < 0.05$, PQ versus OQ and CQ within group.

compared to the white wine placebo (**Table 4**).

There were also no significant differences between organic and conventional wines when comparing taste sensation (**Table 5**). The mean pooled scores were 6.7 ± 0.4 and 7.0 ± 0.4 for intensity of organic and conventional and 6.2 ± 0.6 and 7.3 ± 0.4 for quality, respectively. Both red wines scored significantly ($P < 0.05$) higher than the placebo white wine, which scored 3.9 ± 0.6 and 3.7 ± 0.6 for intensity and quality, respectively.

Feedback in the form of comments was solicited for each wine and quantitated as described previously. There were no significant differences between organic and conventional wines and placebo wine regarding comments. The mean scores were 12.2 ± 0.3, 12.1 ± 0.3, and 12.5 ± 0.4 for organic, conventional and placebo wines, respectively. Collectively, there were no overt, adverse or overwhelming differences between any of the wines. (data not shown).

4. Discussion

We report here that four of five pairings of OW and CW (one vineyard per pair) produced in geographically similar areas of the Southwestern US contained significantly different concentrations of polyphenols but were perceived similarly regarding sensory characteristics. Two of the five organic wines were higher in TP and two were lower than its respective counterpart. One pair was not significantly different. This permitted a comparison of a subset of OW and CW where OW had either higher, lower or equivalent amounts of TP. Despite significant differences in polyphenol concentrations, there were no perceived differences in overall quality and intensity of visual, aroma, and taste perceptions.

Table 5. Taste sensory quality scores for test wines[1].

Group	Wine	ID[2]	Quality	Intensity
1	Barra	OQ1	5.8 ± 2.1	6.5 ± 2.6
1	Graziano	CQ1	6.5 ± 1.7	5.8 ± 1.7
1	Bella Sera	PQ1	4.0 ± 0.0*	3.8 ± 0.5*
2	Preston	OQ2	6.8 ± 1.3	6.0 ± 2.2
2	Francis Ford Coppola	CQ2	6.8 ± 1.9	7.0 ± 0.8
2	Bolla	PQ2	3.5 ± 2.6*	1.8 ± 0.5*
3	Adastra	OQ3	6.5 ± 1.3	5.5 ± 3.5
3	Kent Rasmussen	CQ3	6.0 ± 1.0	7.7 ± 2.1
3	Yellow Tail	PQ3	5.3 ± 3.5*	6.7 ± 2.5*
4	Halter Ranch	OQ4	6.8 ± 2.1	6.0 ± 2.6
4	Zenaida	CQ4	8.0 ± 1.4	8.0 ± 1.4
4	Bella Sera	PQ4	2.3 ± 3.2*	2.7 ± 3.1*
5	Colibri	OQ5	8.3 ± 1.5	7.0 ± 1.7
5	Fort Bowie Winery	CQ5	7.7 ± 2.3	8.7 ± 0.6
5	Bella Sera	PQ4	2.3 ± 3.2*	2.7 ± 3.1*

[1]Data are expressed as means ± std dev from 3 - 4 participants; [2]OQ1, organic quality group 1; CQ, conventional quality group 1; PQ1, placebo quality group; *$P < 0.05$, PQ versus OQ and CQ within group.

OW theoretically should have higher amounts of TP and perhaps specifically phytoalexins such as resveratrol due to decreased use of pesticides and, as a result, increased exposure of organic grapevines to microbial infestation [27,28]. In a study by Dani *et al*., organic grape juices (8 total) showed statistically significant higher amounts of TP and specifically resveratrol compared to paired conventional grape juices, which translated into higher in vitro antioxidant activity [14]. TP were 120 and 250 mg catechin/mL for conventional and organic Bordo juices, respectively, and resveratrol was 75 and 200 ug/L, respectively. We found that two organic wines (OQ1 and OQ3; Pinot noirs) out of five wine pairs had significantly higher TP than their respective, paired CW (also Pinot noirs), whereas two red wines (OQ4 and OQ5; Syrahs) out of five had lower levels than their respective CW (also Syrahs). Although the wines were different, each was paired with is respective control, grown and processed similarly. The paired zinfandels were equivalent. These mixed results were similar to Levite *et al*. who obtained wine samples from six vineyards in western Switzerland and reported that OW showed higher resveratrol, a polyphenol stilbene contributing to TP, in seven cases, whereas in two cases the resveratrol levels were lower [17]. In contrast, Vian *et al*. compared the polyphenolic anthocyanin composition of Syrah grapes grown using organic and conventional agricultural practices and found that grapes from conventional agricultural viticulture had higher proportions of the polyphenol anthocyanins delphinidin, petunidin, malvidin, and malvidin glucosides compared to organic grapes presumably contributing to increased TP levels. Our data agree with the latter since both conventionally produced Syrahs were significantly higher in TP (5.24 ± 0.17 and 8.38 ± 0.65 mg/mL) than their organic counterparts (4.55 ± 0.14 and 3.70 ± 0.33, respectively).

TP levels can vary considerably in grapes and subsequently translate to different TP levels in wines. Goldner and Zamora report a maximum TP concentration in wine to be 5.0 g/L [24]. This equates to delivery of 600 mg per four ounce glass. This is in contrast to others who have stated that the total amount of phenols found in a glass of red wine is on the order of 200 mg versus about 40 mg in a glass of white wine [29]. It is, however, in agreement with our study where we found red wines to contain 2.6 - 8.4 g/L TP (mean 5.5 g/L). We also calculate delivery of 419 - 703 mg TP from OW, 316 - 1006 mg TP from CW, and 103 - 222 mg TP from the PW.

Several methods have been used to quantitate polyphenols in wines with differing levels of support. For example, Landon *et al*. determined tannin, anthocyanin and small (SPP) and large polymeric pigment (LPP) concentrations using the Hagerman-Butler method as adapted by Adams-Harbertson based on protein precipitation for determination of tannins [30,31]. The investigators then used the results as a means of examining astringency through stratification of wines by SPP or LPP levels [31]. The methyl cellulose-precipitable tannin assay similar to the Adams-Harbertson protein precipitation-based wine tannin method has been used frequently for analysis of tannins [32]. The latter, however, has recently been scrutinized and determined to be invalid [33]. As such, we selected one of the most widely used, although less specific, assays for the analysis of total phenolics in wine. The Folin-Ciocalteau method is sensitive to wine phenolics including low molecular weight compounds such as resveratrol, which would presumably be elevated in OW [34]. Based on this analysis, we then determined if changes in TP levels would be correlated to relative sensory differences. The differences were apparent between PW and the red wines.

TP, and their higher molecular weight, condensed structures, viz., tannins, confer astringency to wine in a directly proportional manner. The in-mouth textural properties of Shiraz red wines are positively, significantly associated with their tannin and anthocyanin composition and concentration as well as their acidity and alcohol content [35]. Recall that in our study, two wine pairs of 5 total pairs were Syrahs. Astringency is also correlated with TP levels as shown by Monteleone *et al*. who enlisted 30 subjects with similar salivary flows to rate the perceived astringency of tannic acid and grape seed extract solutions [36]. The intensity of the perceived sensation steeply increased with increasing TP concentrations over 0 - 3.2 g/L in agreement with others [37]. In our study, the range of TP concentrations was 0.86 - 1.86 g/L and 2.63 - 8.38 g/L for PW and red wines (OW and CW), respectively, clearly encompassing a range where astringency could be discerned. Goldner and Zamora tested the astringency effect of TP at 1.40 - 4.70 GAE/L (low group) and 5.20 - 7.20 GAE/L (high group) and found a significant positive correlation between TP and astringency but not beyond 5.20 g/L [24]. In our study, we did not note significant differences between the sensory qualities of OW and CW. TP ranged from 3.49 - 5.86 mg/mL for OW and 2.63 - 8.38 mg/mL for CW. The PW contained significantly less TP with a range of 0.86 - 1.86 mg/mL. This suggests that the differences between TP concentrations in organic and conventional red wines may not have been great enough to alter, either positively or negatively, sensory perception. We included, however, an artificially colored white wine control to demonstrate that untrained tasters could detect a difference when a beverage was considerably different as the data in this study comparing red wines and PW clearly indicate.

Interestingly, we did note in two groups that CW contained higher TP concentrations than the OW. Both wine pairs were Syrahs (OQ4 and OQ5) and were produced agriculturally by sustainable viticulture. Sustainable viticulture is a broad term and a single definition is lacking, however, the practice generally involves encouraging biodiversity, creating natural habitats, leaving areas fallow, and reducing or avoiding use of chemicals, which would align sustainable viticulture with organic practices [38]. This is important since grape content alone does not determine polyphenolic concentrations of wines. It is possible that wine production techniques for individual wines within a pair, or vinification techniques, were a primary determinant of phenolic content since wine makers may adjust the vinification variables to produce the best quality wine possible [39]. Each wine pair was produced similarly by the same vineyard in the same geographical area using similar techniques specific to the respective vineyard.

Wines may be evaluated by trained or untrained panels, which may or may not affect the conclusions regarding sensory properties. For valid results, many suggest only the use of a trained panel with sensory standards and a discriminative test before a Quantitative Descriptive Analysis (QDA), *i.e*., triangle test or paired comparison, can be obtained [40-42]. The QDA method is dependent on a panelist's ability to reliably verbalize perceptions of a wine and entails a formal screening and training protocol, development and use of specific sensory language, and the scoring of wines in repeated trials to produce a complete, quantitative description [40-42]. This is based on the premise that untrained panelists, in general, are good at judging relative sensory differences but poor at evaluating absolute differences thus more sophisticated techniques and tools are needed. Our objective in this study was to simply determine if there were relative sensory differences perceived by casual wine drinkers that could be correlated with TP levels in 5 sets of paired CW and OW from the Southwestern US. To that end, we recruited, as others have, an untrained panel of students from Arizona State University. At Washington State University, Ross and Weller (2007) conducted a sensory evaluation (aroma, flavor, and mouthfeel) study with untrained panelists to determine if suspected Harmonica axyridis-tainted red wine (Washington state Merlot) would be detected [22]. The panel was able to discern and favored the control wine versus the tainted wine. Landon *et al*. determined the relationship between tannins, anthocyanins, and SPP and LPP concentrations in numerous Washington state red wines using 18 untrained panelists and related this to perceived astringency [31]. The results indicated a relationship between polyphenolic compounds and sensory attributes of astringency and bitterness. Childs and Drake tested clear acidic whey protein beverages for consumer perception of astringency using 6 focus groups (n = 49) recruited from a college student body who were presumably untrained panelists [43]. Although ideally, trained panelists would be better suited to discern absolute differences in the test wines, the recruited untrained panel used in this study was sufficient to determine relative sensory differences of wines.

In this study, we noted no differences between OW and CW regarding the perception of astringency. It is noteworthy that perception of astringency may be affected by many factors such as protein concentration, polyphenol concentration, pH and alcohol content, which can influence protein-polyphenol interaction and induce the sensation of astringency [24]. The pH values for all red wines in our study were not significantly different between groups and ranged from 3.28 - 3.61, which is consistent with industry standards (pH 2.9 - 4.2). The pH was, however, lower in the PW as expected since white wines generally are low in astringency and higher in acidity as the data in **Table 2** clearly show. The ethanol concentrations of wines in our study ranged from 12.5% - 15.7% (v/v) and were within the range expected for commercial wines noting that governmental regulations permit a tolerance, or margin of error, of ±1.5% and ±1.0% for wines with ≤14.0% and >14.0% alcohol by volume, respectively. We noted no significant differences in sensory qualities between the red wines although 13% ethanol reportedly can enhance astringency and salivary protein-tannin interactions [44]. It is possible, but unlikely, that the red dye in white wine may have adversely affected the astringency sensation and flavor more than reduced TP concentrations or lowered pH.

Our results demonstrate no perceived differences between a subset of OW and CW from the Southwestern US in agreement with others. Dupin *et al*. attempted to differentiate wines produced from organic and conventional viticulture according to their sensory profiles and aroma composition. It was concluded that the quality of organically grown wines did not generally suffer from limited pesticide and fertilizer use and organic viticultural practices did not yield an overall higher intensity of aroma compounds than conventional counterparts [45]. In a different study, 23 commercial, organic Italian wines were compared based on chemical parameters, biologically active polyphenol concentrations and sensory analysis. Overall, the data showed inconsistent differences in resveratrol and p-coumaric acid contents in comparison with non-organic wines. Furthermore, the chemical analyses and sensory data of organic wines did not significantly differ from those previously cited suggesting organic wines display satisfactory sensory properties such as flavor intensity, body and a general acceptance [46].

We have shown that TP concentrations can and often do differ between wines produced from organic versus conventional agricultural practices. Although theoretically organic wines should higher TP, data do not support a sweeping generalization to this effect. We conclude from this pilot study using a subset of wines from the Southwestern US that OW were perceived similarly to CW even with significantly differing TPP concentrations.

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