Note

Flavor Compounds in Wines Produced from Chardonnay Grapes Fermented with Fruit Juices

Sangeeta PATEL and Takayuki SHIBAMOTO*

Department of Environmental Toxicology, University of California, Davis, One Shields Avenue, Davis, CA 95616, USA

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Chardonnay grapes were fermented with or without juice of apple, pear, cantaloupe, peach, banana, or orange with a *Saccharomyces cerevisiae* yeast strain. Volatile chemicals formed in the seven wines were isolated and identified by gas chromatography/mass spectrometry. A total of 29 major volatile compounds were identified in the seven wines. They were 8 alcohols, 12 esters, 6 acids, and 3 miscellaneous compounds. Isoamyl alcohol was the most abundant volatile chemical found in all the wines. It comprised from 31.35% (pear wine) to 44.94% (orange wine) of the total GC peak area. Cantaloupe wine contained the highest amount of 2-phenyl alcohol in the seven wines. Amounts of monoethyl succinate, which was one of the most abundant compounds found in wine fermented alone, ranged from 8.35% (apple) to 23.95% (banana). Ethyl 2-hydroxy propionate, amounts of which ranged from 3.93% (cantaloupe) to 5.41% (without fruit), was one of the major esters found in wines. The addition of fruit juices did not significantly change the overall volatile composition of fermented grapes. However, each fruit juice gave its characteristic flavor to the final wine. There have been only a few reports on wines flavored with other fruits.

Keywords: Chardonnay grapes, fruit juices, *S. cerevisiae*, flavor chemicals, wines

Although wine is the fermented product of grapes, various flavored wine beverages are also available. These flavored wines are prepared by adding flavoring materials, such as concentrated fruit essences, after the manufacture of the wine. Fruit flavored wines currently being produced include Wild Vines (E & J Gallo), three fruit flavored wines under the Soleo brand (Sutter Home), and Arbor Mist (Canandaigua Wine Co.). Wine coolers, which are low alcohol wines flavored with fruit juices, have also been sold in the U.S.

There have been many reports on the volatile aroma compounds in fruit juices, including banana (Jordan *et al.*, 2001), orange (Moshonas & Shaw, 1994), peach (Horvat *et al.*, 1990), apple (Lavilla *et al.*, 1999), cantaloupe (Beaulieu & Grimm, 2001), and pear (Takeoka *et al.*, 1992). However, there have been virtually no reports on the volatile aroma compounds in fermented fruit juices other than grape juice. Studies on volatile aroma compounds in wine prepared from the fermentation of grapes and other fruits are also lacking. Consequently, it is unknown whether the aromatic qualities of non-grape fruits carry through the fermentation process. In the present study, volatile aroma compounds produced during fermentation of Chardonnay grapes with various fruit juices were investigated.

Experimental

Wine preparation Chardonnay grapes were harvested from the Sonoma Valley in September 1997. Grapes were crushed and maintained at temperatures of less than 36°C until transported to the Department of Environmental Toxicology, where the must was frozen at –26.7°C for two weeks until ready

for fermentation. The must was fermented in 50-gal plastic containers fitted with a carbon dioxide vent through a water trap. Each batch of must was blended to 22 degree brix sugar measured with a Leica refractometer (Fisher Scientific, Pittsburgh, PA), and the titratable acidity ranged from 8.5–10 g/l. The sulfur dioxide concentration was adjusted to 50 ppm using a 10% stock solution of potassium metabisulfite (Glen Ellen Winery, Modesto, CA). To each 2700 ml of Chardonnay must, 300 ml of various fruit juices (Fuji apple, pear, cantaloupe, peach, banana, and orange) were added. The juices of all fruits except orange were made by blending the fruit in a Waring blender and then straining out the pulp through a muslin cloth. Orange juice was squeezed using a Braun orange juice squeezer. Six 50-gal batches of must were each fermented with *Saccharomyces cerevisiae* Fermiblanck yeast (Gist Brocades, Canada). The amount of yeast added (22.7 g/50 gal) was that recommended by the winemaker at the Glen Ellen Winery (Modesto, CA).

Fermentation was allowed to proceed at 16°C in a controlled temperature cooler for two weeks until the sugar concentration was reduced to less than 20 mg/dl. The sugar was monitored using a glucose oxidase test strip (Chemstrip, Boehringer Mannheim Corp., Indianapolis, IN). The fermented must was racked three times: at 3 weeks, again 2 weeks later, and again after 2 months. The must was then filtered through cheesecloth into 750-ml wine bottles that were subsequently corked and stored in an 18°C-storage chamber. The wines were stored at an ambient room temperature of 22°C for 1–3 months. After one year, the wines were extracted and analyzed for volatile aroma compounds.

Isolation of volatile flavor compounds in wine A glass column (250 mm×11 mm i.d.) packed with 5 ml Porapak Q res-

*To whom correspondence should be addressed.
E-mail: tshibamoto@ucdavis.edu

in (50–80 mesh, Alltech Associates, Inc., Deerfield, IL) was conditioned with 2 column volumes each of dichloromethane, methanol, and water. A 200-ml sample of wine was placed in the column connected to a 200-ml reservoir. The eluted wine was discarded. The column was further eluted with 50 ml dichloromethane and the eluate was collected in a separatory funnel. A second volume of 10 ml dichloromethane was added and eluted. A third 5-ml volume of dichloromethane was used to extract any remaining sample.

The water layer was discarded. The dichloromethane layer was transferred to an Erlenmeyer flask and dried over anhydrous sodium sulfate. After removal of anhydrous sodium sulfate, the sample solution was concentrated with a rotary evaporator and then further concentrated to a final volume of the sample of 1.2 ml with a purified nitrogen stream in a 5-ml glass vial with a Teflon liner. The sample was stored at -5°C until analysis for volatiles.

Determination of volatile compounds in wine The GC Kovats retention index *I* (Kovats, 1965) and the MS fragmentation pattern of each component were compared to those of the authentic compound to identify the volatiles in the samples. A Hewlett-Packard 5890 gas chromatograph equipped with a 30 m $\times$ 0.25 mm i.d. DB-Wax bonded phase fused-silica capillary column (J & W Scientific, Folsom, CA) and a flame-ionization detector (FID) was used for routine quantitative analysis. The split ratio was 1 : 18. The peaks from chromatography were integrated with a Spectra Physics 4290 integrator (San Jose, CA).

The injector and detector temperatures were maintained at 250°C . The oven temperature was held at 50°C for 8 min and then programmed at $3^{\circ}\text{C}/\text{min}$ to 180°C for 35 min. The linear helium gas flow rate was 30 cm/s.

A HP 5890A Series II GC interfaced to a HP 5972 mass-selective detector was used for mass spectral identification of the GC components at MS ionization voltage of 70 eV. Column and oven conditions were as stated above.

Results and Discussion

The Chardonnay grape originated in Lebanon and France. It became the only grape grown in Chablis, Burgundy (<http://wine.about.com/food/wine/library>). The grape has also been used in sparkling wines and Champagne. The popularity of Chardonnay wine has grown immensely in the past forty years, and it is now the most popular white wine. Chardonnay was chosen for the present study because it possesses a wide variety of flavors.

The recovery method used for volatile compounds was one previously reported (Wada & Shibamoto, 1997). The use of Porapak Q as a trapping agent and dichloromethane as a solvent has been shown to achieve satisfactory recovery of wine volatiles. For example, major wine volatiles such as 2-phenylethanol, diethyl succinate, and octanoic acid, could be nearly 100% recovered using this method (Wada & Shibamoto, 1997). However, this method is unable to isolate semivolatile compounds such as tartaric acid and their esters. Table 1 shows the major vol-

Table 1. Volatile compounds found in chardonnay wine fermented with and without the addition of various fruit juices.

Compound	GC peak area (%)						
	No addition	Fuji apple	Pear	Cantaloupe	Peach	Banana	Orange
Alcohols							
1-Propanol	0.33	—	0.25	0.53	0.44	0.37	0.49
Isobutyl alcohol	2.75	3.79	2.80	3.04	3.94	4.84	2.32
Isoamyl alcohol	35.04	38.86	31.35	32.27	36.21	34.09	44.94
1-Hexanol	0.88	1.08	1.14	0.54	0.72	0.97	1.86
2,3-Butanediol (D, L)	3.04	2.63	2.03	2.30	3.67	2.50	3.16
2,3-Butanediol (meso)	1.33	0.81	0.81	0.77	1.09	0.31	0.79
Benzyl alcohol	0.26	—	—	0.55	—	0.95	—
2-Phenylethanol	11.41	14.75	12.96	21.16	12.70	9.59	6.86
Esters							
Isobutyl acetate	0.23	—	—	—	—	0.22	—
Ethyl butanoate	0.22	—	0.19	—	0.25	—	—
Isoamyl acetate	4.24	3.06	2.55	2.91	1.63	2.46	—
Ethyl hexanoate	0.51	0.51	0.41	—	—	0.57	—
Hexyl acetate	0.17	—	—	—	—	0.19	—
Ethyl 2-hydroxy propionate	5.41	5.08	3.97	3.93	4.47	4.91	5.32
Ethyl octanoate	0.88	0.97	0.83	0.64	0.56	1.08	—
Ethyl decanoate	0.38	—	0.36	—	—	0.50	—
Diethyl succinate	0.82	0.73	2.66	1.82	1.50	0.67	3.73
2-Phenylethyl acetate	3.09	2.67	2.32	1.72	2.44	2.33	—
Hydroxy diethyl succinate	—	—	—	—	—	0.21	—
Monoethyl succinate	11.94	8.35	21.13	9.72	16.88	23.95	21.36
Acids							
Acetic acid	3.76	1.89	2.04	5.93	2.60	2.75	2.62
Butanoic acid	—	—	—	—	—	0.19	—
Isoamyl acid	—	—	—	—	—	0.89	—
Hexanoic acid	2.28	2.47	2.21	2.27	1.57	2.75	0.79
Octanoic acid	4.11	4.68	4.01	4.67	3.31	5.14	0.57
Decanoic acid	1.99	2.09	1.77	1.75	1.58	2.40	—
Miscellaneous compounds							
Benzaldehyde	—	—	—	—	—	0.54	—
γ -Buryrolactone	0.26	0.75	0.52	—	—	0.76	0.37
3-(Methylthio)-1-propanol	0.14	—	—	—	—	0.11	—
Total GC% of volatiles identified	95.48	95.17	95.95	96.52	95.56	96.24	95.18

—: GC peak area% less than 0.01 or not detected.

atile aroma compounds found in Chardonnay wine fermented with or without fruit juices, along with their GC peak area%. Values are the average of two duplicate experiments. A total of 29 major volatile compounds were identified in seven wines fermented with or without various fruit juices; however, the compounds with GC peak area% less than 0.01 were not reported. The composition of the major volatiles found in the Chardonnay wine was consistent with that reported previously (Wada & Shibamoto, 1997). Isoamyl alcohol was the most abundant volatile chemical, comprising 35.04% of the total volatile chemicals in the wine fermented alone. Overall, the addition of fruit juices did not significantly change the composition of volatile chemicals. However, the addition of various fruit juices subtly changed the composition of the volatile aroma compounds and flavor in the resulting wines. Even though the content of isoamyl alcohol in fresh orange juice is very low (0.001–0.067%) (Moshonas & Shaw, 1994), the relative amount of isoamyl alcohol increased—from 35.04% to 44.94%—considerably with the addition of orange juice to the wine. Isoamyl alcohol possesses a peculiar winey-brandy-like taste in proper dilution (Arctandar, 1969).

The amount of 2-phenylethanol was the second greatest after isoamyl alcohol among alcohols found in the seven wines, which ranged from 6.86% (orange) to 21.16% (cantaloupe). And despite the fact that cantaloupe juice contained a rather low level of 2-phenylethanol (Beaulieu & Grimm, 2001), cantaloupe wine contained the highest amount of 2-phenylalcohol of the seven wines. Major cantaloupe volatile compounds, ethyl 2-methyl propionate and ethyl hexanoate (Beaulieu & Grimm, 2001), were not found in the cantaloupe wine. The amount of 2,3-Butanediol (*D*, *L* and meso), which was the third highest amount among the alcohols, was the greatest in peach wine.

The amount of monoethyl succinate, one of the most abundant compounds found in wine fermented alone, ranged from 8.35% (apple) to 23.95% (banana). Banana wine contained a large amount of monoethyl succinate, but there is no report on this compound in banana essence or banana fruit (Jordan *et al.*, 2001). Succinic acid is one of the major acids found in wine (Aragon *et al.*, 1998); consequently, many esters of succinic acid, such as monoethyl succinate, diethyl succinate, and diethyl 2-hydroxysuccinate, were found in the wines. Therefore, one may conclude that fruit juices may contain high levels of succinic acid because the amount of monoethyl succinate almost doubled in the wines fermented with all fruit juices except apple. Monoethyl succinate contributes an acidic taste. Many esters of succinic acids may be present in wines. These succinic acid esters have been used in various flavor compositions, such as imitation butter, rum, brandy, grape, and raspberry (Arctandar, 1969). Ethyl 2-hydroxypropionate, amounts of which ranged from 3.93% (cantaloupe) to 5.41% (no addition), was one of the major esters found in wines. Ethyl 2-hydroxypropionate is an ethyl ester of lactic acid. It possesses mild, fruity-ethereal, and butter-like tastes in aqueous media and has been widely used in flavor compositions such as in imitation butter, butterscotch, grape, and strawberry (Arctandar, 1969).

Apple essence had a higher proportion of ethyl esters of propionic acid and butyric acid (Lavilla *et al.*, 1999). However, apple wine did not contain many detectable esters. The amount of octanoic acid, which ranges from 0.57% (orange) to 5.15% (banana), was the greatest among the six acids found in the seven

wines. Orange wine seems low in acid content compared with the other wines. The addition of cantaloupe juice increased the relative amount of acetic acid from 3.76% to 5.93%.

The banana wine had a strong note of banana. The chromatograms showed the presence of more complex flavor compounds, including many esters. Isoamyl acetate and ethyl hexanoate are associated with a strong banana flavor (Arctandar, 1969). The results reflect the flavor notes detected in the wine.

Conclusion

The addition of fruit juices did not significantly change the overall volatile composition of fermented grapes. However, each fruit juice gave its characteristic flavor to the final wine. There have been only a few reports on wines flavored with other fruits. A Chinese patent describes the preparation of a fruit-grain wine that has a flavor of both fruit wine and the grain wine (Fuqiang, 2000). Another Japanese patent (Chikako, 1998) describes the production of a black tea-flavored sparkling wine or beer, containing lemon juice. In this preparation, the black tea leaves were added before filtering a grain mash or during the boiling of the mash, and lemon juice was added after completing the fermentation. Most fruit-flavored wines are produced by adding the fruit flavors after fermentation of the grape must. This study may be the first to investigate the addition of fruit juice to the grape must prior to fermentation.

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