SOURNESS–SWEETNESS INTERACTIONS IN DIFFERENT MEDIA: WHITE WINE, ETHANOL AND WATER*

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Accepted for Publication May 17, 2006

ABSTRACT

The aim of this work was to study the sourness–sweetness interactions in water, white wine and alcoholic environment to interpret sweet/sour perception in low concentrations within the range normally encountered in white wine. Nine trained assessors rated sweetness and sourness intensity in mixtures of fructose (11.1, 25.0 and 38.9 mM) and tartaric acid (pH 3.0, 3.4 and 3.8) in water and wine (experiment 1) or ethanol solutions at 2.0, 4.0 and 12.0% v/v (experiment 2). The range of quantitative responses was larger for sourness than for sweetness in the three media. The global sourness intensity perception in wine mixtures was significantly lower than in water and ethanol mixtures, indicating the effect of other wine components. The suppressive effect of tartaric acid on fructose sweetness was stronger than the suppressive effect of fructose on tartaric acid sourness.

INTRODUCTION

Although sweet and sour tastes are perceived by their own unique pathway, the perceived intensity of sweet and sour taste is different when both tastes are presented in a mixture. Mixture suppression is a phenomenon whereby the perceived intensity of two tastes in a mixture is less than if they

* Partly presented at the Twentieth Annual Meeting of the International Society for Psychophysics "Fechner Day 2004," Coimbra, Portugal.

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were unmixed, at the same concentration level (Schifferstein and Frijters 1991; Lawless and Heymann 1998). Research in adults suggested that adding high concentrations of citric acid (>0.01 M) to a sucrose solution suppresses the perceived sweetness (Schifferstein and Frijters 1990; Pelletier *et al.* 2004). Many studies have demonstrated similar suppression patterns of sweet over sour (McBride 1989; McBride and Finland 1989, 1990; Schifferstein and Frijters 1990, 1991; Bonnans and Noble 1993). Generally, sourness is suppressed by sweeteners with a very stable pattern and the amount of sourness suppressed depends on both components' levels.

Sweetness and sourness are among the major defining attributes of white wine flavor; furthermore, the balance between these two tastes is considered an important feature to differentiate the sensory quality of white wines. Quality is always related to a certain harmony of tastes, where one taste does not dominate another (Peynaud 1996). The masking effect of sweet over sour has a double purpose in beverages; on one hand it diminishes sourness intensity and on the other it adds a pleasant sensation which has a favorable impact on consumer preferences (Lawless 1977).

Interactions among binary mixtures in different media have been extensively reported (Kamen *et al.* 1961; Pangborn 1961; Moskowitz 1972; McBurney and Bartoshuk 1973; Schifferstein 1994), but much less work has been devoted to explore context effects in complex matrices like beverages and food (see Keast and Breslin 2003). Interactions among flavor components have been the subject of debate in taste and aroma perception; and many differences existed among authors likely because many substances behave in a different way according to their concentration and matrix composition. For example, an ethanol solution in water is perceived as sweet at low concentrations (4%), but as concentration increases, a burning sensation is perceived along with the sweet taste (Peynaud 1996).

The present work studies the perception and interaction of sweet and sour tastes produced by the addition of fructose and tartaric acid in distilled water, alcohol (ethanol) and wine.

MATERIALS AND METHODS

Experiment 1: Water–Wine Media

Samples. Models consisted of three concentrations of fructose (Analytic Grade, Laboratorios Cicarelli, Buenos Aires, Argentina) 11.1, 25.0 and 38.9 mM, mixed with tartaric acid (Analytic Grade, Alcor Reactivos Analíticos, Buenos Aires, Argentina), adjusted to three pH levels (3.0, 3.4 and 3.8) and dissolved in distilled water and in white wine of Chardonnay type (Nieto

Senetiner, origin Mendoza, Argentina, vintage 2002; pH = 3.8, reducing sugars 1.18 g/L, ethanol 12.0% v/v). The concentrations of fructose and pH levels were within the range normally encountered in Chardonnay wine.

Procedure. Nine assessors (three males and six females; aged 23–55 years old) trained in descriptive methods in wine (minimum 60 h) participated in the study. Samples (5 mL) were presented at 18 ± 2C in white plastic cups coded by random three-digit numbers. All samples were sipped and expectorated. Distilled water was used for oral rinsing ("ad lib") at the beginning of experiments and between samples. A full factorial design of three pH levels and three concentrations of fructose yielded nine different samples, which were presented in different randomized orders to each assessor. Participants were asked to focus their attention on sweetness and sourness intensity of each sample. All samples were tested in duplicate (two sessions); half of the assessors scored sourness first and sweetness second, and the remaining assessors scored in reverse order. The intensity of the two tastes was rated individually using a 100-mm unstructured graphic scale.

Data Analyses. Media (water–wine) effect was analyzed by analysis of variance (ANOVA), with pH level, fructose concentration and replication as fixed effects, and assessor as random effect (SPSS v. 11.5). Multiple means comparisons were carried out by the Tukey Honestly Significantly Different (HSD) test at $P < 0.05$.

Experiment 2: Ethanol Mixtures

Samples. Models consisted of two concentrations of fructose (11.1 and 38.9 mM) mixed with tartaric acid, adjusted two pH levels 3.0 and 3.8, and dissolved in ethanol solutions 2.0, 4.0 and 12.0% v/v (96% v/v, Fradealco S.A., Buenos Aires, Argentina).

Procedure. The same assessors of experiment 1 took two training sessions (2-h long each) to recognize sour and sweet taste in alcoholic environment. Samples (5 mL) were presented in random coded plastic cups at 18 ± 2C. The sipping and spitting method was used, rinsing ("ad lib") with distilled water between samples. A full factorial design of two pH levels, two fructose levels and three ethanol levels yielded 12 different samples, which were presented in different randomized order to each assessor. Participants were asked to focus their attention on the intensity of the sweetness and sourness of each sample and the 12 samples were tested in duplicate (two sessions). In the first one, half of the assessors scored sourness first and sweetness second; the remaining assessors scored in reverse order. In the second session, the order of attribute scoring was reversed for each subgroup. The intensity of the two tastes was rated individually using a 100-mm unstructured graphic scale.

Data Analyses. Intensity ratings were analyzed by ANOVA, with pH level, fructose level, ethanol level and replication as fixed factors and assessors as random factor (SPSS 11.5). Means comparison was carried out using the Tukey HSD test at $P < 0.05$ and the standard error of the mean (SEM) was calculated.

RESULTS AND DISCUSSION

Water–Wine Media (Experiment 1)

Panel performance was examined through a five-factor (assessor, replication, pH, fructose and media [water/wine]) ANOVA and all two-way interactions. The assessor and replication effects and their interactions with pH and fructose were not significant, showing that all the assessors evaluated sourness and sweetness in the same fashion.

Wine mixtures showed lower sourness ratings than water mixtures at pH = 3 and higher ratings at pH = 3.8 [interaction pH × context $F_{(2,\ 262)} = 81.96$]. Sweetness showed similar behavior but in inverse order, higher ratings in wine mixtures than water mixtures at pH = 3 and lower at pH = 3.8 [interaction pH × context $F_{(2,\ 262)} = 40.81$]. The range of quantitative responses was larger for sourness than for sweetness in both contexts.

Figure 1 shows sourness intensity ratings for water and wine mixtures. As expected, the perceived intensity of sourness increased significantly with increasing acidity levels (lower pH) [$F_{(2,\ 302)} = 262.59$], and decreased with increasing fructose levels [$F_{(2,\ 302)} = 10.55$] for water mixtures (either at pH 3.4 and 3.8) and for wine mixtures at pH 3.0 and 3.8. These results show a mixture of suppressive effects in both media (water and wine) but a different behavior indicating that sourness is affected by the media [$F_{(1,\ 302)} = 70.12$].

Figure 2 shows the sweetness intensity ratings for water and wine mixtures. The sweetness ratings increased with increasing fructose levels [$F_{(2,\ 302)} = 15.02$] but the rate of change decreased with increasing acidity levels [$F_{(2,\ 302)} = 217.65$], except for pH = 3 in water mixtures; similar suppression effect in both media [$F_{(1,\ 302)} = 0.16$] was observed.

Alcohol Mixtures (Experiment 2)

Panel performance was examined through a five-factor (assessor, replication, pH, fructose and ethanol levels) ANOVA and all two-way interactions. The assessor and replication effects and their interactions with pH, fructose

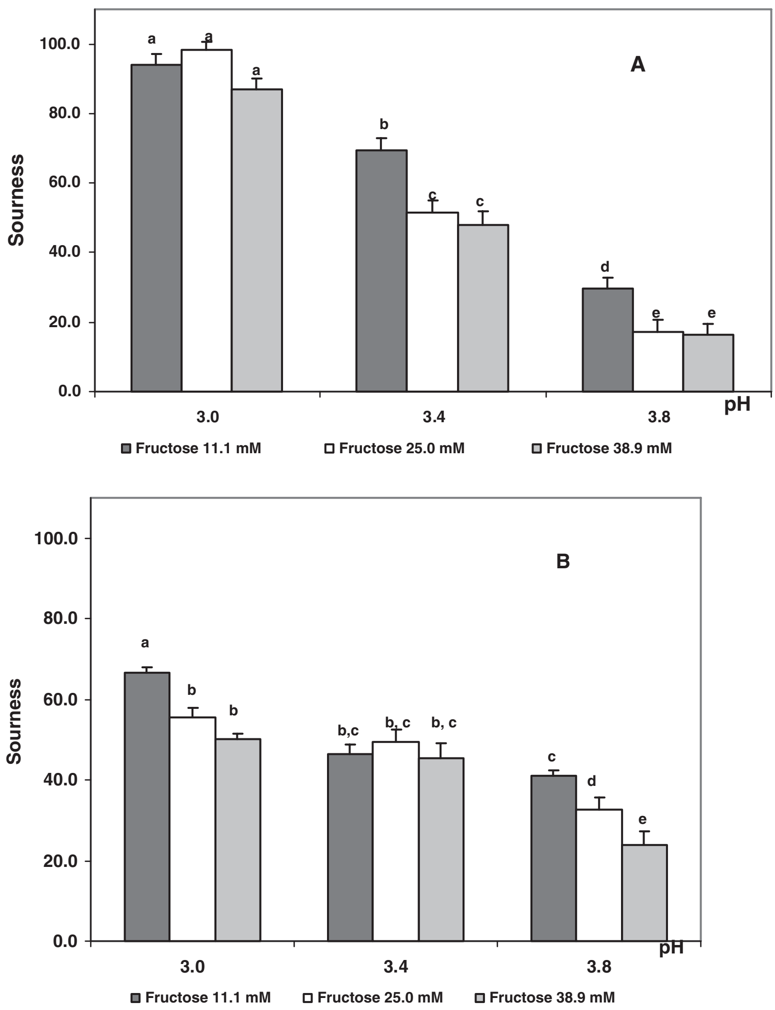

FIG. 1. SOURNESS MEAN INTENSITY OF FRUCTOSE (11.1, 25.0 AND 38.9 mM)–TARTARIC ACID (pH = 3.0, 3.4 AND 3.8) MIXTURES, IN (A) WATER AND (B) WINE CONTEXTS (+ONE STANDARD ERROR OF THE MEAN; TUKEY TEST, DIFFERENT LETTERS CORRESPOND TO SIGNIFICANT DIFFERENCES $P < 0.05$)

and ethanol were not significant, showing that all the assessors evaluated sourness and sweetness in the same fashion.

Alcohol levels had no effect on sourness ratings [$F_{(2,\ 215)} = 0.11$] pH = 3 (Fig. 3), but at pH = 3.8 and fructose 11.1 mM the increase of alcohol concentration from 4 to 12% reinforces sourness perception (interaction pH × ethanol

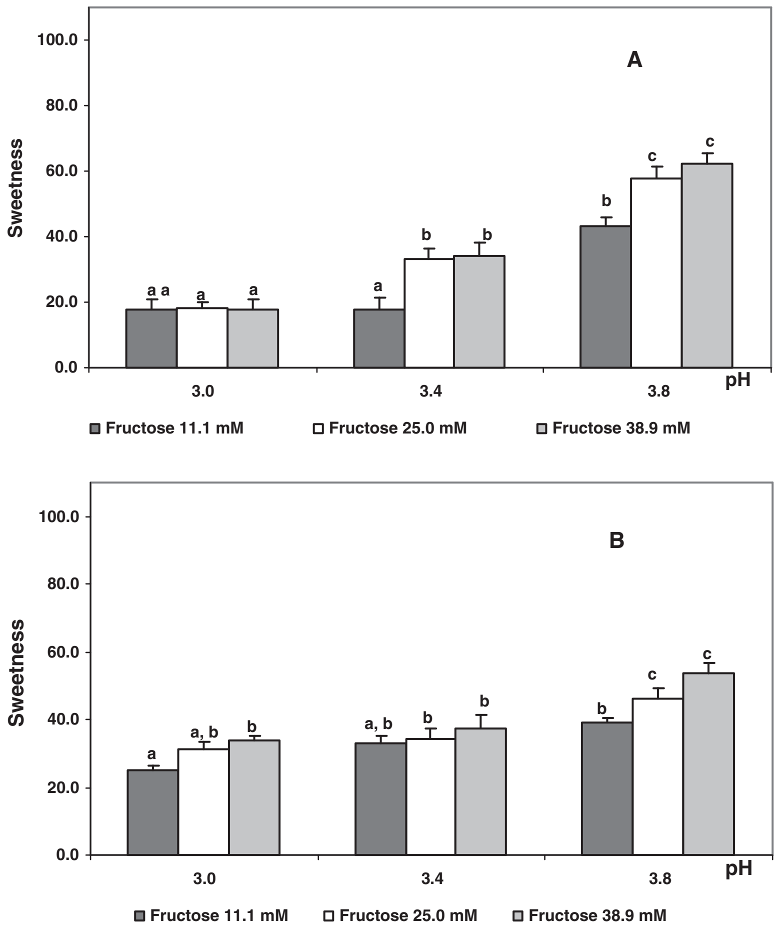

FIG. 2. SWEETNESS MEAN INTENSITY OF FRUCTOSE (11.1, 25.0 AND 38.9 mM)–TARTARIC ACID (pH = 3.0, 3.4 and 3.8) MIXTURES, IN (A) WATER AND (B) WINE CONTEXTS (+ONE STANDARD ERROR OF THE MEAN; TUKEY TEST, DIFFERENT LETTERS CORRESPOND TO SIGNIFICANT DIFFERENCES $P < 0.05$)

[$F_{(2, 144)} = 7.08$]). At pH 3.0 sourness intensity increased with increasing acidity levels [$F_{(1, 215)} = 489.71$] and decreased with increasing fructose levels [$F_{(1, 215)} = 15.87$] indicating a mixture suppression effect. At pH 3.8, however, fructose influence was not observed (interaction pH × fructose [$F_{(1, 144)} = 103.57$]).

Alcohol levels [$F_{(2, 215)} = 13.41$] enhanced sweetness intensity (Fig. 4) especially at the 12% level and the combinations pH 3.8 (interaction

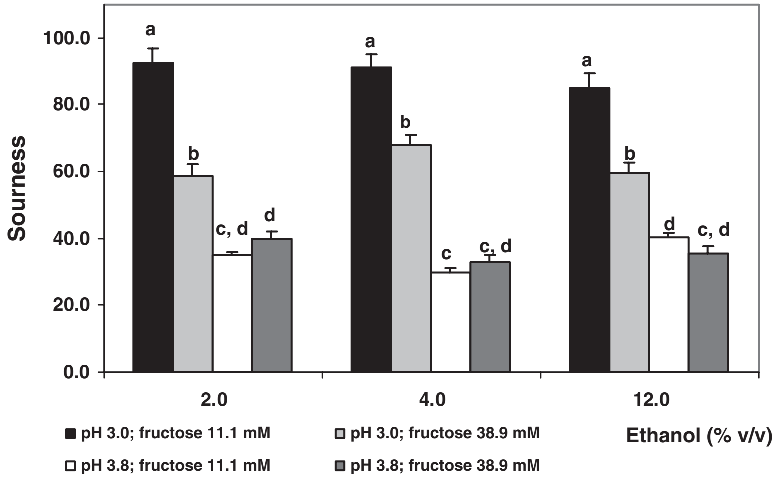

FIG. 3. SOURNESS MEAN INTENSITY OF FRUCTOSE (11.1 and 38.9 mM)–TARTARIC ACID (pH = 3.0 and 3.8) MIXTURES, IN ETHANOL AT 2.0, 4.0 AND 12.0% v/v LEVELS (+ONE STANDARD ERROR OF THE MEAN; TUKEY TEST, DIFFERENT LETTERS CORRESPOND TO SIGNIFICANT DIFFERENCES $P < 0.05$)

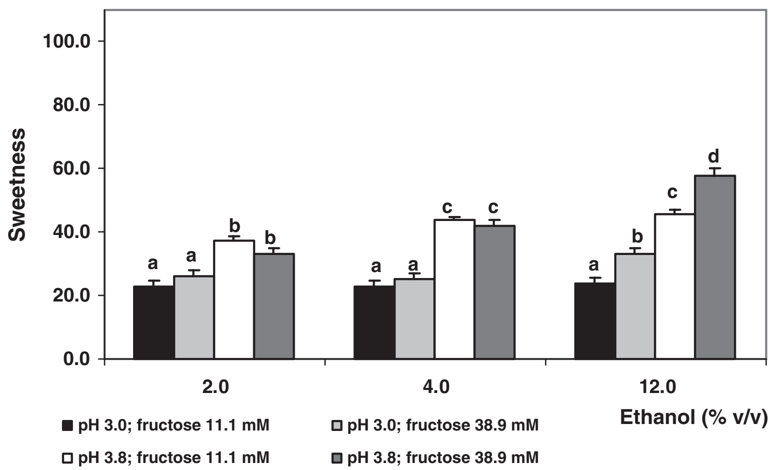

FIG. 4. SWEETNESS MEAN INTENSITY OF FRUCTOSE (11.1 and 38.9 mM)–TARTARIC ACID (pH = 3.0 and 3.8) MIXTURES, IN ETHANOL AT 2.0, 4.0 AND 12.0% v/v LEVELS (+ONE STANDARD ERROR OF THE MEAN; TUKEY TEST, DIFFERENT LETTERS CORRESPOND TO SIGNIFICANT DIFFERENCES $P < 0.05$)

pH × ethanol [$F_{(2, 160)} = 19.33$]) and fructose 38.9 mM (interaction fructose × ethanol [$F_{(2, 160)} = 19.83$]).

Other authors (Amerine and Roessler 1983; Peynaud 1996) also reported the increase of sweetness in the presence of alcohol in a similar concentration range.

The sweetness ratings increased with increasing fructose levels [$F_{(1, 215)} = 3.99$] and decreased with increasing acidity levels [$F_{(1, 215)} = 198.79$], showing a strong mixture suppression effect of tartaric acid on sweetness perception.

Sourness/Sweetness Balance

In white wine, the interaction among components, especially sugars and acids, is particularly important. In the present work, sourness (and sweetness) appears to be less noticeable in wine as compared with water; this effect is clearly noted in Figs. 1 and 2, and was also demonstrated in a previous work (Zamora *et al.* 2004). The relationship between sourness and sweetness in ethanol mixtures was shown in Figs. 3 and 4. At the lowest levels of ethanol the mixtures were perceived more sour than sweet, and at 12% of ethanol sweetness was favored.

Comparing water, wine, ethanol 12% (either at pH 3.0 or 3.8) and fructose (11.1 and 38.9 mM), a media effect for sweetness perception was not observed [$F_{(2, 204)} = 0.02$], opposite to sourness perception [$F_{(2, 204)} = 18.07$]; significant differences were observed between water and wine, while ethanol was halfway. This suggests that other wine components, different from ethanol or sugar, exerted a sourness suppression effect.

Regarding wine medium, several authors have brought forward that taste interactions in complex matrices can be predicted from simple aqueous solutions (Keast and Breslin 2003). In fact, our results show the same tendency as those presented for nonalcoholic beverages by Bonnans and Noble (1993). However, matrix effects in complex multimodal vehicles as wine may induce unparalleled results. Martin *et al.* (2002) studied sucrose and tartaric acid mixtures in unsweetened champagne and found that the suppressive effect of sucrose on sourness of tartaric acid was stronger than vice versa. These results are in contrast with our data and the discrepancy can be attributed to many different factors, mainly because we used different concentration ranges of the two chemicals and different types of sweeteners. It has been demonstrated that the sweetness of fructose is more susceptible to be suppressed by acidity than the sweetness of sucrose (McBride and Finland 1990). Martin and Pangborn (1970) observed heightened sweetness and diminished ratings of sourness with the addition of near-threshold ethanol concentrations (4% v/v) to sucrose and citric acid, respectively. Fischer and Noble (1994) studied the effect of ethanol and pH on sourness of wine, varying in ethanol (8, 11 and 14% v/v) and pH (2.9, 3.2 and 3.8). Lowering the pH produced the biggest increase in sourness. Sourness decreased with increasing pH and ethanol had no effect on sourness except at pH 3.2, where the increase in ethanol from 8 to 14% diminished sourness significantly. It is likely that the reduction in sourness was due to the increasing sweetness caused by the increasing concentration of ethanol.

Studies with multimodal mixtures provided evidence that the variations in instructions and the response context have significant impact on the way panelists make these judgments (Frank 2002). For this reason, dominance of one taste over another could be related to the frame of reference adopted by the assessors. In the present work, assessors were just trained in sensory evaluation of wine. Because of this, they probably generated expectancies about new perceptions by the modification of familiar wine. Zamora and Guirao (2004) observed, in a study of performance comparison between trained assessors and wine experts, that the reference taste adopted by experts was sourness while the trained adopted sweetness.

Martin *et al*. (2002) showed an integration of sweetness and sourness in the global intensity of Champagne wine, and sweetness contributed to a greater extent to total taste intensity judgment. Zamora and Guirao (2002) observed similar results in terms of sweetness contribution to flavor in Chardonnay wine.

CONCLUSIONS

Results indicated that for mixtures of fructose (11.1 and 38.9 mM) at pH 3.0 and 3.8 in combination with water, ethanol (12% v/v) and white wine, sourness over sweetness was the most outstanding taste in the samples. Tartaric acid had a strong suppressor effect on sweetness while fructose had a small suppressor effect on sourness. Global sourness intensity perception in wine mixtures was significantly lower than in water, and intensity in ethanol 12% mixtures was halfway between wine and water. These results suggest that other components present in wine contribute to the suppression effect.

ACKNOWLEDGMENTS

The authors thank the assessors for their participation in the development of the present study. This work was funded by Fondo para la investigación Científica y Tecnológica (Secretaría de Ciencia y Técnica) (FONCYT [SECYT]) of Argentina (Project PICT 2000 N 8820).

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