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Perception of sweetness and bitterness in different vehicles

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In the present study, we investigated taste-taste, taste-vehicle, and simultaneous taste-vehicle-taste mixtures. Subjects made estimates of the sweetness and bitterness of 27 stimuli. Sucrose (292, 585, and 1170 mM), caffeine (13, 26, and 52 mM), and binary mixtures of low (292-13 mM), middle (585-26 mM), and high (1170-52 mM) levels of both components were dispersed in water, carboxymethylcellulose (CMC) 1% w/v, and gelatin 6% w/v. The sweetness and bitterness of the sucrose-vehicle-caffeine combinations were significantly weaker than the respective sucrose-vehicle and caffeine-vehicle combinations. The emerged mutual suppressive effects were asymmetrical and persisted when both tastants were presented in CMC and gelatin. Moreover, the increase in vehicle consistency and the simultaneous addition of another taste reduced the perceived intensity of a taste either presented alone or dissolved in water. For both sweetness and bitterness, the total taste suppression observed was always significant.

Our taste world is one of mixtures rather than single tastes. Current psychophysical research in this area has progressed toward the characterization of the major phenomenon of taste suppression. It has been demonstrated that when human beings evaluate mixtures of primary tastes, one of the tastes in the mixture may be suppressed by the other. This phenomenon occurs after the processing of taste mixtures by peripheral and central taste structures (Bartoshuk, 1979; Bartoshuk & Seibyl, 1982; Kroeze & Bartoshuk, 1985; Lawless, 1982). Specifically, taste suppression has been reported when bitter-sweet mixtures were subjected to sensory evaluation (Bartoshuk, 1979; Bartoshuk & Seibyl, 1982; Calviño, Garcia-Medina, & Cometto-Muñiz, 1990; Lawless, 1979, 1982).

Heterogeneous taste mixtures such as sour-sweet, bitter-sweet, and salty-sweet are taste combinations of obvious relevance to those interested in food science and technology. Within the framework of mixture suppression, taste components have shown mutual, but not balanced, suppressive effects. Several studies have shown asymmetrical degrees of suppression between taste qualities (Calviño et al., 1990; De Graaf & Fritjers, 1989; Frank & Archambo, 1986; Schifferstein & Frijters, 1990, 1992). Sweetness showed the best suppressive behavior; this efficiency in masking may be related to the neural distinctness between sweet and nonsweet gustatory experience (Scott, 1992).

It has also been shown that textural properties affect taste intensity. The replacement of water for a thickening or gelling agent generally reduces perceived taste intensity (Arabie & Moskowitz, 1971; Christensen, 1980a, 1980b; Kokini, Bistani, Poole, & Stier, 1982; Pangborn, Gibbs, & Tassan, 1978; Pangborn, Trabue, & Szczesniak, 1973; Stone & Oliver, 1966).

To be tasted, any solute must diffuse upon reaching the surface of the taste buds. The taste intensity of a solute embedded in a textural matrix can be predicted from the rate of diffusion of the solute in the vehicle, the concentration of the solute, the time of diffusion, and the rheological properties of the thickening agent used (Kokini, 1985; Kokini et al., 1982).

Although binary taste mixtures and binary texture-taste combinations have been subjected to sensory evaluation in several designs, few studies have addressed the question of interactions of taste components embedded in different vehicles. Research on taste mixtures in real foods and complex models simulating actual beverages has been very sparse. One pioneering design compared the apparent taste intensity of salt and citric acid mixtures in water and green-bean puree. Pangborn and Trabue (1967) showed that salt depressed apparent sourness in both media, but apparent saltiness varied in a complex manner that was dependent upon acid concentration and the subjects employed. In both vehicles, half of the subjects in-

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dicated an enhancement of saltiness with increasing acidity and the rest reported the suppression of saltiness with increasing acidity.

Other types of ternary interactions were addressed by Burns and Noble (1985), who evaluated the separate effects of sweetness and the viscosity of sucrose on the perceived viscosity, sweetness, and bitterness of vermouth. They found that perceived sweetness increased and bitterness decreased as sucrose was increased. Similarly, vermouths with higher physical viscosities were sweeter and less bitter than samples with lower viscosities.

The aim of the present study was to determine, in a first step, whether the direct relation between taste intensity (sweetness, bitterness) and tastant concentration (sucrose, caffeine) obtained in an aqueous solution would also be observed in carriers of sodium carboxymethylcellulose (CMC) and gelatin.

It has been demonstrated previously (Calviño et al., 1990) that the perceived intensity of an aqueous mixture of sucrose and caffeine is less than the sum of the perceived intensities of sucrose and caffeine in equimolar unmixed solutions. When the total taste intensity was broken down by the subjects into sweetness and bitterness, the suppression was also the most salient feature for each taste quality. Therefore, independently of textural effects imparted to water by any vehicle, we expect that a mixture of sweetness and bitterness could be less than the perceived intensity of the components presented alone. Conducted within the protocol of heterogeneous taste mixtures, the present design enabled us to evaluate the reduction of (1) sweetness and bitterness by mutual masking of both taste qualities, (2) sweetness and bitterness when water was replaced by CMC and gelatin, and (3) the perceived intensity of one taste component elicited by the addition of the second taste compound and the simultaneous increase in vehicle consistency.

METHOD

Subjects

Twenty subjects (11 women and 9 men) participated. Their average age was 25.4 (*SD* = 7.2) years. They were paid for contributing to the experiment.

Stimuli

The stimuli were three levels of sucrose: 292, 585, and 1170 mM, three levels of caffeine: 13, 26, and 52 mM, and their binary mixtures of low, medium, and high levels of unmixed stimuli: 292-13, 585-26, and 1170-52 mM. These nine sweet, bitter, and bittersweet combinations were dissolved in distilled water, CMC 1% w/v, and gelatin 6% w/v. A total of 27 samples were evaluated by the subjects.

The nine aqueous solutions thickened with CMC were prepared by slowly adding the gum (5 g) to the vortex of a vigorously agitated aqueous solution (500 ml). Depending on the sample, this dissolving process was extended 30-45 min at high shear to obtain clear solutions and to avoid agglomeration of the gum. The viscous stimuli were prepared 72 h before their sensory or physical measurement and stored at room temperature. The physical viscosities were determined at 25° C with an LVT Brookfield viscometer attached with the spindle N° 3. CMC solutions display a nonnewtonian behavior, so the measurement of apparent viscosity was made at 0.6-12.6 seg^{-1} shear rate range. Also, the rheograms were determined first at increasing and then decreasing shear rates to check the thixotropic behavior of the solutions.

The other nine solutions were thickened with gelatin powder until they reached a concentration of 6% w/v. To obtain a gel strength of 150 bloom, the gels were prepared as in Calviño (1982) and stored for 24 h at 10° C before their sensory evaluation. Each sample was served at room temperature (25° C) when the sensory task was performed.

Presentation of Samples

All the stimuli were randomly presented at each of two replicate sessions and were evaluated by the sip-and-spit technique. Rinses of distilled water were interspersed between samples and there were 30- to 90-sec breaks between trials to avoid taste adaptation.

The 18 aqueous and CMC solutions were presented in disposable polyethylene cups containing 5 ml of the appropriate solution. The nine gelatinous stimuli were given as small (1 cm^3) solid cubes, and the subjects were instructed to compress the cubes between tongue and palate without mastication to avoid significant differences in the oral area stimulated by liquid or gelatinous samples.

After the subjects had tasted a solution for 3 sec, they spit out the stimulus, gave ratings of sweetness, bitterness, or both, and then rinsed their mouths.

Assessment Procedure

The subjects were informed that the experiment involved judging the sweetness and bitterness of aqueous, viscous, and gelatinous samples by means of magnitude matching (J. C. Stevens & Marks, 1980). When the subjects perceived single stimuli, they assigned one appropriate number reflecting perceived sweetness or bitterness. When they perceived mixed stimuli, they were asked to rate sweetness and bitterness with two separate numbers reflecting the perceived intensities of both components. The instructions emphasized that they should rate the perceived attributes (sweetness and bitterness) separately instead of giving a number reflecting total perceived intensity.

The subjects were told to judge both taste qualities on a common scale of perceived magnitude. That is, if a perceived bitter intensity seemed two times stronger than a perceived sweet intensity, it should be assigned a number twice that assigned to the bitterness.

At the beginning of each session, the subjects evaluated any one of the unmixed aqueous solutions (single stimuli). From then on, they evaluated the other 26 stimuli. Because the first stimulus was balanced across subjects and sessions among the 6 aqueous stimuli, the context was not set at a given level for either the sweetness or bitterness scale. In each trial, the order of sweetness and bitterness was random.

Data Analysis

The data were summarized in terms of the geometric mean of each subject's average response for each stimulus. To eliminate the scatter due to individual differences in modulus, the data were normalized to make all the subjects' overall geometric means the same (Lane, Catania, & S. S. Stevens, 1961). These normalized data were analyzed by means of a repeated measures analysis of variance (ANOVA) using tastant concentration, presence of another tastant, and vehicle as factors (O'Mahony, 1986). Separate ANOVAs with repeated measures were applied to the sweetness and bitterness data.

Power function exponents (slopes of the least squares regression line in a log-log plot of stimulus concentration vs. intensity rating) served as estimates of how sweetness and bitterness varied with tastant, vehicle, and concentration.

Normalized data were employed to obtain the ratios between mixed and unmixed judgments (Frank & Archambo, 1986). Values below the unity signified suppression, and those above the unity indicated enhancement. Ratios near the unity signified simple additivity. The average ratios gave a measure of how sweetness and bitterness suppress in binary taste-taste, taste-vehicle, and ternary taste-vehicle-taste mixtures.

RESULTS

The perceived sweetness for sucrose (top) and the perceived bitterness for caffeine (bottom) in aqueous, thick, and gel backgrounds are shown in Figure 1. Significant main effects were found for sucrose [$F(2,38) = 35.07$, $p \leq .001$] and caffeine [$F(2,38) = 4.36$, $p \leq .05$] when the respective ANOVAs were performed over the normalized judgments of sweetness and bitterness. Both significant effects indicate that, collapsed over subjects and across the three vehicles, sucrose concentrations varied in sweetness and caffeine concentrations varied in bitterness.

A linear logarithmic relation between sucrose concentration and sweetness may be adjusted by a least squares method design to the average sweetness data. In the presence of water, CMC, and gelatin backgrounds, respectively, the slopes (β) were $\beta = 0.51$, 0.52, and 0.65. Their respective correlation (r) coefficients were $r = .99$, .96, and .98.

Similarly, bitterness tended to increase with caffeine concentration in all the carriers except gel, for which the mean bitterness was lower at the middle than at the lower concentration (see Figure 1). Straight lines fit the bitterness data reasonably well. The slopes for the water, CMC, and gelatin vehicles were, respectively, $\beta = 0.53$, 0.82, and 0.52. The corresponding correlation coefficients were $r = .99$, .99, and .68.

Regarding the suppressive effect of caffeine on sweetness intensity, Figure 2 shows the average data for single and mixed stimuli across the three media. A significant masking of sweetness was established by the presence of caffeine [$F(1,19) = 12.82$, $p \leq .01$], but post hoc multiple comparisons using Tukey's test showed only four significant comparisons. For these combinations, the sweetness reduction varied from 22% to 48% (see Table 1).

Although the main effect of caffeine over sweetness was significant, the data were consistently characterized by a high level of variability. An ANOVA revealed significant effects for subjects [$F(19,76) = 17.5$, $p \leq .001$] and the caffeine × subjects interaction [$F(19,76) = 6.12$, $p \leq .001$]. This indicates that certain individual responses may have been differentially affected by caffeine context; thus, the ratios of mixed/unmixed judgments reflected either enhancement or simple additivity. There was an absence of suppression of sweetness for the five sucrose-vehicle-caffeine combinations, in which 7, 8, and 9 subjects out of 20 failed to show suppression (see numbers in parentheses in Table 1).

The bars in Figure 3 represent the bitterness of the single and mixed stimuli. In this case, the addition of sucrose made the stimuli less bitter [$F(1,19) = 55.95$, $p \leq .001$]. Post hoc multiple comparisons using Tukey's test showed a significant reduction in bitterness for six caffeine-vehicle-sucrose combinations. For these stimuli, the degree of bitterness suppression varied from 49% to 72%.

The subjects differed significantly in their responses to the bitter stimuli [$F(19,76) = 7.95$, $p \leq .001$]. Furthermore, a significant sucrose × subjects interaction was ob-

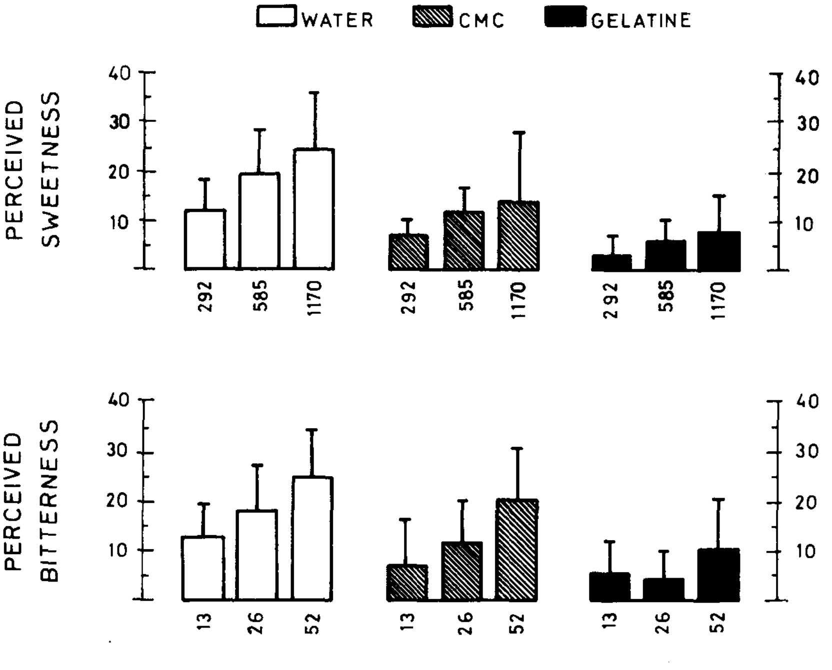

Figure 1. Histograms representing perceived sweetness (top) and perceived bitterness (bottom) of unmixed stimuli. In both portions, each bar represents the geometric mean (+*SE*) of the average of two replicates made by each of 20 subjects for that stimulus.

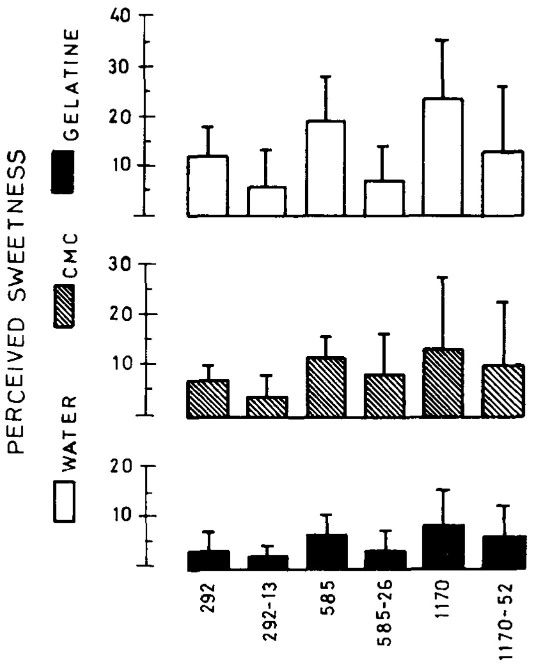

Figure 2. Histograms representing perceived sweetness of single and binary mixtures stimuli. Each bar represents the geometric mean (+*SE*) of the average of two replicates made by each of 20 subjects for that stimulus.

Table 1
Enhancement and Suppression Ratios for Sweetness (Sw) and Bitterness (Bi) in Water (W), Carboxymethylcellulose (CMC), and Gelatin (G) Vehicles

Taste Quality	W	CMC	G
	292 mM Sucrose-13 mM Caffeine		
Sw	(8) 0.81	(6) 0.78†	(6) 0.74†
Bi	(2) 0.48†	(7) 0.79	(4) 0.51*
	585 mM Sucrose-26 mM Caffeine		
Sw	(1) 0.52*	(7) 0.86	(8) 0.86
Bi	(2) 0.56	(5) 0.47*	(6) 0.73
	1170 mM Sucrose-52 mM Caffeine		
Sw	(3) 0.66†	(8) 1.48	(9) 1.98
Bi	0.32*	(1) 0.28*	(2) 0.34*

Note—Numbers in parentheses indicate the subjects who showed judgments of enhancement or simple additivity. *Ratios of suppression significant at $p \leq .01$. †Ratios significant at $p \leq .05$.

tained [$F(19,76) = 3.10$, $p \leq .001$]. In other words, when the bitterness judgments were collapsed across vehicles, the trend for sucrose levels was not consistent over subjects. The variability between subjects led to the absence of bitterness suppression in the remaining three mixtures, for which 2, 6, and 7 individuals' responses showed simple additivity or enhancement (see numbers in parentheses in Table 1).

Figure 4 shows the effects of the vehicle replacement on perceived sweetness (top) and perceived bitterness (bottom). As the physical consistency of the vehicle rises from water to CMC and gelatin, the heights of the bars representing perceived sweetness reduce toward lower perceived values. For bitterness, the effect was similar to that obtained for sweetness but was less intense.

An ANOVA confirmed that change of vehicle was a main significant factor for sweetness reduction [$F(2,38) = 34.14$, $p \leq .001$] as well as for bitterness depression [$F(2,38) = 27.29$, $p \leq .001$]. Post hoc comparisons by Tukey's test were performed to analyze the degree of these significant effects. Significant reductions in sweetness (three mixtures) and bitterness (one mixture) were about 60% when water was replaced by gelatin. Reductions in CMC did not reach significance (see Table 2).

The sensory evaluations from CMC and gelatin yielded data that were more variable than those from aqueous solutions. This variability led to a significant vehicle × subjects interaction for sweetness [$F(38,76) = 2.75$, $p \leq .001$] and bitterness [$F(38,76) = 1.63$, $p \leq .05$]. The trend for variation in taste intensity across the vehicles was not the same for all the subjects. An absence of significant suppression was observed when the assessment of a mixture resulted in three or more judgments of simple additivity or enhancement. The numbers in parentheses in Table 2 reflect the subjects whose ratios of mixed/unmixed judgments were equal to or more than the unity.

The sweetness (top) and bitterness (bottom) of taste-vehicle-taste mixtures were rearranged in Figure 5. The bars representing the unmixed and mixed stimuli were plotted side by side to show the suppression that occurred in the ternary mixtures.

Total sweetness suppression was calculated, comparing the sweetness of each sucrose-CMC-caffeine or

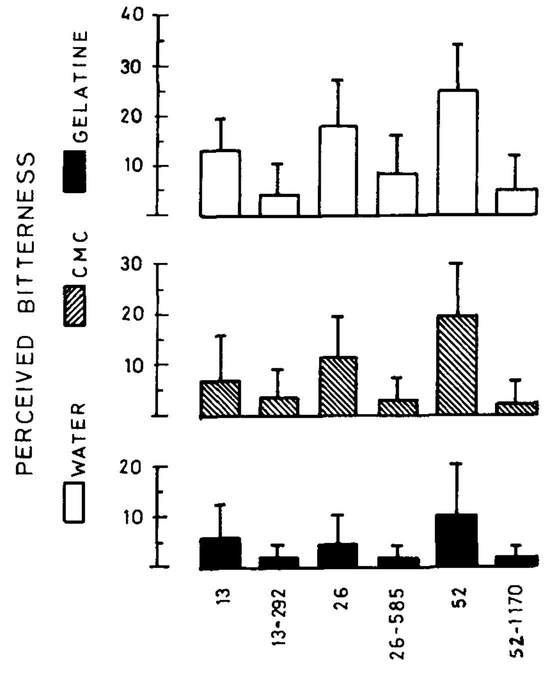

Figure 3. Histograms representing perceived bitterness of single and binary mixtures stimuli. Each bar represents the geometric mean (+*SE*) of the average of two replicates made by each of 20 subjects for that stimulus.

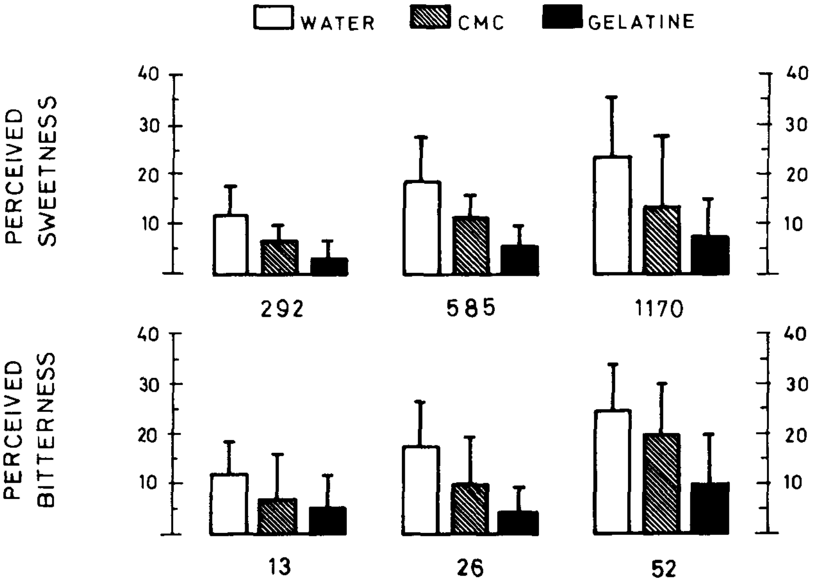

Figure 4. The same data of Figure 1, rearranged to show the vehicle's suppressive effects.

sucrose-gelatin-caffeine combination (mixed state) with the sweetness of the aqueous solution (unmixed state). A similar procedure was carried out with the bitterness data. Table 3 illustrates the observed ratios of total sweetness and bitterness suppression. All the ratios show a significant degree of suppression; coincidently, the judgments of simple additivity or enhancement were very scarce and never surpassed the three values for a given ternary mixture.

A last question emerges about the differential ability of vehicles to suppress tastes qualities in these ternary mixtures. Comparisons between the CMC and gel data showed that the sweetness of two ternary viscous mixtures (292 mM sucrose-CMC-13 mM caffeine and 585 mM sucrose-CMC-26 mM caffeine) differed significantly from the respective ternary gelatinous mixtures. However, the increase in sweetness suppression observed in gelatin dispersions was not obtained for bitterness.

DISCUSSION

Departures from the expected responses of additivity to components of mixtures are called *mixture interactions* (Bartoshuk, 1975) and, usually, these interactions take the form of mixture suppression.

Table 2
Effects of the Change of Vehicle on the Ratios of Suppression for Sweetness (Sw) and Bitterness (Bi)

Taste Quality	Sucrose or Caffeine (mM)	CMC	Gelatin
Sw	292	(3) .69	(1) .38*
Bi	13	(4) .89	(5) .69
Sw	585	(3) .70	.36*
Bi	26	(6) .79	(1) .37*
Sw	1170	(4) .70	(1) .41*
Bi	52	(5) .87	(3) .59

Note—Numbers in parentheses indicate the subjects who showed judgments of enhancement or simple additivity. CMC = carboxymethylcellulose. *Ratios of suppression significant at $p \leq .01$.

Previously, there has been a general agreement regarding taste suppression in aqueous solutions (Bartoshuk, 1979; Bartoshuk & Seibyl, 1982; Kroeze & Bartoshuk, 1985; Lawless, 1979, 1982; Pangborn, 1987). Recently, mutual suppression of sweetness and bitterness was confirmed when sucrose was mixed with caffeine at various levels in each mixture (Calviño et al., 1990).

To elucidate the mechanisms involved in processing the intensity of taste mixtures, Bartoshuk (1975) proposed a model in which taste suppression in a mixture is related to the compression of psychophysical functions. Thus, there is a relationship between the exponent of the intensity function of a substance and the amount by which the taste of that substance is suppressed in a mixture. If the tastant shows compression when added to itself, it shows suppression when other tastants are added to it. In contrast, this model states that a steeper psychophysical function for a tastant leads to a higher degree of additivity in mixtures of this tastant. In heterogeneous mixtures, when the components are equally intense in unmixed conditions, sourness is suppressed the least, and sweetness, saltiness, and bitterness are suppressed to greater extents. This seems to hold for the sweetness and bitterness of our mixtures, with both functions presenting compressed behavior (see slope values) and a significant degree of subadditivity for each quality.

Another approach, the information integration/functional measurement, can be used to assess the combined or integrated resultant of several coacting stimuli. A number of studies on sensory taste integration have shown mutual, but not balanced, suppressive effects in mixtures containing two different-tasting substances (De Graaf & Fritjers, 1989; Frank & Archambo, 1986; Schifferstein & Frijters, 1990, 1992). Using a functional measurement in combination with a two-stimulus procedure, Schifferstein

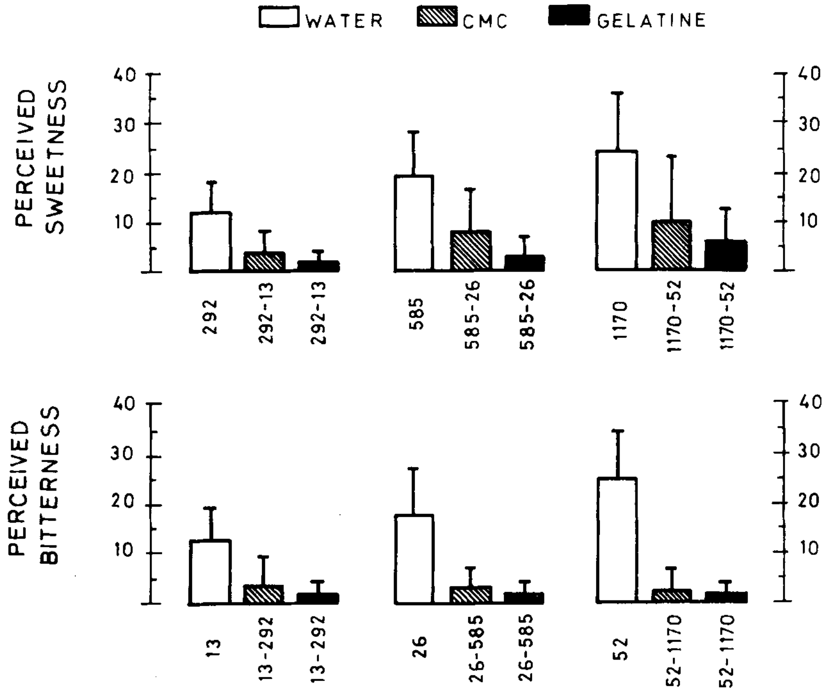

Figure 5. Histograms representing perceived sweetness (top) and perceived bitterness (bottom) of single and ternary mixtures stimuli. Each bar represents the geometric mean (+*SE*) of the average of two replicates made by each of 20 subjects for that stimulus.

and Frijters demonstrated asymmetry in the mutual suppressive effects between citric acid and sucrose as well as between NaCl and QHCl combinations. For both binary mixtures, each component suppressed each other's taste intensity in varying degrees.

De Graaf and Frijters (1989) also found asymmetrical suppressive effects of components in sucrose-NaCl mixtures. The sweetness of these mixtures at low concentrations of sucrose and NaCl was higher than the sweetness of the respective unmixed sucrose levels. When the concentrations of one or both tastants increased, the sucrose-NaCl mixtures were less sweet than the unmixed sucrose levels. Meanwhile, the degree of subadditivity of sweetness in the mixtures depended on the concentrations of both components, whereas the saltiness of the sucrose-NaCl only depended on the NaCl concentration and not on the sucrose concentration. Thus, the saltiness of the sucrose-NaCl mixtures was lower than the saltiness of the respective unmixed NaCl concentrations.

Table 3
Observed Ratios in Suppression for Sweetness (Sw) and Bitterness (Bi) in Caffeine-Vehicle-Sucrose (C-V-S) Mixtures

C-V-S (mM)	Sw	Bi
13-CMC-292	(1) .47*	(3) .46*
13-G-292	.22*	.20*
26-CMC-585	(2) .58*	(1) .29*
26-G-585	.26*	.16*
52-CMC-1170	(3) .61*	.21*
52-G-1170	(2) .41*	.13*

Note—Numbers in parentheses indicate the subjects who showed judgments of enhancement or simple additivity. CMC = carboxymethylcellulose; G = gelatin. *Ratios of suppression significant at $p \leq .01$.

Although the design reported herein was not made with a functional measurement approach, we have also demonstrated the asymmetry underlying the suppression of sweetness and bitterness in different vehicles. Thus, the results of the present study agree, in a broad sense, with the results mentioned above. The present analysis compared the intensity estimates of mixtures in which both sucrose and caffeine levels were of the same perceptual intensity (low, medium, or high). In these mixtures, neither a sweet nor a bitter stimulus would be expected to be dominant because unmixed sucrose and unmixed caffeine showed roughly similar intensities in aqueous solution (compare the lengths of the bars in Figure 1). However, the ratios between mixed and unmixed judgments shown in Table 1 allow one to see that the suppression of sweetness by caffeine (22%-48%) was lower than the suppression of bitterness by sucrose (49%-72%). Mutual suppressive actions registered in the present experiment were asymmetrical, supporting the hypothesis that sucrose is a better masking agent than caffeine in water, CMC, or gelatin. Because the intensities of the single stimuli were about equal, the different mutual suppressive effects may have been due to the qualitative differences between both tastants. Previously, it was noted that sweetness appears to be different from the other qualities of sourness, saltiness, or bitterness. Sucrose and quinine were readily discriminable by activity profiles across neurons and were arranged at the greatest distance in a two-dimensional space representing relative similarities among taste qualities (Scott, 1992).

Furthermore, the results of the present study support the hypothesis that the mutual suppression of sweetness and bitterness in an aqueous solution persists when the tastants are presented in other vehicles such as CMC and gelatin gels. While bitterness was suppressed up to 72% in CMC dispersions, the resistance of sucrose to the suppressive effect of bitterness was also found in thick or gel media, in which the maximum sweetness suppression only reached around 25%. This general conclusion is in line with the number of individual judgments of enhancement or simple additivity. Note that the shift from significant toward nonsignificant sweetness suppression occurred when 7 or more subjects reported that the sweetness in the bitter-sweet mixtures either equaled or surpassed the sweetness of unmixed sucrose solutions.

The degree of suppression may also vary due to habituation (Kroeze, 1982; Kuznicki, Hayward, & Schultz, 1983), and the differences in the suppressive behavior in the present sucrose-caffeine mixtures might be explained by different perceptual and cognitive processing of sweetness and bitterness, as Kroeze (1982) demonstrated for sweetness and saltiness in sucrose-NaCl mixtures.

Within the framework of taste-vehicle interactions, the present study shows that the change of the vehicle might inhibit taste intensity. Previously, it was proved that an increase in taste threshold and a decrease in suprathreshold taste intensity are parallel to the increase in viscosity in which the tastant is dispersed (Arabie & Moskowitz, 1971; Lundgren et al., 1986; Pangborn et al., 1978). However, when a low range of viscosities was analyzed, the effects were rather specific for the gum/compound combination (Pangborn et al., 1973) and were also found to depend on the pseudoplastic nature of the hydrocolloid (Christensen, 1980a).

In a first approach, one could confidently conclude that the physical state of the stimuli influenced taste intensity by controlling the amount of sapid material reaching the taste receptors in a given time. Although a definite trend toward a decrease in sweetness and bitterness was observed when water was replaced by CMC or gelatin, only the taste intensity in the gels proved to be significantly reduced. Though time-intensity recordings were not made in the present experiment, it has been previously documented (Larson-Powers & Pangborn, 1978) that additional oral manipulation time is required to break down gelatin gels in order to release the sapid substance from the gel. Given that the time of sensory evaluation was standarized in 3 sec for all stimuli, the maximum taste intensity was possibly beyond rather than below this time. Thus, this delay could explain the depressed magnitudes of sweet and bitter intensity in gels. Even when the sweet and bitter stimuli showed distinctive patterns of suppression in taste-taste and taste-vehicle mixtures, the taste intensity was arrested in both types of mixtures.

Both portions of Figure 5 clearly indicate that the simultaneous addition of the second tastant and the increase in vehicle consistency produced a higher suppression of sweetness and bitterness than the respective suppressive actions of the tastant or the hydrocolloid alone. This general suppressive effect, analyzed as total taste suppression, could be explained in terms of an integrative model of the individual sources of taste suppression (by the presence of the second tastant and the change of vehicle). The generalized significance of the observed ratios of suppression shown in Table 3 support this view for the ternary heterogeneous mixtures. Furthermore, the total mixture suppression ratios reflect a relative failure of the subjects to give judgments of enhancement or simple additivity for sweetness or bitterness.

Frank and Archambo (1986) analyzed various mixtures along a continuum, ranging from mixtures with a single integrated quality to mixtures composed of multiple-quality components. The more complex the mixtures, the more intense was the degree of suppression observed. According to this explanation, our ternary mixtures exhibit a more pronounced taste-suppression effect than binary taste-taste or taste-vehicle mixtures.

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