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Sensory Evaluation of Mixtures of Maltitol or Aspartame, Sucrose and an Orange Aroma

Denise F. Nahon, Jacques P. Roozen and Cees de Graaf[1]

Department of Food Technology and Nutritional Sciences, Division of Food Science, Food Chemistry Group and [1]Division of Human Nutrition and Epidemiology, Wageningen Agricultural University, Bomenweg 2, 6703 HD Wageningen, The Netherlands

Correspondence to be sent to: D.F. Nahon, Department of Food Technology and Nutritional Sciences, Division of Food Science, Food Chemistry Group, Wageningen Agricultural University, Bomenweg 2, 6703 HD Wageningen, The Netherlands

Abstract

The suitability of Beidler's mixture equation for mixtures of sucrose and maltitol as well as for mixtures of sucrose and aspartame was examined in the presence of an orange aroma. The mean scores for the attribute sweet remained constant for each combination of sucrose and maltitol and for each combination of sucrose and aspartame. Therefore, Beidler's mixture equation can be used to choose combinations of sucrose and maltitol and of sucrose and aspartame giving the same sweetness. Quantitative descriptive analysis of different solutions indicated that the flavour profiles of sucrose and maltitol did not differ significantly at a constant concentration of orange aroma. However, flavour profiles of solutions with increasing aspartame concentrations (but constant aroma levels) showed significantly higher scores for the attributes sour, chemical and aftertaste. Addition of orange aroma provided the different solutions with a more distinct flavour. The mean scores for the attributes orange, sour, fruity and aftertaste increased significantly for most of the sucrose–maltitol mixtures. This effect of orange aroma was even more pronounced in solutions containing combinations of sucrose and aspartame. Further comments on the attribute aftertaste showed similar terms for the different solutions, the most often mentioned being orange, sour, fruity and chemical for solutions containing the orange aroma. The aftertaste of solutions containing relatively more aspartame was mainly described as sweet and chemical.

Introduction

The application of single sweeteners in beverages causes problems which can be solved by using combinations of intense sweeteners. The study of sweetness–flavour interactions in soft drinks demands a fundamental understanding of the behaviour of these intense sweeteners. One important question concerns the amounts of sweeteners in complex mixtures necessary to produce a certain sweetness level, e.g. the sweetness equivalent to 10% w/v sucrose. In 1986 De Graaf and Frijters developed a simple method to predict equisweet combinations of sweeteners based on Beidler's mixture equation. A preliminary study (Nahon *et al.*, 1996) proposed a quaternary extension of Beidler's mixture equation to modulate the concentrations of intense sweeteners used in a light blackcurrant soft drink. It was concluded that the model needed further investigation of the conditions in which Beidler's mixture equation could be used (e.g. dependency of sweet taste receptors). The present study investigated the applicability of Beidler's mixture equation to mixtures of sucrose and maltitol, and mixtures of sucrose and aspartame. In both mixtures the composition of the mixture solutions as well as the concentration of orange aroma was varied.

Bulk sweeteners are assumed to compete for adsorption at the same receptor sites (De Graaf and Frijters, 1986; Ennis, 1996), which means that the sweetness of a solution of bulk sweeteners can be described with Beidler's mixture equation. Several authors (Rapaille and Van der Schueren, 1989; Sicard and Le Bot, 1990; Rapaille *et al.*, 1995; Portmann and Kilcast, 1996) reported close similarities between sucrose and maltitol. Maltitol is mainly utilized for the production of sugarless confectionery. In experiment 1 of the present study, mixtures of sucrose and maltitol in water were studied in the presence of an orange aroma in order to examine the suitability of Beidler's model for these bulk sweeteners. Several combinations of sucrose and maltitol were chosen to study the sweetener contribution to the flavour perception. Also, the effect of different concentrations of orange aroma and interactions between the orange aroma and both bulk sweeteners were studied by descriptive analysis. The overall perception of the solutions was reflected in flavour profiles presenting attributes and their magnitudes.

Several investigations of mixtures of the bulk sweetener sucrose and the intense sweetener aspartame in water have been published. The sweetness of a mixture of sucrose and aspartame was compared with the sweetness of sucrose or aspartame. The presence of synergy between sucrose and aspartame (–33 to 11%) was indicated by the results of Frank *et al.* (1989) and Portmann and Kilcast (ECRO XII Symposium Zürich, August 25–31, 1996, unpublished data). However, Ayya and Lawless (1992) and Schifferstein (1995) showed that the sweetness of a mixture of sucrose and aspartame lies somewhere between the intensities of the composing compounds. Furthermore, Lawless and Stevens (1983) observed a partial cross adaptation with sucrose and aspartame, suggesting that these two sweeteners may share receptor site mechanisms (Ayya and Lawless, 1992). Descriptive analyses of solutions containing aspartame were carried out by Såmundsen (1985), Redlinger and Setser (1987), Ott *et al.* (1991), Ketelsen *et al.* (1993) and Hanger *et al.* (1996). All these studies, except the one by Ott *et al.* (1991), reported a sweet aftertaste as well as bitter and off-flavour (after)tastes. Several sweeteners were arranged by Schiffman *et al.* (1979) in a three-dimensional space, which revealed that aspartame clusters with the sweet taste of sugars. However, at a high concentration (0.25% w/v), a bitter component developed with time. DuBois and Lee (1983) demonstrated that aspartame is similar to sucrose in taste onset and persistence times. Wiet and Beyts (1992) noted a slight nonsweet aftertaste for aspartame in water compared with sucrose. Portmann and Kilcast (1996) found significantly higher scores for aspartame on the attributes liquorice and bitter (after)tastes, in comparison with sucrose or maltitol.

In experiment 2 of the present study, Beidler's mixture equation was studied with mixtures of sucrose and aspartame in water and in the presence of an orange aroma. Several combinations of sucrose and aspartame were chosen, and interactions between the orange aroma and both sweeteners were studied and compared, as in experiment 1. Several authors described the interactions between sweeteners and flavours; however, they only presented the intensities of one to three attributes. Baldwin and Korschgen (1979) asked the panellists to judge fruit flavour, and found that an orange-flavoured beverage sweetened with aspartame had a more intense fruit flavour than its counterpart sweetened with sucrose. Matysiak and Noble (1991) investigated the time-related perception of sweetness and fruitiness in model systems sweetened with aspartame or sucrose and flavoured with an orange extract. Their results show that aspartame has a longer sweetness duration, and that its sweetness was enhanced by the orange flavour. Fruitiness persisted longer in aspartame sweetened samples than in sucrose sweetened ones. Bonnans and Noble (1993) varied the acid content of these beverages, and found the same results as in the previous experiment. Larson-Powers and Pangborn (1978a) found time–intensity curves for the attributes sweet, bitter, sour and flavour of aspartame which were comparable to those of sucrose in all media. Van der Klaauw (1989) demonstrated that changes in perceived taste intensity can be instruction-dependent, and that cognitive factors may affect judgements of chemosensory attributes. It is important to have appropriate descriptors available. Odour-induced enhancement of sweetness depends on the appropriateness of the stimulus attributes that subjects are instructed to rate. As fruitiness and sweetness appeared to be similar attributes, the fruitiness of a taste–smell mixture may be included in the working concept of sweetness under those conditions in which subjects were not asked to pay attention to the fruitiness. The quantitative descriptive analysis used in this study allows subjects to generate their own appropriate descriptors.

Experiment 1

This experiment was designed to examine the suitability of Beidler's mixture equation for mixtures of the bulk sweeteners sucrose and maltitol. Interactions between the orange aroma and both bulk sweeteners were also analysed.

Materials and methods

Subjects

Of the 61 applicants for the panel screened by a questionnaire, 48 were further selected on such criteria as motivation, possession of good general perception, judgement of sweetness, and the ability to generate and distinguish attributes and score these separately. From a pool of 35 available subjects, a panel of 24 paid subjects (four men and 20 women) was chosen to be trained for experiment 1. Most subjects were students of Wageningen Agricultural University, ranging in age from 19 to 27 years, and having no prior experience of psychophysical experiments. Informed consents were obtained from the subjects, and the study was approved by the Medical Ethical Commission of Wageningen Agricultural University.

Stimuli

The stimuli were solutions of sucrose (CSM Suiker BV, Amsterdam, The Netherlands) and of maltitol (Roquette Frères, Lestrem, France), and mixtures of these two substances in demineralized water. Solutions of limonene (Sigma, St Louis, MO) and octanal (Merck, Hohenbrunnen, Germany) were used to generate attributes.

According to Portmann and Kilcast (1996), the 10% SEV (sucrose equivalent value) for maltitol is 13.5% w/v. These concentrations, 10% w/v sucrose and 13.5% w/v maltitol, were chosen as starting concentrations for the Beidler's mixture equation. This equation should then predict the concentration and composition of sucrose–maltitol mixtures having a constant perceived taste intensity of 10% SEV. The validity of the Beidler's mixture equation was assessed over a series of nine sucrose/maltitol ratios (100/0, 90/10, 75/25, 60/40, 50/50, 40/60, 25/75, 10/90 and 0/100). The overall sweetness of each mixture was equisweet at 10% SEV. The orange aroma added was a sample of the

Table 1 Attributes describing the flavour of several solutions containing sucrose (10% w/v), aspartame (0.056% w/v), maltitol (13.5% w/v), orange aroma (15 g/l), limonene (1 g/l) and/or octanal (0.05 g/l)

Attributes	
Sweet	Prickling
Orange	Spicy
Sour	Viscosity
Bitter	Musty
Fruity	Grassy
Mint	Aftertaste
Chemical	

watery vapour phase of stripped orange juice (Cargill Juice Division, Amsterdam, The Netherlands). It was used in concentrations of 0, 15 and 30 g/l. The standard stimuli 'not sweet' and 'very sweet' consisted of 0 and 16% w/v sucrose respectively. The solutions were prepared at least 24 h before evaluation, and stored at 4°C overnight. A stimulus consisted of 15 ml of solution, presented in a glass jar, and covered by a plastic lid and aluminium foil to prevent interactions between the plastic and the orange aroma. The stimuli were presented to the panel at room temperature (22°C).

Procedure

The relative sweetness factors (10% SEV) of sucrose (10% w/v) and maltitol (13.5% w/v) are introduced in Beidler's mixture equation. Beidler's mixture equation then becomes

$$W + 0.74X = 10\% \text{ w/v} \qquad (1)$$

for mixtures of sucrose (= W) and maltitol (= X) (De Graaf and Frijters, 1986). The panel performed a quantitative descriptive analysis to evaluate the solutions containing nine different combinations of sucrose and maltitol chosen with equation (1) and three concentrations of orange aroma. With the help of several solutions, flavour attributes were generated, during training of the subjects, which were ranked and clustered in consultation with the panel (Table 1). The panel was calibrated by tasting sucrose references of 0 and 16% (w/v), which were the anchors of the visual analogue scale for sweetness. Similar scales for the other attributes were not anchored. The solutions were evaluated by tasting according to the sip-and-spit method, the time intervals between stimuli being kept at 60 s. After tasting of a solution, the subjects neutralized their mouth with water and crackers. All solutions were evaluated twice, with the stimuli presented randomly to the subjects. The intensities of the attributes were marked on a 120 mm visual analogue scale on a portable computer screen. Subjects were asked to comment on aftertastes. The survey information was gathered by a computer interactive interviewing system (Ci2 system; Sawtooth Software Inc., Ketchum, USA).

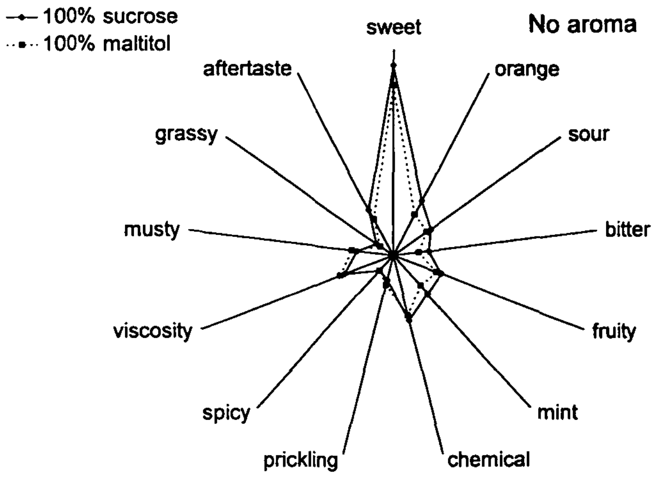

Figure 1 Spider web diagram representing the mean scores for sensory attributes of a sucrose and a maltitol solution at 10% SEV (in the absence of orange aroma).

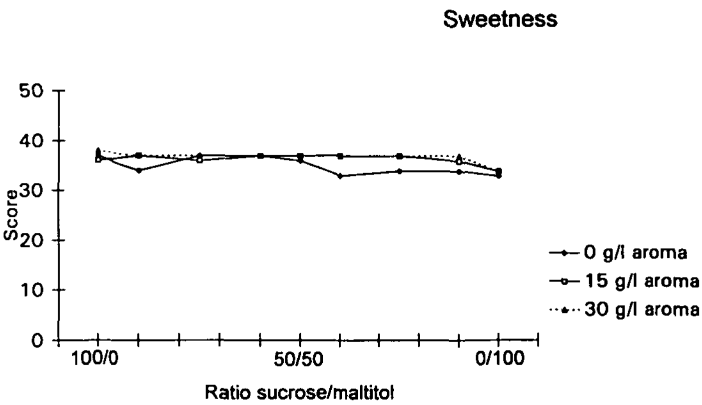

Figure 2 Mean scores for the sensory attribute sweetness for solutions containing mixtures of sucrose and maltitol. Three different concentrations of orange aroma: 0, 15 and 30 g/l.

Sensory data were subjected to Student's t-tests to determine significant differences between solutions. A significance level of $P < 0.01$ was used for sweetness (anchored scale), and $P < 0.05$ for the other attributes.

Results

Figure 1 presents the flavour profile of a 100% sucrose solution compared with a 100% maltitol solution, both in the absence of orange aroma. Maltitol does not differ significantly from sucrose in its mean scores for any of the chosen attributes. For the attribute sweet, the mean scores remain constant for each combination of sucrose and maltitol (Figure 2). This confirms the assumption that Beidler's model is suitable for mixtures of these two bulk sweeteners. Figure 3 shows the evaluation of a solution containing a mixture of 50% sucrose and 50% maltitol

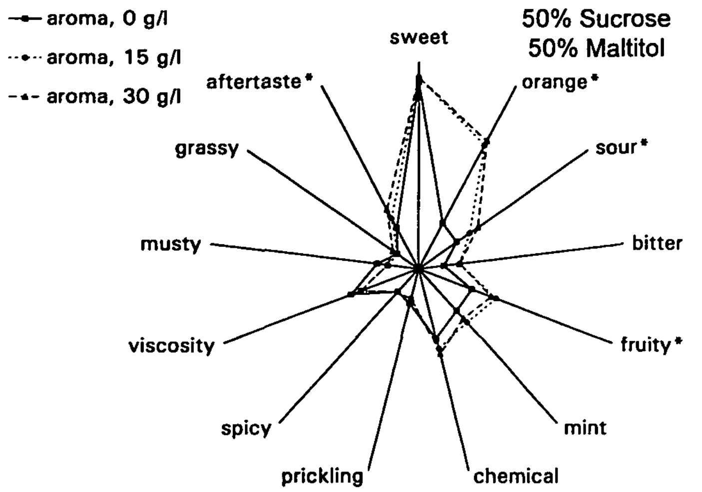

Figure 3 Spider web diagram representing the mean scores for sensory attributes of a mixture solution of a 50/50 sucrose/maltitol ratio, at three concentrations of orange aroma: 0, 15 and 30 g/l; * = significant differences ($P < 0.01$ for sweetness, $P < 0.05$ for other attributes).

at different concentrations of orange aroma. Flavour attributes characterizing the orange aroma (orange, sour, fruity and aftertaste) were significantly perceived in sucrose–maltitol mixtures with orange aroma. However, a twofold increase of the original concentration of orange aroma increases the mean scores of the attributes involved only slightly. Stevens and Cain (1985) demonstrated similar results in their figures for iso-amyl butyrate and limonene, showing the normalized odour intensity estimation as a function of odorant concentration. The attribute sweet showed low standard deviations for each combination of sucrose and maltitol. As the scale for sweetness was anchored with the help of sucrose references, mean scores remained constant. Standard deviations for the other attributes were larger. The mean scores for the different attributes remained fairly constant for every combination of sucrose and maltitol.

The comments on aftertastes of the different solutions were similar to the attributes used. Solutions containing 0, 15 and 30 g/l of orange aroma were compared across the nine different sucrose–maltitol mixtures. The number of subjects reporting the aftertastes sweet, orange, sour, fruity or chemical were counted and are presented in Table 2. Solutions containing 15 or 30 g/l of orange aroma gave stronger orange, sour, fruity and chemical aftertastes. The addition of 30 g/l orange aroma instead of 15 g/l provided a stronger orange aftertaste.

Conclusions

Beidler's mixture equation makes it possible to choose equisweet combinations of the bulk sweeteners sucrose and maltitol. The flavour profiles of the sweeteners sucrose and maltitol do not differ significantly at a constant concentration of orange aroma. Flavour profiles of different concentrations of orange aroma show significant differences for several attributes.

Table 2 Number of subjects reporting aftertastes sweet, orange, sour, fruity or chemical for solutions containing 0, 15 and 30 g/l of orange aroma (experiment 1)

Orange aroma (g/l)	Aftertaste				
	Sweet	Orange	Sour	Fruity	Chemical
0	7–16	0–2	0–3	0–1	0–4
15	7–14	3–9	2–6	1–3	3–8
30	7–14	6–14	3–7	0–5	3–9

Experiment 2

The aim of this experiment was to examine the suitability of Beidler's mixture equation as in experiment 1, but this time for mixtures of sucrose and aspartame.

Materials and methods

Subjects

Again the panel consisted of 24 paid subjects (four men and 20 women), ranging in age from 19 to 27 years. Nineteen of the subjects also participated in experiment 1, the five additional subjects being taken from the pool made in experiment 1.

Stimuli

The stimuli were solutions of sucrose (CSM Suiker BV, Amsterdam) and of aspartame (Holland Sweetener Company, Maastricht, The Netherlands), and mixtures of these two substances in demineralized water.

As in experiment 1, nine sucrose/aspartame ratios (100/0, 90/10, 75/25, 60/40, 50/50, 40/60, 25/75, 10/90 and 0/100) were chosen to assess the validity of the Beidler's mixture equation, with the overall sweetness of each mixture equisweet at 10% SEV. Again the orange aroma added was a sample of the watery vapour phase of stripped orange juice, used in concentrations of 0, 15 and 30 g/l. Further preparation, storage and presentation of the solutions was done as in experiment 1.

Procedure

In several previous studies, the SEV of aspartame has been determined (Table 3). Whereas we found one SEV for maltitol in the literature, the values for aspartame were quite different, which may result from differences between panels or methods of preparation. The SEV for aspartame described by Nahon *et al.* (1996) was determined in a blackcurrant soft drink, in which some additional sweetness from a fruit concentrate may be present. Therefore the 10% SEV of aspartame was again determined with the described

Table 3 Sucrose Equivalent Values (SEVs) for aspartame, as reported by several authors, the standard sucrose reference, details about the preparation of the solutions and the number of subjects used for the determination

Authors	Year	10% SEV (% w/v)	Sucrose (% w/v)	Preparation solutions	No. of subjects
Ayya and Lawless	1992	0.100	10	24 h before	10–13
Baldwin and Korschgen	1979	0.065	9.5	flavoured beverage	8 (lab panel)
Bornstein *et al.*	1993	0.053	9	fresh	15?
Cloninger and Baldwin	1974	0.090	10	–	20
DuBois and Lee	1983	0.075	10	–	12
Faurion *et al.*	1980	0.085	9.6	frozen samples	9
Frank *et al.*	1989	0.080	8.6	24 h before	18–20
Ketelsen *et al.*	1993	0.090	9	–	±30
Larson-Powers and Pangborn	1978a	0.190	10	16 h before	13
Lawless and Stevens	1983	0.056	10.3	informal	
Matysiak and Noble	1991	0.085	10	48 h before	25
Ott *et al.*	1991	0.113	10	16 h before	8
Portmann and Kilcast	1996	0.120	10	24 h before	12
Schifferstein and Frijters	1991	0.088	8.6	24 h before	14
		0.094	9.2		
Theunissen and Kroeze	1995	0.130	10.5	24 h before	15

panel and method of preparation. The 10% SEV was determined using the method of constant stimuli (Guilford, 1954) and weighted linear regression (Bock and Jones, 1968) as described previously (De Graaf and Frijters, 1986). Substituting the established 10% w/v for sucrose and the resulting SEV of 0.096% w/v for aspartame to Beidler's mixture equation gives

$$W + 104.06X = 10\%\ \text{w/v} \qquad (2)$$

for mixtures of sucrose (= W) and aspartame (= X). Similar to the first experiment, nine sucrose/aspartame ratios were chosen and three different concentrations of orange aroma were added. Again the panel performed a quantitative descriptive analysis to evaluate the solutions containing several combinations of sucrose and aspartame chosen with equation (2). The experimental design was the same as in the first experiment, except that the solutions were tasted only once. The attributes generated and used in experiment 1 also involved solutions containing aspartame (Table 1). Therefore, the same attributes were used in experiment 2. To stimulate a better use of the scales, 5 and 12.5% (w/v) sucrose solutions were evaluated in experiment 2. These solutions were randomly given with the other solutions to be evaluated.

Results

In Figure 4 a sucrose solution is compared with an aspartame solution at 10% SEV, both in the absence of orange aroma. In comparison with sucrose, the mean scores for aspartame are significantly higher for the attributes sour, chemical and aftertaste. The mean scores for the attribute sweet (Figure 5) remain constant for each combination of

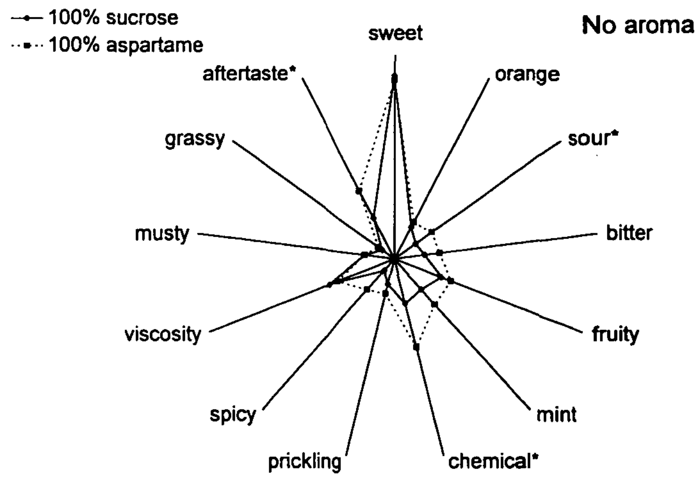

Figure 4 Spider web diagram representing the mean scores for sensory attributes of a sucrose and an aspartame solution at 10% SEV (in the absence of orange aroma); * = significant differences ($P < 0.01$ for sweetness, $P < 0.05$ for other attributes).

sucrose and aspartame. Apparently Beidler's model can be used to compose equisweet mixtures of these two sweeteners.

Almost all attributes show significant differences when different concentrations of orange aroma are compared for mixtures of a 50/50 sucrose/aspartame ratio (Figure 6). For every solution containing a mixture of sucrose and aspartame, the addition of orange aroma increases the mean scores for all attributes except sweetness, viscosity and musty. The addition of orange aroma again clearly gives the solution a more distinct flavour. In this experiment, subjects scaled 5 and 12.5% w/v sucrose solutions as well. This

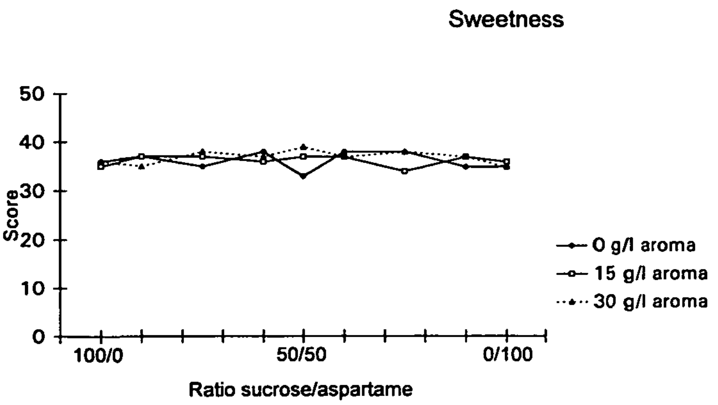

Figure 5 Mean scores for the sensory attribute sweetness for solutions containing mixtures of sucrose and aspartame. Three different concentrations of orange aroma: 0, 15 and 30 g/l.

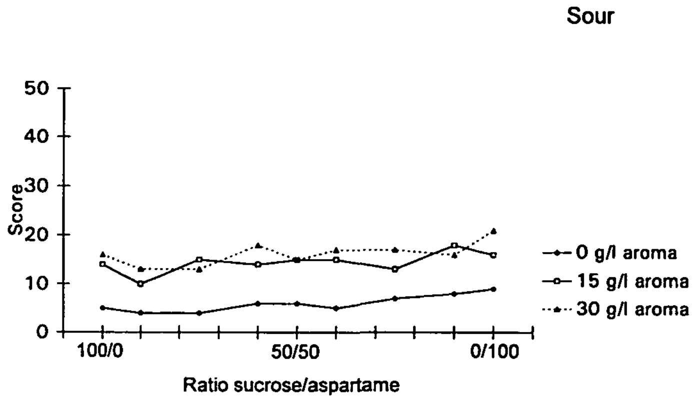

Figure 7 Mean scores for the sensory attribute sour for solutions containing mixtures of sucrose and aspartame. Three different concentrations of orange aroma: 0, 15 and 30 g/l.

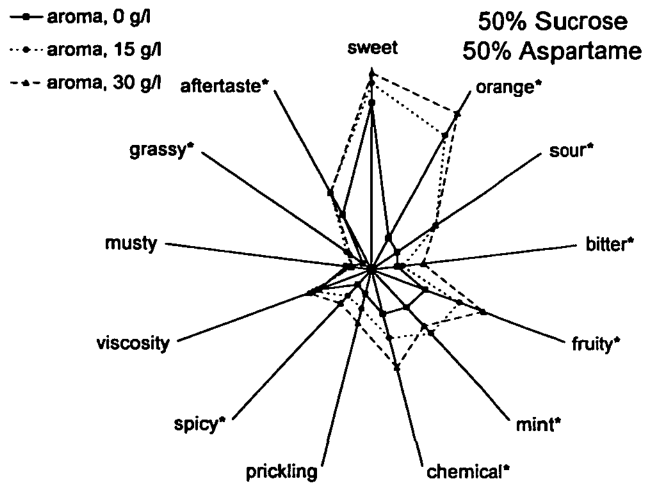

Figure 6 Spider web diagram representing the mean scores for sensory attributes of a mixture solution of a 50/50 sucrose/aspartame ratio, at three concentrations of orange aroma: 0, 15 and 30 g/l; * = significant differences ($P < 0.01$ for sweetness, $P < 0.05$ for other attributes).

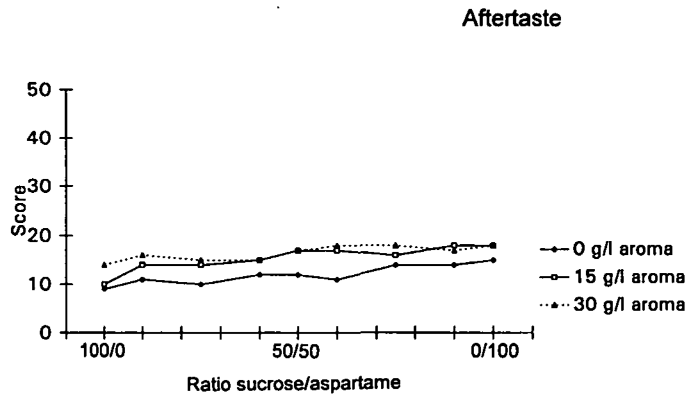

Figure 8 Mean scores for the sensory attribute aftertaste for solutions containing mixtures of sucrose and aspartame. Three different concentrations of orange aroma: 0, 15 and 30 g/l.

probably introduced more variations in sweetness among solutions (compare Figures 2 and 5), although significant differences were not found. Standard deviations calculated for the attribute sweet were again low for each combination of sucrose and aspartame. As in experiment 1, it is difficult to find significant differences for the other attributes, but some tendencies may be recognized. The mean scores for the attributes sour, bitter, chemical, prickling, spicy and aftertaste tend to be higher when more aspartame is present in the mixture (see e.g. Figures 7 and 8). In the case of interaction between the components of the solutions the differences in mean scores of the attributes would be expected to either decrease or increase when the ratio sucrose/aspartame changes. However, the contribution of orange aroma to the mean scores of the attributes is of equal magnitude for every mixture solution. Therefore, interactions between aroma and sweetener are assumed to be absent. Also, the mean scores for the attributes orange and fruity remain fairly constant for every possible combination of sucrose and aspartame. These attributes would change with the ratio sucrose/aspartame if either sucrose or aspartame implied any of these tastes.

The terms used for the comments on the aftertastes of the different solutions did not differ from the attributes. However, solutions containing more aspartame tended to have more aftertaste, which is mainly described by the attributes sweet and chemical. Similar to solutions in experiment 1, solutions containing 15 or 30 g/l of orange aroma provided stronger orange, sour, fruity and chemical aftertastes than solutions without orange aroma.

Conclusions

Beidler's mixture equation can be used to choose combinations of the sweeteners sucrose and aspartame having the same sweetness. The flavour profiles of mixtures containing more aspartame provide significantly higher scores on the attributes sour, chemical and aftertaste than those containing sucrose. Different concentrations of orange aroma provide significantly different flavour profiles.

Discussion

Beidler's mixture equation seems to be suitable for mixtures of sucrose and maltitol and for mixtures of sucrose and aspartame. The addition of orange aroma gives the solutions a more distinct taste. Solutions containing maltitol did not differ significantly from solutions containing sucrose in this study, whether in the absence or the presence of orange aroma. The same results were reported in the literature (Rapaille and Van der Schueren, 1989; Sicard and Le Bot, 1990; Rapaille *et al.*, 1995; Portmann and Kilcast, 1996). As expected, Beidler's mixture equation was appropriate for mixtures of these two sweeteners; the two bulk sweeteners seem to share the same receptor sites.

The 10% SEV determined for aspartame agrees with values reported in the literature which were determined with larger panels (panel >10). However, the sweetness values found for the mixtures of sucrose and aspartame were quite dissimilar. Our findings concerning the sweetness of mixtures of sucrose and aspartame agreed with those of both Ayya and Lawless (1992) and Schifferstein (1995). Beidler's mixture equation seems to be appropriate for these solutions. Once the use of Beidler's mixture equation for composing our equisweet mixture solutions had been established, the effects of added orange aroma could then be investigated. Larson-Powers and Pangborn (1978a), Baldwin and Korschgen (1979), Matysiak and Noble (1991) and Bonnans and Noble (1993) asked their subjects to judge one attribute at a time. Whereas we did not find any changes in the attribute orange aroma, all except Larson-Powers and Pangborn (1978a) found enhancement of fruitiness by aspartame. The applied quantitative descriptive analysis seems to be an appropriate method to avoid instruction-dependent changes in perceived taste intensity (Van der Klaauw, 1989).

Le Quéré *et al.* (1994) evaluated several sweeteners in an orange soft drink by quantitative descriptive analysis. Comparison of aspartame with sucrose shows that synthetic and pineapple flavours are associated with high concentrations of aspartame. In contrast with their study, an unanchored descriptive analysis by Larson-Powers and Pangborn (1978b) showed a decrease in 'fresh orange peel' and 'orange-flavoured aspirin' aroma in orange-flavoured drinks, when comparing aspartame with sucrose. The flavour of drinks sweetened with sucrose or aspartame was judged as sweet-chemical and bitter. The aftertaste of samples containing sucrose or aspartame was described as 'sweet-clean' (Larson-Powers and Pangborn, 1978b). In the present study, mixtures containing more aspartame were characterized by higher scores on attributes related to sour, bitter and chemical-related tastes. The aftertaste of these solutions was described as sweet-chemical. The quantitative descriptive analysis of the solutions did not reveal interactions between the sweeteners and the orange aroma. Mixtures of sweeteners showing synergistic effects might give more flavour effects. Orange aromas containing other flavour compounds, such as aromas based on peel oil, could also give different results.

In conclusion it was shown that Beidler's mixture equation is valid for mixtures of maltitol or aspartame, sucrose and an orange aroma. Equisweet mixtures of them can be formulated to provide a basis for studying sweetness–flavour interactions. Furthermore, a quantitative descriptive analysis seems to be the most appropriate method for the study of these interactions.

Acknowledgement

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