

## Sensory Profiles of Sweeteners in Aqueous Solutions

ALENA ŠEDIVÁ, ZDEŇKA PANOVSKÁ and JAN POKORNÝ

*Department of Food Chemistry and Analysis, Faculty of Food and Biochemical Technology, Institute of Chemical Technology Prague, Prague, Czech Republic*

### Abstract

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Sensory profiles of saccharin, acesulfame K, aspartame, and neotame were compared with that of sucrose in three different types of water (tap water, commercial Crystallis water, and distilled water) under the conditions of the respective ISO standards. The intensities of off-flavours, especially bitter and metallic tastes, were higher in the solutions of synthetic sweeteners than in that of sucrose. The aspartame solution was the sample closest to the sucrose solution, and the intensity of off-flavours was significantly higher in acesulfame solution. Ratings of the bitter taste were related to those of the metallic taste, the relation being semilogarithmic. The performances of different assessors were nearly the same in all ratings, and the absolute values of the ratings of sweetness and different off-flavours had the same repeatabilities. The relative accuracy was, naturally, much higher in off-flavours than in the case of sweetness.

**Keywords:** sensory profile; sucrose; sweeteners; sweetness; synthetic sweeteners

Sucrose, a traditional sweetener, possessing a considerable content of energy, is now often replaced by low energy sweeteners, especially in some fruit products and beverages. Several low-energy sweeteners possess a common disadvantage of various off-flavours and after-tastes, absent or extremely weak in sugar solutions. Metallic, bitter, and astringent tastes were most often reported among off-flavours (REDLINGER & SETSER 1987). The bitterness of saccharin has been emphasised (MEYER 2003). Therefore, the bitterness should be tested in sensory profiling of sweeteners (CARDELLO *et al.* 2000). The metallic taste is often present, but it was not distinguished from the bitter taste in many experiments. Off-flavours are usually less pregnant in mixtures of sweeteners (SAELZER 2004a, b).

Aspartame belongs to the sweeteners most resembling sucrose in the sensory profile (CARDELLO *et al.* 2003). Recently, the structurally related neotame (ABBOTT 2004) – *N*[*N*-3,3-dimethyl]-*L*- $\alpha$ -aspartyl-*L*-phenylalanine] – was found more efficient as a sweetening agent than aspartame, but of a similar sensory profile (PRAKASH *et al.* 2002).

On the basis of the available literature, numerous data can be found on the application of neotame to foods, beverages, and chewing gums, but the sensory profile of neotame was not compared in detail with those of other sweeteners in aqueous solutions. Therefore, we have tested the sensory profiles of acesulfame K, aspartame, neotame, and saccharin – all sweeteners having been approved by Food and Drug Administration, USA (ADA

2004), with that of sucrose under the conditions specified by the international standards.

## MATERIAL AND METHODS

**Material.** Tap water contained mineral components in agreement with the national standard (ČSN 75 7121 – Ukazatele jakosti pitné vody. Vyhláška 252/2004 Sb., Ministry of Health CR, 22. 4. 2004): at least 30 mg/l Ca (the recommended content 40–80 mg/l) and at least 10 mg/l Mg (the recommended value 20–30 mg/l). Commercial potable water Crystalis (supplied by Crystalis, s.r.o., Prague, Czech Republic), supplied from Teplice-Aderšpach Rocks, Police n. M., Czech Republic, contained 34.0 mg/l Ca, 6.1 mg/l Mg, 2 mg/l Na, 7.5 mg/l  $\text{NO}_3^-$ , and 128.0 mg/l  $\text{HCO}_3^-$ , the total mineral content 208 mg/l. Distilled water was prepared in an all-glass apparatus.

The following sweeteners were used: sucrose p.a. (Lach-Ner, s.r.o., Neratovice, Czech Republic), saccharin Na, acesulfame K and aspartame (all the above sweeteners, purity higher than 99% dry matter, Urseta, s.r.o., Doksy u Kladna, Czech Republic), and neotame (The Nutrasweet Co., Augusta, USA).

**Sensory analysis.** The test room was equipped according to the requirements of the international standard (ISO 8589 – Sensory analysis – General guidance for the design of test rooms). Three or four samples were served at a session, each time 30 ml of sample in a 50 ml coded beaker, served at random order. The sample was ingested, moved in the mouth for 5–6 s by movements of the tongue,

and swallowed. Flavour intensities were rated after swallowing. After mouth washing with water and waiting for 20 s, the second sample was evaluated. The sample serving was in agreement with the respective international standard (ISO 6658 – Sensory analysis – Methodology – General guidance). The sensory profile (ISO 6564 – Sensory analysis – Flavour profile methods) consisted of four descriptors (sweet, bitter, sour, metallic), rated on an unstructured graphical scale (ISO 4121 – Sensory analysis – Methodology – Evaluation of food products by methods using scales), represented by a straight line 100 mm long, oriented by the description at the two ends (0% = imperceptible; 100% = extremely strong). Rank tests were performed using the international standard (ISO 8587 – Sensory analysis – Ranking). The assessors were selected, trained, and monitored according to the respective standard (ISO 8586 – Sensory analysis – General guidance for the selection, training and monitoring of assessors – selected assessors); they had experience in sensory profiling of a year at least. They were trained for the special task after DUBOIS *et al.* (1991).

**Statistical analysis.** The two-way analysis of variance, the one-way ANOVA, were applied using the software Microsoft Statistica 7.0; the probability level was fixed at  $P = 0.95$ . The ranking evaluation was performed after KRAMER (BARYŁKO-PIKIELNA 1975).

## RESULTS AND DISCUSSION

All samples were tested 20 times under the same conditions using the same panel of assessors. The

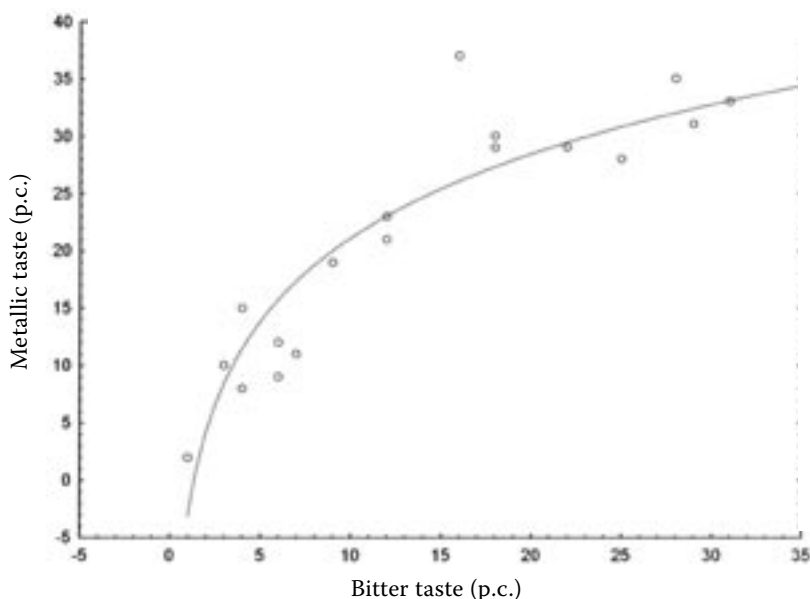


Figure 1. Relationships between bitter and metallic off-flavours in solutions of sweeteners (expressed in % of the graphical scale)

Table 1. Sensory profiles of sweeteners

Water	Sweetener	Sweet taste	Bitter taste	Acid taste	Metallic taste
Tap water	aucrose	82 ± 8	7 ± 2	7 ± 2	11 ± 3
	saccharin	62 ± 4	25 ± 3	12 ± 3	28 ± 4
	acesulfame	69 ± 2	31 ± 4	7 ± 2	33 ± 4
	aspartame	69 ± 3	4 ± 1	6 ± 1	15 ± 2
	neotame	76 ± 3	22 ± 4	14 ± 3	29 ± 4
	blank	2 ± 1	3 ± 1	5 ± 2	10 ± 2
Krystalis	aucrose	72 ± 2	6 ± 2	12 ± 1	9 ± 1
	saccharin	73 ± 3	12 ± 2	10 ± 2	23 ± 3
	acesulfame	65 ± 3	29 ± 5	7 ± 2	31 ± 4
	aspartame	72 ± 2	9 ± 2	4 ± 1	19 ± 3
	neotame	75 ± 2	18 ± 3	9 ± 2	30 ± 4
	blank	1 ± 1	1 ± 1	1 ± 1	2 ± 1
Distilled water	aucrose	71 ± 2	4 ± 1	10 ± 2	8 ± 2
	saccharin	74 ± 3	18 ± 3	11 ± 3	29 ± 3
	acesulfame	69 ± 3	28 ± 4	7 ± 2	35 ± 5
	aspartame	70 ± 2	12 ± 1	4 ± 1	21 ± 3
	neotame	68 ± 3	16 ± 3	11 ± 3	37 ± 3
	blank	2 ± 1	6 ± 2	3 ± 1	12 ± 2
Mean values	aucrose	75 ± 6	6 ± 2	10 ± 2	9 ± 2
	saccharin	69 ± 6	18 ± 5	11 ± 3	27 ± 3
	acesulfame	68 ± 3	29 ± 3	7 ± 1	32 ± 3
	aspartame	70 ± 3	7 ± 2	5 ± 1	18 ± 3
	neotame	73 ± 3	17 ± 3	11 ± 3	32 ± 3
	blank	2 ± 1	3 ± 1	3 ± 1	8 ± 1

solutions of sweeteners were tested in three types of water (tap water, water Krystalis, and distilled water), and the respective water was tested for comparison. The concentrations of sweeteners corresponded approximately to 9% sucrose (the reference sample), i.e. 0.257 g/l in the case of saccharin, 0.45 g/l in the case of acesulfame K, 0.45 g/l in the case of aspartame, and 0.011 g/l in the case of neotame. The solutions were prepared immediately before testing, and were tested at 23°C. The responses were based on literature data (TUNALEY *et al.* 1987), but the sweetness responses were not exactly those of sucrose solutions as they depended on the water used. Nevertheless, they were not significantly different in the three

solvents tested (Table 1); the exact agreement could not be expected. Nevertheless, substantial bitter and metallic off-flavour notes were observed in the case of all sweeteners, they were the lowest, however, in the case of aspartame, in agreement with the literature (CARDELLO *et al.* 2003). Neotame was found always slightly less favourable from the standpoint of off-flavours than aspartame.

The intensities of metallic and bitter tastes were interrelated ( $\text{Metallic} = 24.3 \log \text{Bitter} - 3.1$ ;  $R^2 = 0.79$ ;  $N = 18$ ), the relationship being semilogarithmic (Figure 1). The high correlation coefficient shows that the dependence was very close, and in some cases, it was probably not possible to dis-

Table 2. Average differences between two results of sensory ratings

Sweetener	Sweet taste	Metallic taste	Bitter taste
Sucrose	6	5	6
Saccharin	15	14	12
Acesulfame	12	15	18
Aspartame	9	7	6
Neotame	11	16	14
Mean value	11	11	11

Expressed in % of the graphical scale

Table 3. Average differences obtained by rating the same solutions by different assessors

Taste	Assessor A	Assessor B	Assessor C	Assessor D	Assessor E	Assessor F	Mean value
Sweet	12	10	10	8	11	9	10
Metallic	12	10	9	19	12	12	12
Bitter	12	10	12	12	10	10	11
Mean	12	10	10	13	11	11	11

Expressed in % of the graphical scale

tinguish clearly between the two tastes. The values of off-flavours obtained in our experiments were moderately higher than those reported by other authors (PRAKASH *et al.* 2002; NOFRE & TINTI 2000). The probable reason was that in our experiments, the assessors were more concentrated on the evaluation of off-flavours.

No significant differences were observed among the ratings of the sensory profiles in the three different brands of water used as solvents.

The average differences between two results on rating the same solution by different assessors are given in Table 2. The lowest values were obtained in the case of sucrose and aspartame,

Table 4. Significance of difference between sweeteners in intensities of off-flavours

	Sucrose	Saccharin	Acesulfame	Aspartame
<b>Metallic taste</b>				
Neotame	+	–	–	+
Aspartame	+	+	+	
Acesulfame	+	–		
Saccharin	+			
<b>Acidic taste</b>				
Neotame	–	–	–	–
Aspartame	–	–	+	
Acesulfame	–	–		
Saccharin	–			
<b>Bitter taste</b>				
Neotame	+	–	+	+
Aspartame	–	–	+	
Acesulfame	+	–		
Saccharin	+			

the latter being the sweetener closest to sucrose in its character (CARDELLO *et al.* 2000). No substantial differences were found between saccharin, acesulfame and neotame.

The performances of the individual assessors were tested as well (Table 3). No significant differences were found, probably due to the long experience of the assessors. Their ratings could be thus considered as reliable.

Statistical differences between the ratings of off-flavours are shown in Table 4. The ratings of the bitter taste of the synthetic sweeteners were higher than in the case of sucrose solutions (very low bitter taste). Aspartame solutions were less bitter than those of other sweeteners, and acesulfame solutions were bitterer, similarly as it was reported in the literature (CARDELLO *et al.* 2000). The bitterness of neotame solution was slightly higher than that of aspartame solution, and similar to that of saccharin, however, still lower than that of acesulfame. The acidity was not important in evaluating synthetic sweeteners. In the case of the metallic taste, all synthetic sweeteners differed from the sucrose solution; the aspartame solution had more intensive metallic taste than the sucrose solution but less intensive than those of all other synthetic sweeteners. The ranking test (6 cases, three replications) showed that the off-tastes were lower in water and in sucrose solutions, but significantly higher in the case of synthetic sweeteners. All solutions differed from that of the acesulfame solution, in which it was the highest.

## CONCLUSIONS

Bitter and metallic off-tastes of neotame solution were more intensive than those of sucrose solutions, of the same order as in case of aspartame and saccharin solutions, and less intensive than in acesulfame solutions. The three types of water used for dissolving the sweeteners yielded similar values. The absolute accuracy of the off-flavour ratings was about the same as that of the sweetness rating.

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### Corresponding author:

ALENA ŠEDIVÁ, MSc., Vysoká škola chemicko-technologická v Praze, Fakulta potravinářské a biochemické technologie, Ústav chemie a analýzy potravin, Technická 5, 166 28 Praha 6, Česká republika  
tel.: + 420 220 443 263, fax: + 420 233 339 990, e-mail: jan.pokorny@vscht.cz