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Time–intensity studies of astringent taste

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Abstract

The intensity of astringent taste was studied in wine, vermouth and other beverages during ingestion and for up to 100 s after swallowing, and the reproducibilities determined. Better reproducibility was observed of the same assessor on different days than between different assessors on the same day. Preprinted forms and mouse operated or touch-sensitive computer recording gave similar results. The residence time in the mouth influenced the maximum intensity and the rate of its decrease, which followed exponential relation. Solutions of tannic acid and catechin tasted more astringent in water than in wine or orange juice. Natural astringent substances in red wine or in tea infusion gave similar time dependence as model solutions. Sugar decreased the astringency in red wine, but quinine hydrochloride or additional ethanol had no pronounced effect. © 2002 Published by Elsevier Science Ltd.

Keywords: Astringency; Catechin; Orange juice; Sensory Analysis; Tannic acid; Tea infusion; Time–intensity course; Vermouth; Wine

1. Introduction

The astringency belongs to mouthfeel sensations, particularly important in beverages, such as fruit juices, tea or wine. The scalar sensory evaluation of astringency does not give a satisfactory information on the sensation as the sensation of astringent taste lasts relatively long time even after swallowing the draught. Therefore, time–intensity technique was applied for the measurement of astringency (Lee & Lawless, 1991). The intensity was tested for up to 5–6 min after swallowing. The time–intensity procedure was found better than the use of category scales (Lundahl, 1992). The time–intensity behaviour depends very much on the chemical structure of the respective compounds, for instance, the intensity of 5-O-caffeoylquinic acid faded quite differently after swallowing than tannic acid or grape-seed tannin (Naish, Clifford, & Birch, 1993) in spite of a similar taint of the astringent taste. The technique of time–intensity procedures and the statistical evaluation of results were described by Dijksterhuis (1997).

The application of time–intensity procedures was found particularly useful in the evaluation of astringency and bitterness of wine (Noble, 1995). Trained judges rated the astringency and bitterness of catechin, gallic acid, grape seed tannins and tannic acid in white wine (Robichaud & Noble, 1990). They found that monomeric phenolic compounds were rated more biter than astringent, while polymeric compounds were rated more astringent than bitter. The duration of aftertaste increased with the increasing concentration of test substances. Sucrose decreased both the maximum intensity and the aftertaste duration in red wine (Ishikawa & Noble, 1995). Tartaric acid, on contrary, increased the astringency (Guinard, Pangborn, & Lewis, 1986a, 1986b). The intensity and duration of astringent sensation increased with repeated ingestion (Guinard, Pangborn, & Lewis, 1986a, 1986b), which was in agreement with the reported observation (Lee & Lawless, 1991) that no taste adaptation occurred in case of astringency sensations (Lee & Lawless, 1991).

It is evident that the flavour of a beverage changes during the degustation because of the time-dependence of individual tastes. The time dependence is different for different tastes so that their contribution to the resulting overall flavour changes with time after the swallowing. As the astringent taste is important in many beverages, we have compared the time dependence of astringent sensations in model solutions and different beverages, and studied interactions of the astringent sensation with those of basic tastes and ethanol.

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2. Material and methods

2.1. Material

Tannic acid (Aldrich-Chemie, Steinheim, Germany); (+)-catechin (Sigma Chemical Co., St. Louis, MO, USA); citric acid, chemically pure for food use (Lachema, Brno, CZ); orange emulsion base No. 62105 (Aroco s. r. o., Prague, CZ); sucrose, pure for food use (Lachema, Brno, CZ); ethanol. extra fine for food use (Lihovar Kralupy, Kralupy n. V., CZ); quinine hydrochloride, pure for food use (FLUKA Chemie AG, Buchs, Swiss); red wine A: Frankovka, semidry (Mikulov, Moravia, CZ), conform with the Czech standard ČSN 56 7741 requirements; red wine B: Abruzzi, semi dry, packed by Bohemia Sekt, Starý Plzenec, CZ, conform with the current Czech legislation; red wine C: Valet, table wine, dry, packed by CA.VI.M. s. r. l., Costigliole d'Asti, Italy; model orange sirup was prepared by dissolving 94.5 g sucrose, 30 g citric acid and 10.5 g orange emulsion base in 42.0 g of tap water; the orange drink was prepared by diluting 123 ml of the above orange sirup with 905 ml tap water. Model vermouth samples were prepared by dissolving 6% sugar or 6% ethanol or 1 mg/l quinine hydrochloride or their combinations in the respective red wine. Ceylon tea, packed by Mljesna, Prague; Zlatý čaj, Jemča, Jemnice, CZ, a mixture of North Indian fermented tea brands, packed in 2-g bags. For the preparation of tea infusions, 150 ml boiling water was added to 2 g tea leaves, the suspension stirred, left for 2 min, stirred again, and left for another 2 min period, and 25 ml brew served at 60 °C.

2.2. Methods

The procedure used for the sensory analysis was in agreement with requirements of the international standard (ISO, 1985), performed in a standardized test room provided with 6 test booths (ISO, 1988). The room temperature varied between 20–23 °C, the relative moisture content between 40–70%.

Colourless samples or samples with the same colour were served in 30 ml colourless glasses coded with four-digit numbers, while the samples, where the addition of an astringent substance caused a colour change, were served in dark coloured 30 ml glasses. Not more than four samples were served in the random order, in intervals of 2 min after disappearance of astringent taste. Tap water was used for mouth washing between the samples.

The panel of sensory assessors was selected, trained and monitored after standard recommendations (ISO, 1993), and consisted of 19 ladies and 10 gentlemen. The same panelists participated in subsets of samples, which were compared. They had a minimum experience of 6 months, mainly in sensory profiling and time intensity studies of bitter flavour. As they had no particular preliminary experience in evaluation of the astringent flavour, they had to participate in four introductory sessions. They were tested for their immediate psychic and physiological ability immediately before each session.

The astringency was rated using a procedure developed for the determination of bitterness (Pilková & Pokorný, 1992). Unstructured graphical scales (ISO, 1983) were represented by straight lines 100 mm long, oriented by description on the two ends (0 mm = imperceptible astringency; 100 mm = very strong astringency). Earlier time-intensity procedure was followed (Valentová, Škrovánková, Pokorný, & Velíšek, 1997). The assessors (judges) were instructed (unless otherwise stated) to take a draught of 10–15 ml, to record the astringency after 2–3 s while keeping the draught still in their mouths and moving it slowly using their tongues for the total of 5 s. For the second time, they recorded the astringency immediately after swallowing, and then in 10-s intervals for 100 s. Separate graphical scales were used for each rating.

In some experiments, the assessors rated the astringent taste using a printed form (in 10 s intervals between ratings), in other cases using a computer screen operated with a mouse or a touch sensitive monitor (Microtouch Studioworks 57, LG Electronics Inc., Seoul, Korea), recording again on an unstructured graphical scale. In these experiments with computers, the time of rating depended on the assessors, and was recorded automatically.

In agreement with the literature (McBride, 1985) the graphical scale was considered as an interval scale (excepting 5 mm at each end), and mean values and standard deviations were calculated using the one-way ANOVA procedure (Microsoft STATISTICA 3.0); the probability level was $P = 0.95$ (a significance level of 0.05). The average difference between two ratings was calculated after Gini (1912) as explained by Weber (1957).

The time–intensity course was characterized by time to reach the maximum intensity, the intensity at the maximum, and the duration of astringent sensation (Noble, 1995).

3. Results

3.1. Validation of the method

The method of the time-intensity determination of astringency was tested using a matrix of 446 analyses and 11 time intervals. The average differences between duplicate analyses are shown in Table 1. In case of the same assessor's ratings, the difference decreased with decreasing absolute rating (and thus, increasing time after swallowing) while in case of different assessors, the

difference remained nearly constant during the whole time interval tested.

If the time-dependence is evaluated, as suggested by Noble (1994) in case of wine tasting, in the analysis of the same sample of red wine, the maximum astringency of different assessors varied between 55 and 82% of the scale, the time to reach the maximum between 5 and 25 s, and the time needed for disappearance of the astringent taste between 70 and 175 s.

No difference in the time dependence was observed between the results obtained with the printed form and the computerized procedure, operated with a mouse. Table 2 shows average values of 24 analyses of the same sample of red wine. No significant differences were found between the results obtained using a mouse and a touch pen on a touch sensitive monitor.

The time when the draught was kept in the mouth before the swallowing influenced both the maximum astringency ratings and the rate of astringency decrease after the swallowing (Fig. 1), where several replicates with the same assessor have been compiled.

3.2. Time–intensity studies of the astringency in model water solutions

The time course of tannic acid astringency was determined at the concentration of 1 g/l. Average results of 20 assessors are shown in Table 3. The astringency was perceived as nearly the same ($P = 0.95$) both at 7 and 18 °C. The standard deviation of the mean values (20 replicates) varied between 4 and 6% of the graphical scale during the first minute of the test, gradually decreasing later with decreasing intensity of the astringent taste. The maximum intensity was observed either at swallowing or within 10 s after the swallowing (depending on the assessor). The maximum intensity of the tannic acid solution was near 60% of graphical scale, approaching the sensory saturation value of the substance. The concentration tested was chosen in such a way that the results varied within the interval of 10–90% of the graphical scale. The decrease of intensity after reaching the maximum followed an exponential dependence, but some residual astringency was detected even after 100 s after swallowing.

Table 1
Reproducibility of the determination of intensity of astringent taste

Time of recording	Average difference (% of scale) between results of the same assessor on different days	Average difference (% of scale) between results of different assessors on the same day
At swallowing	16	16
After 10 s	16	22
After 20 s	10	23
After 30 s	10	20
After 40 s	11	25
After 50 s	13	22
After 60 s	11	21
After 70 s	9	21
After 80 s	6	21
After 90 s	5	20
After 100 s	4	19

Table 2
Differences of results obtained with use of a printed form and a computer operated with a mouse

The indicator	Printed form	Computer
Maximum astringency (mm of scale)	71 (5)	66 (5)
Time to reach the maximum (s)	10 (2)	12 (3)
Time of disappearance of astringency (s)	202 (14)	167 (18)

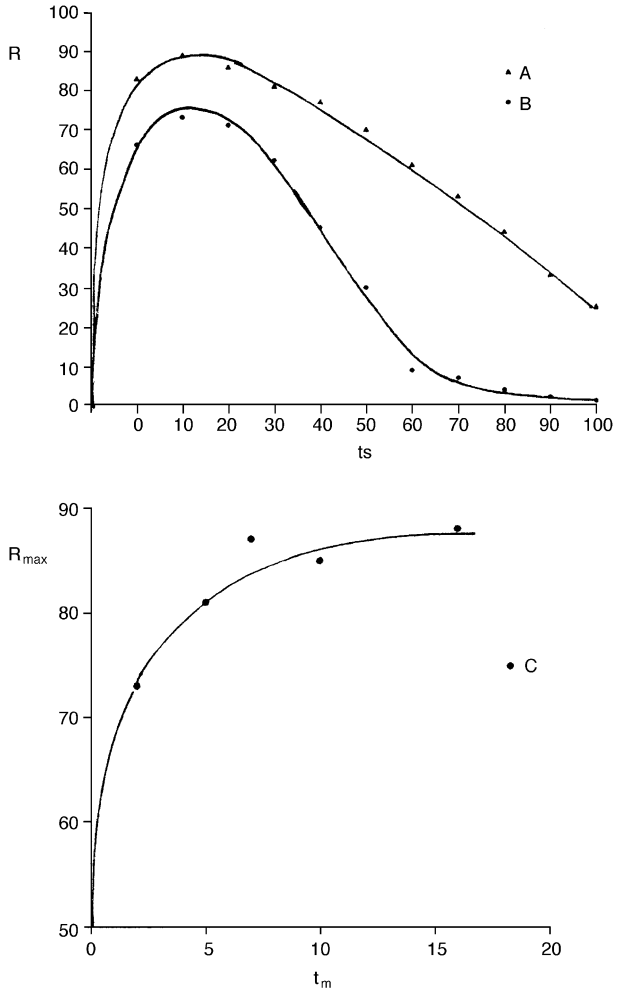

Fig. 1. Effect of keeping time of a draught in the mouth before swallowing on the time-development of astringent taste. R = intensity (% of the graphical scale); t_S = time after swallowing; 0 = time of swallowing; A = residence time in the mouth for 15 s; B = residence time in the mouth for 2 s; C = effect of the residence time in the mouth on the maximum intensity; R_{max} = maximum response after swallowing (% of scale); t_M = residence time in the mouth.

Results obtained using a solution of (+)-catechin (concentration of 2 g/l) are given in Table 3. They are averages of 20 responses by the same persons as in assessing the tannic acid solution. The maximum value was reached at swallowing or during the following 10 s, the intensities being independent on the temperature. The maximum intensity was slightly higher than in case of the tannic acid solution. The astringency decreased in agreement with an exponential time course, some residual astringency remaining even after 100 s after the swallowing.

3.3. Time–intensity course of astringency in case of red wine

Red wine A was tasted without additions, with addition of 1 g/l tannic acid, and 2 g/l catechin. The average results of 20 observations are shown in Table 4 (standard deviations of the means were 2–5% of scale). The concentrations of model astringent substances were the same as used in model water solutions. Contrary to Table 3, no substantial increase of astringency was, however, observed in red wine after addition of either of the earlier astringent substances. The maximum astringency was found immediately after swallowing in the original red wine, after a few seconds in case of the tannic acid solution, and about 7–9 s after swallowing in case of the catechin solution. Residual astringent taste after 100 s was only slight, but statistically significant.

The development of astringency of red wine B, without any additions, while still kept in the mouth before the swallowing could be approximated using a semi-logarithmic expression:

$$R = 34(1 + \log\ t)$$

The variable R is the astringency rating (% of the scale) and t = residence time in the mouth (s). Similar expressions were calculated for other wines.

After the swallowing, the decrease of astringency followed approximately an exponential relationship:

$$R = 103\ e^{-0.016t}$$

where R is the astringency rating (% of the scale), t = time after swallowing (s). Both expressions were obtained with the same sample and the same panel of 12 assessors (in the duplicate).

Table 3
Time–intensity course in model astringent solutions

Time interval recorded	Tannic acid at 7 °C (% of scale)	Tannic acid at 18 °C (% of scale)	Catechin at 7 °C (% of scale)	Catechin at 18 °C (% of scale)
In the mouth	44	44	42	43
At swallowing	59	61	66	64
After 10 s	52	60	59	60
After 20 s	42	49	47	49
After 30 s	33	36	37	38
After 40 s	23	27	26	27
After 50 s	17	19	19	19
After 60 s	12	13	13	14
After 70 s	9	9	9	10
After 80 s	7	6	6	7
After 90 s	5	3	3	4
After 100 s	4	2	2	3

Table 4
Time–intensity course of astringent taste in red wine

Time interval	Red wine without additions (%)	With 1 g/l tannic acid (%)	With 2 g/l catechin (%)
In the mouth	50	57	58
At swallowing	70	7373	
After 10 s	65	69	76
After 20 s	52	54	67
After 30 s	41	40	57
After 40 s	32	27	45
After 50 s	23	19	35
After 60 s	15	12	28
After 70 s	9	8	21
After 80 s	7	5	15
After 90 s	6	3	12
After 100 s	5	1	9

3.4. Time course of astringency in model vermouths

Vermouths contain bitter extracts, sugar and additional alcohol. Therefore, we have studied the effect of these additions on the intensity of astringent taste, Red wines B and C were used for these experiments. Some examples of time–intensity relationships are shown in Fig. 2 (red wine B). We added 6% ethanol to the original red wine containing already 11% ethanol. The additional ethanol had no pronounced effect. Quinine hydrochloride slightly suppressed the astringency, but it did not affect the astringency-suppressing effect of sucrose in any significant degree.

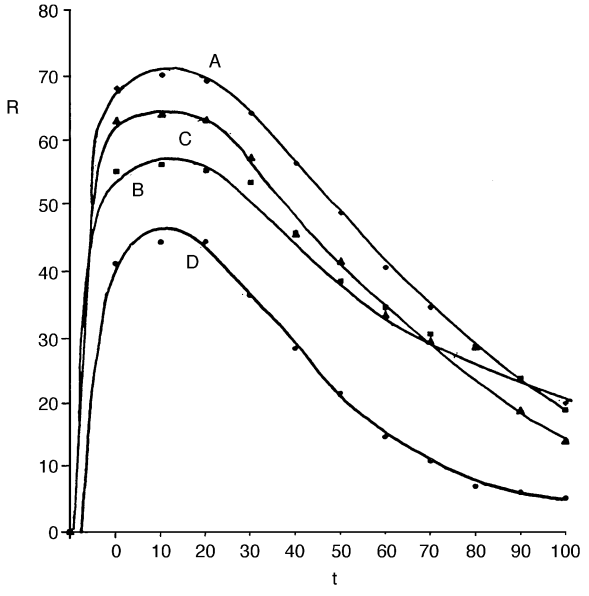

Fig. 2. Effect of taste-active ingredients on the time–astringency relationship. R = intensity of the astringent taste (% of the graphical scale); t = time after swallowing (s); 0 = time of swallowing; A = red wine without ingredients; B = wine with 6% sugar, 1 mg/kg quinine hydrochloride and 6% ethanol; C = wine with 1 mg/kg quinine hydrochloride; D = wine with 6% sucrose.

The effect of the ingredients and their combinations on the maximum astringency rating, and the time to reach the maximum are shown in Table 5. The rate of disappearance of astringency can be guessed from the difference between the maximum intensity and the intensity after 1 min. The total duration is not given in the Table 5 as it could not be determined with sufficient precision, and varied between 100 and 300 s for different samples and different assessors. The data in Table 5 show pronounced differences between two samples of red wine of related composition, when they were expressed in absolute values, but not in average differences between the duplicates.

3.5. Time–intensity course of astringent taste in an orange beverage

Orange beverages were prepared from the ingredients (Section 2.1), and the resulting solutions showed only very negligible astringency (up to 6% of the scale), therefore, they are not shown. The results, obtained after addition of astringent substances—tannic acid and (+)-catechin, showed substantially higher, well measurable astringency. They are shown in Table 6. The additions of tannic acid and of catechin were 1 and 2 g/l, respectively, i.e. the same as in model water solutions. However, the maximum astringency was much lower in orange beverages than in water, and the astringent taste disappeared at faster rate.

3.6. Time–astringency course in tea infusions

Infusions of Indian and Ceylon tea samples behaved similarly. The same set of 10 assessors rated the two

Table 5
Time–intensity characteristics of red wine modified by additions of taste-active substances

Wine sample	Additions	Time to maximum (s)	Maximum intensity (%)	After 1 min (%)
C	Original wine	12	77	40
	With 6% sucrose	15	44	13
	With 6% ethanol	10	70	42
	With 1 mg/kg quinine	10	65	33
	With sucrose and ethanol	18	64	40
	With sucrose and quinine	10	70	32
	With quinine and ethanol	10	59	45
	With sucrose, quinine and ethanol	4	57	34
B	Original wine	11	72	38
	With 6% sucrose	12	66	18
	With 6% ethanol	13	76	39
	With 1 mg/kg quinine	16	67	25
	With sucrose and ethanol	21	66	35
	With sucrose and quinine	18	61	32
	With quinine and ethanol	19	71	38
	With sucrose, ethanol and quinine	18	62	34

Table 6
Time–intensity course of astringency in an orange beverage

Time interval	Beverage containing tannic acid at 7 °C (%)	Beverage containing tannic acid at 18 °C (%)	Beverage containing catechin at 7 °C (%)	Beverage containing catechin at 18 °C (%)
In the mouth	41	42	31	38
At swallowing	51	62	49	51
After 10 s	38	56	47	46
After 20 s	24	44	38	35
After 30 s	14	33	29	25
After 40 s	8	23	21	16
After 50 s	5	16	14	12
After 60 s	3	10	9	7
After 70 s	2	7	7	5
After 80 s	1	5	4	3
After 90 s	0	4	3	3
After 100 s	0	3	2	2

samples. The astringency maximum was attained after 4 and 10 s after swallowing, respectively, and maximum intensities were 75 and 85% of the graphical scale, respectively. The astringent taste entirely disappeared after 2 min in both cases. Its disappearance could be approximated using semilogarithmic expressions, but the relation was very close to linear in case of Ceylon tea (astringency $\log R = 2{,}1 - 0.009\ t$, where t = time (s); for a linear regression: $r = -0.90$, $N = 12$, and for a semilogarithmic regression: $r = -0.97$). In case of Indian tea infusion, deviations from the linearity were statistically more important than in case of the linear regression, but the relation could be again linearized by transformation: $\log R = 2.04 - 0.009\ t$ ($r = -0.99$; $N = 12$).

4. Discussion

4.1. Validation of the method for time–intensity studies of astringency

For the time-intensity rating of astringency, we used the same procedure developed earlier for the time-dependence of bitterness (Pilková & Pokorný, 1992). The procedure is based on the bitterness rating at regular intervals up to 100 s after swallowing, using unstructured graphical scales. The same method was used for the time-intensity study of bitter extracts from plants (Príbela, Kováčová, Takácsová, Podhájeczká, & Škrovánková, 1999). Unstructured graphical scales were used with success for the sensory evaluation of wine (Castino, 1983b). The rating using unstructured graphical scales shows linear intensity vs. concentration dependence, except at both extremes of the scale (McBride, 1985) so that parametric statistical methods could be used for the statistical analysis (Castino, 1983a), but still, remarkable improvement could be achieved with the use of nonparametric tests after the author. However, we could use parametric tests as the differences were insignificant in our case.

In this study concerning time-dependence of astringency, we applied the approach reported by Dijksterhuis (1992). The intensity increased after ingestion while the sample was kept in the mouth, and still a few seconds after swallowing, and then decreased at a rate depending very much on the assessor. Dijksterhuis (1993) used the Principal Component Analysis (PCA) for studying the fading process, and similarly it was used for evaluating bitterness fading in our laboratory (Pokorný, Kalinová, & Velíšek, 1995). An analogous procedure was applied for the study of astringency (Valentová et al., 1997). The variability among the assessors was about the same as in case of bitterness, and it will be discussed later.

The repeatability of the same assessor and the reproducibility among assessors (Table 1) were very similar in case of astringency as in our previous studies on bitterness. Differences between assessors were obviously due to differences between their respective salivary flow rates (Fischer & Noble, 1994), similarly as in case of bitterness. The fading of bitterness is due to washing bitter substances out of the respective receptors with saliva. Astringent substances react with salivary proteins as observed in experiments with phenolic substances (Kallithraka, Bakker, & Clifford, 1998). Human parotid saliva showed high affinity for tannins and various other phenolic compounds forming stable non-astringent complexes (Bacon and Rhodes, 2000), which are gradually diluted and removed by saliva.

To simplify the records of wine tasting, Noble (1994) suggested to substitute the time-intensity curve by three data: the maximum intensity, the time to reach the maximum intensity, and the time of taste disappearance (bitterness in her studies). In our results on astringency evaluated in this way (Table 2), the time of disappearance showed great variation. Therefore, it was

replaced by the intensity at 60 s after the swallowing, which showed the rate of astringency disappearance with better accuracy.

In our earlier experiments on the time dependence of bitterness (Pilková & Pokorný 1992), we used preprinted forms which were completed by the assessor. We have compared the records obtained using analogous forms on astringency with those using computer screen scales (either operated with a mouse or a pen on a touch-sensitive monitor). We have obtained similar results in all cases. In the experiments on the sweetness of sugar solutions (Grison & Sauvage, 1992), similar sensitivities were also obtained using a graphical scale on a sheet, a line scale on a video screen, and a touch frequency.

The effect of duration while the draught was kept in the mouth, and the intensity ratings was investigated for several times between 0 and 20 s between ingestion and swallowing. The results (Fig. 1) showed that the time before the swallowing had an effect both on the maximum intensity of astringency and the rate of its fading. It means that about 10–15 s are necessary for the interaction of astringent substances with the respective receptors to take place. The results are in fair agreement with those obtained on the determination of saltiness of sodium chloride solutions (Matuszewska & Barylko-Pikielna, 1995).

4.2. Time–intensity studies of astringency in model aqueous solutions

In case of tannic acid the concentration of 1 g/l could be used because of good solubility of the substance, i.e. 20 times more than the perception threshold (Valentová, Škrovánková, Panovská, & Pokorný, 2001). The advantage was that the intensity rating varied in the range of the graphical scale, where the scale behaved nearly like an interval scale (McBride, 1985). Still higher concentrations could be used, but the astringency would become atypically high for food fluids, and our previous experiments (Valentová et al., 2001) showed that the intensity of astringency would become too close to the saturation sensory threshold, which would make the statistical evaluation difficult, and the measurement less accurate.

In case of (+)-catechin, the tested solution was only about seven times higher than the perception threshold (Valentová et al., 2001). The concentration could, however, not be increased because the solubility of (+)-catechin in water is rather low.

The results (Table 3) show sharp increase in astringency during residence of the sample in the mouth, followed by short further increase to the maximum after swallowing. The decrease following the swallowing showed an exponential regression, not given here, but similar to that discussed later in case of red wine. Similar courses were reported in case of tannic acid, alun, and tartaric acid solutions (Lee & Lawless, 1991). Some residual astringency was detected in our experiments even after 100 s, and in some cases even after several minutes, in agreement with the above paper (Lee & Lawless, 1991).

The time course character was very similar for tannic acid and for catechin solutions. The exponential time dependence was in agreement with the double logarithmic relationship between the concentration of the astringent substance and the intensity of astringency (Stevens, 1957).

Time–intensity studies are subject to different biases, discussed in another paper in detail (Lawless & Clark, 1992). We have paid particular attention to the variability of assessors' responses. Similarly as reported in the literature (Van Buuren, 1994), there are slow, medium and rapidly reacting subjects. We observed similar types of reactivities in studying time-dependence of bitterness (Pokorný et al., 1995) and of astringency (Valentová et al., 1997). Therefore, we tried to keep the compositions of assessor panels constant to minimize these influences. Different reactivities of assessors could affect the evaluation of their ability to distinguish small differences in astringency, similarly as was reported for sweetness of sugar solutions (Hoppe, 1994).

4.3. Time–intensity course of astringency in red wine

The effect of astringent substances in wine is much more difficult to ascertain than that of model substances in aqueous solutions. Wine, especially red wine, contains many astringent substances of different activities. Phenolic derivatives present in wine, may taste either astringent or bitter or both. Monomeric anthocyanins had rather a bitter taste while polymeric substances tasted more astringent than bitter (Noble, 1994). Both tastes are usually included in a sensory profile as separate tastes (Castino, 1983b). The astringent taste may be, moreover, a complex phenomenon (Lee & Lawless, 1991), consisting of several attributes. Certain relations exist between the astringency and the bitterness (Lea & Arnold, 1978) as most phenolic substances may taste both astringent and bitter. The close relationship between the two tastes was discussed earlier in detail (Lee & Lawless, 1991).

Better differentiation between related tastes in wine may be obtained by proper training (Lawless, 1985). Therefore, we used only those assessors in wine tasting, who had experience with tasting the aqueous solutions of astringent substances. Among untrained assessors, 31.2% named an 0.05% tannic acid solution as astringent and 25.0% as bitter (Pilková, Nováková, & Pokorný, 1991), while our group of trained assessors named the 0.05% tannic acid solution in 88.2% cases correctly as astringent, when compared with an aqueous

0.01% caffeine solution. The contribution of either tannic acid or catechin was far lower when added to red wine than when added to water at the same concentration. The difference could be most probably due to the antagonism of individual astringent substances and their competition for the same receptor (or salivary protein).

The development of astringency was approximated by analyzing the ascending and the descending parts of the curve separately as recommended in the literature (MacFie & Liu 1992). Expressions approximating the ascending and the descending courses are in agreement with the processes of adsorption and desorption, respectively.

4.4. Time course of astringency in model vermouths

Vermouths are very popular on the continental Europe. Vermouth models were prepared by adding sucrose, quinine hydrochloride (as a representative of bitter substances) and ethanol to red wine. An example of their effect on the time dependence of astringency is shown in Fig. 2. As expected, sucrose suppressed the astringency, probably by increasing the salivary flow (Lyman & Green, 1990), and thus by increased washing active substances out of the receptors. Another explanation could be the interaction of sucrose with complexes of salivary proteins with astringent substances.

In our experiments, ethanol had no significant effect on astringency, which may seem a contradiction to the bitterness increasing effect in wine (Fischer & Noble, 1994; Noble, 1994). The reason is that the above authors added ethanol to ethanol-free wine while in our experiments, ethanol was added to red wine containing the natural volume of ethanol so that its relative increase was much lower (about by 50%). In our unpublished experiments, experienced assessors were not able to distinguish between wine samples containing 10% and 15% ethanol (based on 24 results, $P = 0.05$). The effect of ethanol could be due to destruction of hydrophobic phenol–salivary protein complexes or increasing their solubility in saliva, which would affect the percept of astringency (Clifford, 1986).

The astringency was moderately suppressed by quinine hydrochloride, but the effect could be due to its competition with phenolics or binding sites of bitter substances. It is also possible that in presence of quinine hydrochloride, the astringency of the sample was partially confused with bitterness, similarly as reported by Robichaud and Noble (1990).

The effect of ingredients added to red wine, used in the preparation of vermouth, is summarized in Table 5. For the characterization of their effect, we are using data on the maximum intensity of astringency, time to reach the maximum, but instead of the total duration of astringent taste, we give the intensity measured 1 min after swallowing the draught as it was substantially better reproducible in the case of vermouths than the duration of disappearance as suggested for wines by Noble (1994). High bitterness of vermouths obviously masks low intensities of astringency. The results show that the effect of sucrose is much more important than the effect of quinine hydrochloride and ethanol.

4.5. Time-intensity course of astringent taste in an orange beverage

Citrus-fruit beverages are very popular among European population. Citrus fruits contain flavonoids and other astringent substances, however, citrus beverages are mostly produced from synthetic or nature-identical ingredients from fruits. Therefore, the model orange beverage was not prepared from oranges, but from different ingredients, not containing any astringent substances. For this reason, the astringency of the original sample was about the same as that of water. The influences of either tannic acid or of catechin (Table 6) were thus very similar to their influence in water. Contrary to model water solutions, orange beverages contained also sugar, which suppressed the astringency in an orange beverage, similarly as in red wine (Ishikawa & Noble, 1997). The antagonism could be also observed in other tastes, e.g. the antagonism between sweetness and sourness was reported in shorbets and other fruit beverages (Stampanoni, 1993). A similar antagonism could be expected in case of astringency.

In orange beverages from natural sources, D-fructose and D-glucose are more important than sucrose. This difference is not substantial in beverages because at concentrations of about 8–10%, differences in viscosities would be only moderate (Portmann, Serghat, & Mathlouthi, 1992). Therefore, the addition of sucrose instead of simple sugars in our experiments would not much influence the results.

4.6. Time course of astringency in tea infusions

Black tea is a very popular beverage in Europe and on other continents, among other attributes, also because of its fine astringent taste. Theaflavins, catechins and epicatechins belong to main astringent substances in fermented tea leaves, but their concentration is rather low in tea brew (Ding, Kuhr, & Engelhardt, 1992) to become the overwhelming taste. Nevertheless, the astringency could be detected without difficulties in presence of other tastes. The time dependence of the astringent taste in black tea brew was similar to that of (+)-catechin in aqueous solutions, and therefore, it is not given here. Regressions expressing changes of astringency during consumption of tea brew are different from those expressing the astringency in red wine, which could be expected because of different structures of astringent substances present.

5. Conclusions

A method of measurement of astringency changes depending on time after ingestion and swallowing was developed, and the reproducibility was determined. The method was applied to aqueous model solutions, wines, vermouth, orange drinks, and tea brew. The time-dependence of astringency in beverages was similar to that of bitterness. Differences among assessors were similar in the two tastes, obviously depending on the intensity of salivary flow. Both tastes can be distinguished in presence of one another by experienced assessors. The development of astringency and its fading after swallowing the draught follows exponential course, but it is different for different beverages.

References

Bacon, J. R., & Rhodes, M. J. C. (2000). Binding affinity of hydrolyzable tannins to parotid saliva and to proline rich proteins derived from it. *Journal of Agricultural and Food Chemistry*, *48*(3), 838–843.

Castino, M. (1983a). La valutazione organolettica dei vini con una scala non strutturata. *Ann. Ist. Sper. Enol. Asti*, *14*, 287–312.

Castino, M. (1983b). La valutazione organolettica dei vini con una scala non strutturata. *Vignevini*, *10*, 53–61.

Clifford, M. N. (1986). Phenol–protein interactions and their possible significance for astringency. In G. G. Birch, & M. G. Lindley (Eds.), *Interactions of Food Components* (pp. 143–163). London: Elsevier.

Dijksterhuis, G. (1992). *Matching time-intensity curves*. Montpellier: Agro-Industrie et Méthodes Statistiques.

Dijksterhuis, G. B. (1993). Principal component analysis of time-intensity bitterness curves. *Journal of Sensory Studies*, *8*(4), 317–328.

Dijksterhuis, G. B. (1997). *Multivariate data analysis in sensory and consumer science*. Trumbull, CO: Food & Nutrition Press.

Ding, Z., Kuhr, S., & Engelhardt, U. H. (1992). Influence of catechins and theaflavins on the astringent taste of black tea brews. *Z. Lebensm. Unters. Forsch.*, *195*, 108–111.

Fischer, U., & Noble, A. C. (1994). The effect of ethanol, catechin concentration, and pH on sourness and bitterness of wine. *Am. J. Enol. Vitic.*, *45*(1), 6–10.

Gini, C. (1912). *Variabilita e mutabilita contributo allo studio delle distributioni e delle relationi statistiche*. Bologna: Universita degli Studi.

Grison, L., & Sauvage, F. (1992). Comparison between a graphical scale on sheet, a line scale on video screen and a touch frequency for sweetness intensity estimation. *Sci. Alim.*, *12*, 357–369 FSTA, 92-12-A 0065.

Guinard, J.-X., Pangborn, R. M., & Lewis, M. J. (1986a). Preliminary studies on acidity-astringency interactions in model solutions and wines. *J. Sci. Food Agric.*, *37*, 811–817.

Guinard, J.-X., Pangborn, R. M., & Lewis, M. J. (1986b). The time-course of astringency in wine upon repeated ingestion. *Am. J. Enol. Vitic.*, *37*(3), 184–189.

Hoppe, K. (1994). Zur individuellen Variabilität der Geschmackssensibilität. *Nahrung*, *38*, 442–444.

Ishikawa, T., & Noble, A. C. (1995). Temporal perception of astringency and sweetness in red wine. *Food Quality and Preference*, *6*(1), 27–33.

ISO 4121. (1983). *Sensory analysis—methodology—evaluation of food products using scales*. Geneva: International Organization for Standardization.

ISO 6658. (1985). *Sensory analysis—general guidance*. Geneva: International Organization for Standardization.

ISO 8586-1. (1993). *Sensory analysis—general guidance for the selection, training and monitoring of assessors—part 1. Selected assessors*. Geneva: International Organization for Standardization.

ISO 8589. (1988). *Sensory analysis—general guidance for the design of test rooms*. Geneva: International Organization for Standardization.

Kallithraka, S., Bakker, J., & Clifford, M. N. (1998). Evidence that salivary proteins are involved in astringency. *Journal of Sensory Studies*, *13*(1), 29–43.

Lawless, H. T. (1985). Psychological perspectives on wine tasting and recognition of volatile flavours. In G. G. Birch, & M. G. Lindley (Eds.), *Alcoholic beverages* (pp. 97–113). Barking: Elsevier Applied Science.

Lawless, H. T., & Clark, C. C. (1992). Psychological biases in time-intensity scaling. *Food Technology*, *46*(11), 81, 84–86, 90.

Lea, A. G., & Arnold, G. M. (1978). The phenolics of cider. Bitterness and astringency. *J. Sci. Food Agric.*, *29*, 478–483.

Lee, C. B., & Lawless, H. T. (1991). Time-course of astringent sensations. *Chem. Senses*, *16*(3), 225–238.

Lundahl, D. S. (1992). Comparing time–intensity to category scales in sensory evaluation. *Food Technology*, *46*(11), 98–103.

Lyman, B. J., & Green, B. G. (1990). Oral astringency: effects of repeated exposure and interactions with sweeteners. *Chem. Senses*, *15*(2), 151–164.

MacFie, H. J. H., & Liu, Y.-H. (1992). Developments in the analysis of time–intensity curves. *Food Technol.*, *46*(11), 92–97.

McBride, R. L. (1985). Sensory measurements: an introductory overview. *CSIRO Food Res. Quart.*, *45*, 59–63.

Matuszewska, I., & Barylko-Pikielna, N. (1995). The effect of sample exposure time on the time of intensity response to NaCl solutions. *Food Quality and Preference*, *6*, 43–48.

Naish, M., Clifford, M. N., & Birch, C. G. (1993). Sensory astringency of 5-O-caffeoylquinic acid, tannic acid and grape-seed tannin by time–intensity procedure. *J. Sci. Food Agric.*, *61*(1), 57–64.

Noble, A. C. (1994). Bitterness in wine. *Physiology Behavior*, *56*(6), 1251–1255.

Noble, A. C. (1995). Application of time–intensity procedures for the evaluation of taste and mouthfeel. *Am. J. Enol. Vitic.*, *46*(4), 128–133.

Pilková, L., Nováková, M., & Pokorný, J. (1991). Naming and identification of tastes in aqueous solutions. *Nahrung*, *35*, 999–1002.

Pilková, L., & Pokorný, J. (1992). Time–intensity determination of bitterness. *Nahrung*, *36*, 309–310.

Pokorný, J., Kalinová, L., & Velíšek, J. (1995). Time-intensity bitterness evaluation of bitter liqueurs. *Potr. Vědy*, *13*, 257–265.

Portmann, M. O., Serghat, S., & Mathlouthi, M. (1992). Study of some factors affecting intensity/time characteristics of sweetness. *Food Chemistry*, *44*, 83–92.

Príbela, A., Kováčová, M., Takácsová, M., Podhájeczká, D., & Škrovánková, S. (1999). Doznievanie horkej chuti extraktov z rastlín. *Bull. Potrav. Výsk*, *38*, 9–15.

Robichaud, J. L., & Noble, A. C. (1990). Astringency and bitterness of selected phenolics in wine. *J. Sci. Food Agric.*, *53*(3), 343–353.

Stampanoni, C. R. (1993). Influence of acid and sugar contents on sweetness, sourness and the flavour profile of beverages and shorbets. *Food Quality and Preference*, *4*, 169–174.

Stevens, S. S. (1957). On the psychophysical law. *Psych. Rev.*, *64*, 153–181.

Valentová, H., Škrovánková, S., Panovská, Z., & Pokorný, J. (2001). Determination of astringent taste in model solutions and beverages. *Czech J. Food Sci.*, *19*, 6–12.

Valentová, H., Škrovánková, S., Pokorný, J., & Velíšek, J. (1997). Time–intensity studies of the astringent flavour. In H. P. Kruse, & M. Rothe (Eds.), *Flavour Perception, Aroma Evaluation* (pp. 61–68). Potsdam: Universität Potsdam.

Van Buuren, S. (1994). Analyzing time–intensity responses in sensory evaluation. *Food Technol.*, *48*(2), 101–104.

Weber, E. (1957). *Grundriss der biologischen Statistik für naturwissenschaftler, landwirte und mediziner. 3. Aufl.* Jena: G. Fischer.