Effect of Viscosity on the Perceived Intensity of Acid Taste

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Abstract

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The effect of methyl cellulose as a thickening agent for beverages on the rating of sensory viscosity was pronounced. Acidity ratings depended on the assessors as their sensitivities were different. Therefore, a larger number of assessors was necessary. The effect of the thickening agent on the sensory rating of acidity was only moderate, but still statistically significant. The correlation between sensory ratings of viscosity and acidity was not significant. In the significance of differences between individual samples, differences were observed depending on the concentrations of methyl cellulose and the acid used.

Keywords: acid taste; beverages; methyl cellulose; sensory analysis; sour taste; viscosity

The consumption of the packed non-alcoholic beverages is rising every year in all countries. The flavour belongs to the most important characteristics of these products. The perceived flavour intensity of beverages is influenced by the presence of all flavour substances and other factors affecting the mouthfeel as they interact and influence one another. Even flavour-neutral substances can affect the flavour.

Physical properties of beverages also exert great influence, such as temperature, consumed sample volume, the content of dissolved carbon dioxide, or viscosity. The viscosity of a beverage rises by increasing the sugar concentration, therefore, most consumers prefer beverages moderately more viscous than water, the viscosity corresponding to that of the optimum 10% aqueous sugar solution. Interactions between sweet and bitter tastes and viscosity were studied in vermouth (Burns & Noble 1985). Different sensory characteristics of sparkling wines were compared, and the effect of parameters, which could affect the viscosity, was discussed (Gerbi *et al.* 1990). High viscosity suppresses the intensity of the sweet and salty tastes perceived (Christensen 1980a, b). Viscosity is encoded in the DNA of primates as an important positive factor (Pfaffmann 1974; Glaser 1986). Higher viscosity may also be due to a higher fat content which was desirable in prehistory because of its high energy content. Therefore, higher viscosity was found connected not only with a higher texture acceptance, but also with a higher flavour acceptance in margarine (Štern *et al.* 2000), mayonnaise (Štern *et al.* 2001) and other oil-in-water emulsions (Štern *et al.* 2002). Relations between the sensory properties of tastes and the texture were studied in various solid food products (Urbányi 1983).

Light beverages, in which sugar is replaced by low concentrations of intensively sweet sugar substitutes, have lower viscosity, close to that of water. The difference would be considered as a negative factor by the consumers. Therefore, light beverages contain various thickening agents increasing their viscosity to a level close to that of a 10% sugar solution.

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Soft beverages have not only the sweet taste due to sugar, but also other tastes, especially the acid taste. It is due partially to phosphoric acid, but mainly to carboxylic acids, such as citric, malic, tartaric, acetic or lactic acids, which are present in fruit or are produced by fermentation. The sensory acidity is not affected by the pH value but by titratable acidity (Noble *et al*. 1986). The acid taste contributes to the fresh taste, expected in fruit beverages. Increased viscosity of a sample resulted in an increased stimulus and recognition thresholds of the basic taste substances including citric acid (Paulus & Haas 1980). On the contrary, a higher concentration of citric acid suppressed the perceived viscosity (Christensen 1980a). It is probable that viscous beverages inhibit the access of acids to the flavour receptors and thus decrease the percept of the acid taste. Therefore, we have studied the effect of viscosity on the intensity of the acid taste as the acidity has a pronounced effect on the acceptability of a beverage.

MATERIAL AND METHODS

Material. Citric acid monohydrate, p. a., was produced by Penta (Prague, Czech Republic), malic acid, p. a., was purchased from Sigma-Aldrich Chemie (Steinheim, Germany) and methyl cellulose (Benecel 943-HR) was a product of Herkules CZ spol. s r. o. (Prague, Czech Republic). Distilled water was used as a solvent. Samples were prepared immediately before the analysis, and left at the ambient temperature of 23–25°C.

Sensory analysis. The testing took place in a sensory test room, equipped as specified in the respective ISO (International Standardisation Organisation) standard (ISO 8589, 1988: Sensory analysis – General guidance for the design of test rooms), provided with 6 assessor booths. Sensory assessors were selected, trained and monitored according to the respective ISO standard (ISO 8586-1, 1993: Sensory analysis – General guidance for the selection, training and monitoring of assessors – Part 1. Selected assessors). The assessors had experience of at least six months in the sensory analysis, particularly in the sensory profiling.

The procedure and sample serving were in agreement with the respective ISO standard (ISO 6658, 1985: Sensory analysis – Methodology – General guidance). Two coded samples (about 100 ml) in a translucent glass beaker were served at a session in random order at 25°C. Constant temperature is important as the temperature affects the receptor activity and the viscosity of the test solutions (Sato 1962). Tap water was used as a neutralising agent for the washing of the mouth before the first sample and between the samples. The assessors were instructed to ingest about 20 ml of the sample, move it in the mouth by movements of the tongue for 3–5 s, and swallow it. It was reported that the sourness is best evaluated after 13–18 s in gels (Muñoz *et al.* 1986), but in our experiments the sample would become diluted with saliva in the meantime, and the viscosity would substantially change. The assessors first determined the viscosity sensorically, then took another draught and determined the intensity of the acid taste. Unstructured graphical scales 100 mm long were used for the intensity ratings (ISO 4121, 1987: Sensory analysis – Methodology – Evaluation of food products by methods using scales). The scales were oriented by descriptions at both ends of the line (thin to thick for the viscosity rating; absence of acidity to strongly acid for the acidity rating).

Measurement of viscosity. The viscometer UBBELOHDE TS 1823 produced by Technosklo s. r. o. (Držkov, Czech Republic), was used; diameter of the capillary 0.64 mm, temperature 24°C.

Statistical analysis. The software MS Statistica 3 was used; the probability level was $P = 0.05$, unless otherwise stated. The methods are given in the text at the respective place.

RESULTS AND DISCUSSION

Solutions of either 0.5% malic acid or 0.5% citric acid were used. Four levels of methyl cellulose were tested, i.e. 0 g, 1 g, 2 g, and 5 g per litre. The kinematic viscosity of the methyl cellulose solutions was 1.00, 1.81, 2.20, and 5.55 mm^2/s, respectively. The samples were tested by 10 assessors four times on different days, and by an assessor twice on different days, the total of 42 analyses of each sample. Sufficient numbers of assessors are important for the evaluation of small flavour differences, especially in the case of nonparametric tests (Basker 1980).

The performances of 10 assessors, where four sets of results were available, are shown in Table 1. Linear regressions were tested and the respective correlation coefficients were calculated. Differences from the linearity were not statistically significant ($N = 16$; $P = 0.05$). The determination of viscosity as a function of the concentration of methyl cellulose

Table 1. Performances of individual assessors (N = 16; P = 0.05; statistically significant values are printed bold)

Acid present in the solution	Assessor number	*R* values between		
		C and V	C and A	V and A
Citric acid	1	**0.91**	–0.03	–0.10
	2	**0.91**	**–0.84**	**–0.63**
	3	**0.91**	**–0.53**	–0.44
	4	**0.95**	**–0.60**	**–0.55**
	5	**0.90**	–0.17	**–0.77**
	6	**0.91**	0.14	0.37
	7	**0.84**	0.06	0.25
	8	**0.71**	**–0.72**	**–0.54**
	9	**0.88**	–0.36	–0.34
	10	**0.86**	–0.16	–0.19
Malic acid	1	**0.68**	0.17	–0.33
	2	**0.53**	–0.05	0.07
	3	**0.73**	**–0.77**	–0.27
	4	**0.87**	**–0.67**	**–0.67**
	5	**0.80**	**–0.69**	**–0.78**
	6	**0.86**	0.43	**–0.55**
	7	**0.86**	**–0.72**	**–0.60**
	8	**0.94**	0.16	0.16
	9	**0.77**	–0.11	–0.05
	10	**0.89**	–0.13	–0.17

R = correlation coefficient; C = concentration of methyl cellulose (g/l); V = sensory viscosity (% of the scale); A = sensory acidity (% of the scale)

was statistically significant for both malice acid and citric acid solutions in the case of all 10 assessors. The dependence of the acid taste intensity on the concentration of methyl cellulose was statistically significant with citric acid solutions in the case of 4 assessors, and with malic acid solutions in the case of 4 assessors. The dependence between the sensorial perceived viscosity and the sensorial perceived acidity was found statistically significant only in four cases with solutions of both citric acid and malic acid, but only two assessors were successful with the solutions of the two acids tested. Average differences between two determinations of viscosity of the same sample varied between 7–14% in citric acid solutions and between 9–21% in malic acid solutions. The respective values in the determination of acidity were 12–20% in citric acid solutions and between 7–26% in malic acid solutions. There was no correlation between the reproducibility of the assessors' ratings and the corresponding correlation coefficient. The average difference between two determinations of the same samples was 11% in the case of the viscosity of citric acid solutions, and 14.4% in the case of that of malic acid solutions, the average of 13% for all solutions, irrespective of the acid used. Analogous values for the acidity ratings were 16% in the case of citric acid solutions and 14% in the case of malic acid solutions, and 15% for the whole set. The acidity was rated with a slightly lower reproducibility than the viscosity, but the differences were not pronounced. Differences among the performances of assessors should not be too pronounced (Lundahl & McDaniel 1988), otherwise the panel

Table 2. Correlation between the concentration of methyl cellulose and a) the viscosity and b) the acidity as determined by sensory analysis in malic and citric acid solutions (N = 168)

Dependent variable	Organic acid added	Spearman coefficient R	Value of T (n – 2)	Probability level P
Viscosity	Malic acid	0.675	11.79	0.000000
	Citric acid	0.767	15.42	0.000000
Acidity	Malic acid	–0.297	–4.01	0.00009
	Citric acid	–0.186	–2.44	0.0157

performance would not correspond to the random distribution. In our case, the differences did not deviate from the random distribution. The performances of different assessors were sometimes very different, therefore, the evaluation by 11 assessors, used in our experiments, was reasonable and in agreement with Basker's experience.

Correlations between the sets of the sensory samples of all the four concentrations of methyl cellulose (N = 168) were studied using the Spearman nonparametric test. Correlations between the concentration of methyl cellulose in the solution and both the sensory viscosity and acidity were statistically significant (Table 2). The correlation coefficients of relations between the concentration and the acidity were lower than those of sensory property, but still highly significant. Correlation coefficients between the sensory characteristic of viscosity and the instrumentally measured viscosity or its logarithms were nearly the same as correlation coefficients between the sensory characteristics and the concentration of methyl cellulose. The effect of gelation on the perception of sweet and acid tastes was reported (Baryłko-Pikielna *et al.* 1999); the acidity was suppressed more in gelatin than in agar gels. The relation between the viscosities of solutions of malic and citric acids were significantly different (T = 9.995; P = 0.000000), but the differences between the viscosity and acidity ratings of the same samples were not statistically significant at the P = 0.05 level.

If the concentration of methyl cellulose and the sensory viscosity ratings were used for the prediction of the acidity ratings, the application of multiple regression was useful. The regression was statistically highly significant in the case of malic acid solutions (P < 0.00001) but it was not significant at the P = 0.05 level in the case of citric acid solutions (P < 0.054), even if the value was very close to the limit of significance.

Samples with different concentrations of methyl cellulose, in the presence of either malic acid or citric acid (N = 16, each sample tested 42 times), were evaluated by statistical methods. Means and standard deviations of the total of 42 cases (including all assessors' ratings) of the same samples are shown in Table 3. Standard deviations of the mean values of 42 cases, obtained by the whole panel of

Table 3. Mean sensory ratings and standard deviations

Acid	Methyl cellulose (g/l)	Viscosity (% of the scale)	Standard deviation (% of the scale)	Acidity (% of the scale)	Standard deviation (% of the scale)
Citric	0	18	2	49	3
	1	25	2	41	2
	2	38	2	40	3
	5	73	2	38	3
Malic	0	25	3	58	2
	1	38	4	57	3
	2	41	2	48	4
	5	74	2	41	3

Table 4. Significance of differences between samples as determined using the sign test (N = 42)

Acid	Descriptor	Concentrations C	Number of non-ties	Percentage of $v < V$	Z value	Probability level P
Malic	Viscosity	0 & 1	41	75.6	3.12	0.0018
		0 & 2	40	72.5	2.59	0.0072
		0 & 5	42	100.0	2.59	0.000000
	Acidity	0 & 1	42	50.0	0.15	0.877
		0 & 2	40	35.0	1.74	0.082
		0 & 5	42	33.3	2.06	0.045
Citric	Viscosity	0 & 1	41	82.9	4.06	0.00005
		0 & 2	40	90.0	4.90	0.000001
		0 & 5	42	100.0	6.33	0.000000
	Acidity	0 & 1	41	34.1	1.67	0.061
		0 & 2	41	36.6	1.56	0.118
		0 & 5	40	22.5	3.32	0.009

C = concentration of methyl cellulose (g/l); for the statistical parameters see the Microsoft Statistica 3.0 Manual

assessors, varied between 2–4%, and were slightly higher in the acidity ratings than in the viscosity ratings. The viscosity rating increased with increasing concentration of methyl cellulose in the samples tested. The sensory characteristics were statistically significantly different in solutions of both citric acid and malic acid. Linear regressions were observed between the concentration of methyl cellulose and both the sensory viscosity and the sensorically perceived acidity, and also between the viscosity and the acidity ratings. If all combinations of the samples were correlated with one another using the sign test, the acidities of some samples were significantly different (N = 42; P = 0.05) in the case of malic acid solutions, but only in a single case of citric acid solutions (Table 4).

Differences between the samples containing different concentrations of methyl cellulose were tested by pair comparison between two samples (42 pairs; the significant difference at the P = 0.05 level was at 28 responses or higher). All differences between the viscosity ratings of the analysed samples were statistically significant (P = 0.05). On the contrary, the differences between the ratings of acidity were significant only in a few cases (Table 5). The samples underlined with an uninterrupted line were not significantly different at the above probability level. In case of the pair test, only the positive responses are counted. Therefore the difference may be statistically significant between a selected sample or a subset of selected samples, but may not be significant between another sample and a subset of other samples. The differences in the acidity of samples in these experiments are a typical example. The samples containing 0 g, 1 g, and 2 g of methyl cellulose per litre were not significantly different from one another, but they

Table 5. Significance of differences in the acidity between the analysed samples as compared using the pair test (N = 42; P = 0.05; samples between whose ratings a difference was not observed are underlined, while the samples outside the underline were statistically different)

Concentration of methyl cellulose							
Malic acid solutions				Citric acid solutions			
0 g/l	1 g/l	2 g/l	5 g/l	0 g/l	1 g/l	2 g/l	5 g/l
____	____	____		____	____	____	
	____	____	____		____	____	____

were significantly different from the sample containing 5 g of methyl cellulose per litre. The most concentrated solution of methyl cellulose could not be distinguished from the samples containing 1 g or 2 g of methyl cellulose per litre. The same significance of differences was observed in solutions of malic acid and of citric acid.

The cluster analysis showed that the concentration of methyl cellulose had a greater effect on the viscosity than had the difference between malic and citric acids. In the case of the acidity rating, the result was different as the samples containing citric acid formed a single cluster, separating the cluster of samples containing malic acid in two groups.

Conclusions

The concentration of methyl cellulose as an example of thickening agents had not a very pronounced, but still statistically significant effect on the sensory ratings of acidity, and even greater on the sensory ratings of viscosity in model solutions. The viscosity of a beverage should thus be taken into account when determining the flavour, even though the correlations between the ratings of viscosity and the ratings of acidity were not statistically significant because of a high scatter of the results.

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Souhrn

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Vliv methylcelulosy jako zahušťovadla nápojů na vjem senzorické viskozity byl výrazný. Hodnocení kyselosti na rozdíl od hodnocení viskozity však značně záviselo na osobnosti hodnotitele, proto byl nutný větší soubor hodnotitelů (v našich experimentech 11). Vliv zahušťovadla na hodnocení acidity byl malý, ale přesto statisticky průkazný. Naproti tomu souvislost mezi senzorickým hodnocením viskozity a kyselosti téhož vzorku nebyla průkazná, i když někteří hodnotitelé uspěli při hodnocení. Byly pozorovány významné rozdíly také mezi jednotlivými vzorky s různou koncentrací methylcelulosy nebo instrumentálně stanovenou viskozitou.

Klíčová slova: kyselá chuť; nápoje; senzorická analýza; viskozita; zahušťovadla

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