

Research Article

Association of Sweet Taste Sensitivity and Caries Experience with BMI and Hedonic Responses

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Abstract

The aim of the study was to determine the correlation between sweet taste sensitivity, dental caries experience and the Body Mass Index (BMI) and to evaluate whether the caries experience, sweet taste sensitivity or BMI play an important role in hedonic perception of the taste, and/or differentiation of several sucrose concentration. A total number of 98 adults (83 females, 15 males) aged 18 to 35 were examined and both the clinical findings and the physicophysical measurements were collected using DMFT and BMI. Sweet taste sensitivities for sucrose were estimated by using the cumulative R-index (Area Under the Curve (AUC)) scores. Seven-point scale was used to define hedonic responses. No significant correlation was found between AUC, dental caries experience and glycaemic load. Individuals with BMI value over 20 had higher perceptions for sweet taste to that of BMI lower than 20. Individuals describing low (0.5 mg/dl) sucrose concentration as “good” had significantly low dental caries experience. Participants sensing sucrose concentrations over 2.8 mg/dl as “good” had the highest BMI levels. In conclusion, BMI greater than 20 seems to have an elevating effect for taste perception at high sucrose levels. Individuals sensing low-level sucrose (0.5 mg/dl) as “good” taste have decreased overall sensitivity to sweet and express low dental caries risk.

Keywords

Body mass index; Dental caries; Hedonic response; Sweet taste sensitivity

Introduction

Obesity and overweight are expanding public health problems wide-reaching [1]. Overweight and obese populations are at increased risk for developing both of psychosocial and medical problems compared with individuals

with normal weight [2]. High sugar intake is reported to be more common among overweight and obese than those with normal weight [3]. In order to establish the risk of obesity Glycaemic Index (GI) is used [4]. Moreover the Glycaemic Load (GL) is considered to be an alternative for providing the relationship between foods and chronic diseases. Risk of type II diabetes, obesity, metabolic syndrome, cardiovascular disease and dental caries were significantly associated with dietary GI and GL in some [5,6] but not all epidemiologic studies [7-9]. Body Mass Index (BMI) has been shown to be correlated to

low GL diet via weight loss [10]. The evidence shows that sugar intake is certainly the most important dietary factor highlighted in many studies as a reason of development of dental caries [11]. It is well established that the frequency of sucrose intake, particularly between meals, is associated with increased levels of caries occurrence [12]. Therefore, the claimed eating pattern among overweight or obese persons might be a risk factor in common for overweight and caries. Studies from different countries have been shown the relationship between obesity and dental caries, but no conclusion has been extrapolated on the connections between obesity and dental caries [13].

Another research from Sweden, by Alm and colleagues (2008), also reports that obese compared with normal weight teenagers, were twice as likely to have dental caries. Several factors may influence sucrose intake, including taste preference [14]. A liking for sweetness is a universal human attribute and may be related to the fact that no foods in nature are sweet and poisonous [15]. The more exposure there is to sweet products, the greater the preference for sweetness and consequently, the greater the sugar consumption. A positive significant correlation between sweetness preference and dental caries has been demonstrated [16]. Responses to sweet tastes in adults show wide personal differences. Such differences follow in terms of perception, liking, wanting, and intake [17]. Sensitivity to sweet taste may be related to eating behaviour for sweetness. Measuring personal preferences for a sweet taste, as sweet identification and/or discrimination are not easy, and techniques are less well developed [18]. Several methods like chemosensory tests, electrogustometry, visual assessment presentations and other psychophysical measures have been suggested and investigated in the literature. In chemosensory tests, aqueous solutions of sucrose have often been used as the taste stimulus [19,20]. In a number of studies, sucrose solutions with succeeding concentrations were practiced plain or with some flavours for determining sweet taste intensity, taste quality and thresholds. An easier and less expensive way to collect data on sweetness preferences is to use postal or electronic questionnaires. Other common methods of measuring sweet pleasantness include tests with several point hedonic scales where measurements can be either labelled hedonic or labelled affective magnitude scales [21,22]. The aim of the study was to determine the relationship between sweet taste sensitivity, dental caries experience and BMI. Furthermore we aimed to evaluate whether caries experience, sweet taste sensitivity and BMI makes a difference in hedonic preferences of individuals according to various sucrose concentrations.

Materials and Methods

Study subjects

The study group composed of 98 staff members (83 females, 15 males) from Marmara University Istanbul, Turkey. Prior to study, ethical approval was received from Medical Ethical

Committee of Marmara University (protocol 09.2012.0063-4). Participants were assigned with a written informed consent form. The study was performed on varying degrees of body weight ($15 < \text{BMI} < 35 \text{ kg/m}^2$). Exclusion criteria included: age over 35 years, pregnancy, using tobacco products, assumption of drugs known to change or alter taste (such as dorzolamide, amprenavir etc.), any systemic diseases [23].

Glycaemic load quantification

The glycaemic load for each individual participating to the study was calculated per month according to International glycaemic load chart [24].

Intraoral examination

Intra-oral examination was performed visually in a dental setting with proper illumination, air-drying and a blind explorer by two experienced dentists (EH and FEG). DMFT (total of Decayed, Missed and Filled Teeth) scores were recorded according to WHO criteria [25].

Psychophysical measurements

The purpose was to determine subject's discrimination abilities at peri and suprathreshold concentrations in an effort to quantify sensitivity over a meaningful sucrose range. Measurements of sensitivity to sucrose were performed as described by Fushan et al., [26]. A series of sucrose solutions of 0%, 0.5%, 1%, 2%, 2.4%, 2.8%, 3.2%, 3.6% and 4% sucrose was produced based on the cited study. Each sucrose concentration was used to calculate a detection threshold for a given pairwise sucrose interval (i.e., 0-0.5%, 0.5-1% etc.). The testing, which consisted of 6 replications, has been performed over 3 sessions. Subjects were asked to complete 2 replications of the ranking test per session with a 5-min break between replications at the same day. 20 ml of each of the solution was given to participants in a randomized order and allowed to try again if requested during the experiment. Study participants were asked to rank each of the solution in order from the least to the most sweet. A min. of 24 hr time was given between individual sessions. To minimize adaptation effects, subjects rinsed mouth with water between each sample [27].

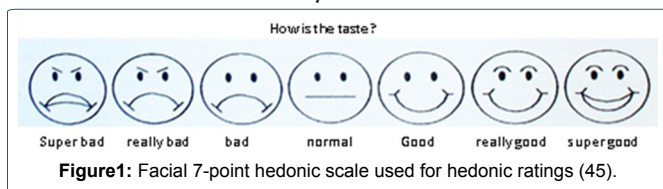
Calculation of pairwise perception differences (R_p) and Area Under the Rc Curve (AUC)

Sucrose perception score of each individual was achieved from 6 replications. The R-index was calculated for each pairwise glucose concentration (0-0.5%, 0.5-1%, etc.) as described by O'Mahony et al., [28]. The R_p -index is the R-index calculated between solutions p and p+1; which ranges from 0.5 to 1 and reflects the discrimination performance of the individual by accounting for differences in decision making criteria. So, the R_p is the estimation of the magnitude of difference between two difficult to discriminate stimuli. Thus, as the R_p -index is high, the sweetness discrimination task

performance (taste sensitivity) is increased. The Rc-index was plotted according to correlation between Rp_s for each subject. Thus, AUC determined for each individual. Rc corresponds to the cumulative sensitivity of a subject within a sucrose concentration range. Rc can be used to estimate the theoretical suprathreshold sensitivity at each concentration across the range since it is derived from the sum of Rp calculated at each concentration interval. Because Rc is obtained by the sum of Rp₁ and Rp₂, it also reflects a subject's ability to discriminate the 1% stimulus from 0%. For each subject, all Rc-indices across the range were plotted. The format of the resulting graph is equivalent to a concentration response curve with increasing sucrose concentrations receiving larger Rc scores. The AUC is the unitary measure of overall discriminability across the concentration range tested. Measuring the sucrose sensitivity as according to Fushan et al., [26], by briefly pairwising the sucrose intervals and were summed all to create a concentration-response function for each subject to determine the AUC. The AUC, which can range from 0 (complete nondiscrimination) to 9.25 (perfect discrimination) in this testing paradigm, was used as the dependent variable to assess the association of BMI with DMFT and GL on sucrose sensitivity.

Hedonic ratings

To measure hedonic ratings of the individuals, a 7-point scale questionnaire for the sweetness perception of each solution was rated as bad, normal, good for each sucrose concentration in the same session (Figure 1). When all results were gathered and extreme ratings were noticed to be in small numbers, we reduced the testing to 3-point hedonic scale for more accurate statistical analysis.



Statistical analysis

Participants BMI and DMFT data are expressed as mean ± SE. The correlation between the intensity and liking degree of sweet perception was evaluated. Baseline differences between BMI groups were examined by student-t test. Hedonic ratings were compared with Kruskal-Wallis one-way analysis of variance if the distributions were independent. When the Kruskal-Wallis test results were significant, Bonferonni corrected Mann-Whitney U test was used for comparison of two groups. If the hedonic ratings were normally distributed, a one-way ANOVA test was used to compare the groups. Variables were analyzed by Spearman's correlation test using SPSS 17.0 software. Statistical significance was taken as p<0.05.

Results

Correlation matrix between DMFT, AUC and GL in the whole study group is presented in table 1. No significant

correlation was observed between DMFT, glycemic load and AUC scores for sucrose. The comparison of study groups composed according to BMI for antropometric and clinical data is presented in table 2.

	DMFT		AUC		GL	
	r _s	p	r _s	p	r _s	p
DMFT	-	-	0.067	0.563	-0.115	0.336
AUC	0.067	0.563	-	-	-0.060	0.613
GL	-0.115	0.336	-0.060	0.613	-	-

Table 1: Correlation matrix between DMFT, AUC and GL in the whole study group.

AUC: Cumulative R-index Area Under the Curve; r_s: correlation matrix; DMFT: Decayed (D), Missing (M), Filled (F), Total (T); GL: Glycemic Load

	BMI < 20 (n=24) Mean ± SE	BMI >20 (n=53) Mean ± SE	p
Age (year)	23.13 ± 0.92	24.17 ± 0.70	>0.05
Weight (kg)	51.45 ± 0.96	62.73 ± 1.45	>0.05
Height (m)	1.65 ± 0.01	1.65 ± 0.01	>0.05
Waist (cm)	65.83 ± 0.83	75.37 ± 1.24	>0.05
Hip (cm)	91.04 ± 0.74	100.07 ± 1.00	>0.05
GL	1830 ± 218.52	2106.63 ± 161.70	>0.05
DMFT	5.12 ± 0.75	6.59 ± 0.55	>0.05
AUC	(-7.16) ± 0.06	(-6.80) ± 0.06**	P<0.001
Rp 1	(-4.30) ± 15.26	21.63 ± 9.91	>0.05
Rp 2	14.02 ± 5.89	22.22 ± 4.95	>0.05
Rp 3	5.23 ± 3.70	10.85 ± 2.29	>0.05
Rp 4	4.29 ± 1.98	6.04 ± 1.87	>0.05
Rp 5	2.90 ± 1.48	6.83 ± 1.65	>0.05
Rp 6	4.84 ± 0.97	9.31 ± 1.09*	<0.05
Rp 7	6.98 ± 1.04	9.47 ± 0.90	>0.05
Rp 8	4.53 ± 0.79	9.23 ± 0.86**	P<0.001

Table 2: The comparison of antropometric and clinical parameters in body mass index groups.

Results are expressed as mean ± SE; n: Sample size, *p<0.05; **p<0.001; DMFT: Decayed, Missing and Filled Teeth; GL: Glycemic Load; Rp- The sweet taste sensitivity as reflected by pairwise sucrose concentrations (0-0.5% (Rp1), 0.5-1% (Rp 2), 1-2% (Rp 3), 2-2.4% (Rp 4), 2.4-2.8% (Rp 5), 2.8-3.2% (Rp 6), 3.2-3.6% (Rp 7), 3.6-4 (Rp 8); AUC: cumulative R-index Area Under the Curve. The unitary measure of overall discriminability across the full concentration range (0-4% sucrose) tested.

In overweight (BMI>20) individuals, the discrimination data for sugar perception was higher compared to individuals with BMI less than 20 kg/m² for Rp 6 (p<0.05) and Rp 8 (p<0.001); which represent high sucrose concentrations. The Area Under the Rc Curve (AUC) which represents the overall discriminability across the 0-4 % sucrose range has been found to be higher in individuals with BMI>20 compared to individuals with BMI<20 (p<0.001) (Table 2). As reflected by pairwise sucrose concentrations lower than 2.8% (Rp 1-5) the sweet taste sensitivity levels did not reach significance values when study groups were compared according to BMI, although the individuals with BMI>20, had always higher sensitivity to that of BMI<20 (Table 2). The DMFT index reflecting caries experience has been detected to

	Rp 1		Rp 2		Rp 3		Rp 4	
	r _s	p	r _s	p	r _s	p	r _s	P
GL	0.015	0.896	-0.084	0.478	0.168	0.156	-0.032	0.786
DMFT	-0.056	0.631	-0.017	0.882	-0.051	0.659	0.087	0.454
Rp 1	-	-	0.402	0.0001***	0.344	0.002*	0.464	0.0001***
Rp 2	0.402	0.0001***	-	-	0.126	0.273	0.130	0.261
Rp 3	0.344	0.002**	0.126	0.273	-	-	0.414	0.0001***
Rp 4	0.464	0.0001***	0.130	0.261	0.414	0.0001***	-	-

Table 3a: Correlation matrix between pairwise percentage difference, DMFT and GL.

*p<0.05; **p<0.01; ***p<0.001; r_s: correlation matrix; Rp: Pairwise percentage difference for different sucrose concentration; DMFT: Decayed, Missing and Filled Teeth; GL: Glycemic load

	Rp 5		Rp 6		Rp 7		Rp 8	
	r _s	p	r _s	p	r _s	p	r _s	P
GL	0.091	0.446	0.091	0.446	0.014	0.909	-0.063	0.598
DMFT	0.051	0.664	0.004	0.962	0.037	0.752	0.066	0.573
Rp 5	-	-	0.280	0.014*	0.365	0.001**	0.501	0.0001***
Rp 6	0.280	0.014	-	-	0.503	0.0001***	0.618	0.0001***
Rp 7	0.365	0.001**	0.503	0.0001***	-	-	0.454	0.0001***
Rp 8	0.501	0.0001***	0.618	0.0001***	0.454	0.0001***	-	-

Table 3b: Correlation matrix between pairwise percentage differences, DMFT and GL.

*p<0.05; **p<0.01; ***p<0.001; r_s: correlation matrix; Rp: Pairwise percentage difference for different sucrose concentration; DMFT: Decayed, Missing and Filled Teeth; GL: Glycemic Load

be higher in BMI>20 groups compared to BMI<20 (p<0.05) (Table 2).

The correlation between pairwise percentage differences Rp 1-4, DMFT and GL is presented in table 3a, and Rp 5 - 8, DMFT and GL in table 3b. Significant positive correlation exists between Rp 1-Rp 2 (p=0.0001), Rp 1-Rp 3 (p=0.002), Rp 1-Rp 4 (p=0.0001), Rp 3-Rp 4 (p=0.0001); whereas no significant correlation exists between Rp 2-Rp 3 and Rp 2-Rp 4 (p>0.05) (Table 3a).

These findings demonstrate that an individual with high discriminability at low sucrose levels (0-0.05%, Rp 1) shows high correlation with discrimination for higher sucrose levels (Rp 2, Rp 3, Rp 4).

None of the pairwise percentage differences (Rps) showed correlation with neither GL nor DMFT (p>0.05) (Table 3a and 3b). Positive correlation has been found between Rp 5-Rp 7 (p=0.001), Rp 5-Rp 8 (p=0.0001), Rp 6-Rp 7 (p=0.0001), Rp 6-Rp 8 (p=0.0001) and Rp 7-Rp 8 (p=0.0001) (Table 3b). Beginning from 2.8% sucrose level up to 4%, all the pairwise percentage differences show highly significant correlation, which demonstrates that sucrose discrimination sensitivity exist at high-level sucrose concentrations (Table 3b).

The effects of hedonic scales over BMI, DMFT and AUC scores were analyzed in a 7-point scale reduced to 3-point scale. The comparison of hedonic scale for the analyzed parameters as a response to sucrose concentrations varying between 0-4% were given in table 4a-c. Individuals who have

tasted 0.5 mg/dl sucrose, the DMFT index was found to be different among hedonic scale ratings (p<0.05) (Table 4a). The DMFT index was found to be significantly (p=0.034) high in individuals with “normal” rating in comparison to “good” and “bad” ratings within hedonic scale test (Table 4a). Individuals with “good” rating who have received 0.5 mg/dl sucrose were found to have the lowest AUC, thus the lowest sucrose sensitivity among other hedonic scale ratings (p=0.017) (Table 4b). High sucrose concentrations (3.2, 3.6 and 4.0 mg/dl) tasting individuals among BMI levels differed among hedonic scale ratings with the “good” ratings having high BMI levels (p<0.05) (Table 4c).

Discussion

Dental caries and obesity share common characteristics in being complex conditions with multiple risk factors and prevalent among low socio-economic status. Both conditions risk factors such as diet and nutrition are important in the development and progression of the disease [29]. In the literature, no clear answer exists to the question of whether there is an association between BMI and sweet taste sensitivity or DMFT. Question of whether obesity leads to increase dental caries risk [29]. Hong et al., [30] evaluated the relationship between BMI and dental caries experience and recommended differential association between caries and obesity among Black and Hispanic children. Marshall et al., [31] analyzed data of young children and suggested that children at risk for obesity may have higher caries risk compared with children with normal or overweight. In

mg/dl sucrose	DMFT Bad Mean ± SE	DMFT Normal Mean ± SE	DMFT Good Mean ± SE	p
0	6.54 ± 0.75	6.49 ± 0.61	4.85 ± 0.92	0.402
0.5	5.67 ± 0.74	7.30 ± 0.61	4.67 ± 0.90	0.034*
1	6.73 ± 0.79	5.85 ± 0.59	6.77 ± 1.05	0.508
2	5.22 ± 0.83	6.05 ± 0.58	7.83 ± 0.86	0.074
2.4	6.55 ± 0.85	5.46 ± 0.71	6.65 ± 0.67	0.492
2.8	5.76 ± 0.87	5.89 ± 0.55	7.46 ± 0.96	0.335
3.2	5.27 ± 0.77	6.26 ± 0.69	7.41 ± 0.76	0.139
3.6	6 ± 0.68	6.94 ± 0.79	5.83 ± 0.75	0.488
4	5.31 ± 0.68	7.86 ± 1.19	6.6 ± 0.61	0.134

Table 4a: Comparison of reduced 7-point hedonic scale for DMFT as a response to different sucrose concentrations.

Results are represented as mean ± SE; DMFT: Decayed, Missing and Filled Teeth

mg/dl sucrose	AUC Bad Mean ± SE	AUC Normal Mean ± SE	AUC Good Mean ± SE	p
0	-6.79 ± 0.08	-6.97 ± 0.07	-7.09 ± 0.08	0.083
0.5	-6.75 ± 0.09	-6.97 ± 0.06	-7.13 ± 0.08	0.017*
1	-6.87 ± 0.09	-6.89 ± 0.06	-7.14 ± 0.09	0.174
2	-7.01 ± 0.08	-6.85 ± 0.07	-6.91 ± 0.09	0.206
2.4	-6.93 ± 0.09	-6.98 ± 0.08	-6.85 ± 0.08	0.395
2.8	-6.88 ± 0.12	-6.91 ± 0.06	-6.96 ± 0.09	0.819
3.2	-6.98 ± 0.09	-6.91 ± 0.07	-6.85 ± 0.09	0.214
3.6	-6.96 ± 0.09	-6.81 ± 0.08	-6.96 ± 0.07	0.127
4	-7.03 ± 0.07	-6.79 ± 0.15	-6.85 ± 0.07	0.079

Table 4b: Comparison of reduced 7-point hedonic scale for AUC as a response to different sucrose concentrations.

Results are represented as mean ± SE; AUC: Cumulative R-index Area Under the Curve

mg/dl sucrose	BMI Bad Mean ± SE	BMI Normal Mean ± SE	BMI Good Mean ± SE	p
0	21.61 ± 0.48	22.13 ± 0.66	19.99 ± 0.48	0.180
0.5	21.37 ± 0.51	22.44 ± 0.68	20.14 ± 0.43	0.116
1	22.01 ± 0.73	21.73 ± 0.53	20.46 ± 0.48	0.484
2	22.04 ± 0.77	21.65 ± 0.58	21.15 ± 0.60	0.833
2.4	21.52 ± 0.57	20.72 ± 0.54	22.29 ± 0.069	0.194
2.8	21.50 ± 0.79	21.59 ± 0.56	21.79 ± 0.61	0.784
3.2	20.93 ± 0.32	20.89 ± 0.52	23.09 ± 0.88	0.050*
3.6	20.57 ± 0.58	22.96 ± 0.74	21.15 ± 0.5	0.023*
4	21.59 ± 0.63	19.85 ± 0.53	22.13 ± 0.55	0.041*

Table 4c: Comparison of reduced 7-point hedonic scale for BMI as a response to different sucrose concentrations.

Results are represented as mean ± SE; BMI: Body Mass Index

agreement to the results of Hong et al., [30] we did not find DMFT (dental caries experience) in correlation with BMI, which support the idea of the association between BMI and dental caries, seems to be flat, or negative. So, the association of BMI with caries experience is still obscure and needs to be further analyzed. According to our knowledge, no data exists evaluating sweet taste sensitivity and BMI relationship. In the present study, individuals with BMI over 20 had a higher discrimination for sweet taste to that of BMI lower than

20 especially in sucrose levels over 2.8 mg/dl. The overall sweet taste discriminability, represented by AUC, across the analyzed 0-4% sucrose range is detected to be higher in BMI>20 than BMI<20 individuals; which demonstrated that overweight people have higher sweet taste sensitivity.

Only a few studies report data on relationship between dental caries and sweet perception. Drewnowski A [32] and Frank RA [20] were not able to find any significant

correlation between sucrose preferences and BMI, weight and body fat whereas McMillan-Price et al., [33], Wu et al., [34] and Vorster HH et al., [35] have reported positive correlations. Drewnowski et al., [36] found that no correlation between sweet likers and dislikers for individual hedonic response. Furthermore they showed that hedonic preferences were not associated with BMI, weight and eating [37]. Wrobel et al., [38] determined that the caries-free group had a mean detection threshold of 10.7 mM/litre for the sucrose solution, whereas the caries-active group had a significantly increased mean detection threshold of 16.7 mM/litre for the sucrose solution. On the other hand, Nilsson B and Holm AK [38] found no statistically significant difference in threshold of sucrose between high and low caries groups. According to Furquim et al., [39] girls were largest in the high sweet perception taster group (62.3%) and no significant difference in sweet perception status was detected between the groups of low and high caries severity. In our study, no correlation between sucrose perception and DMFT was determined. Fukunaga et al., [40] found that in 18-29 year-old subjects 0.03 and 0.05 M (1% and 1.7%) sucrose solutions were detected as sweet by less than 40% and more than 80% of subjects respectively. Similarly, our results showed a positive response of sweetness from approximately 12% to 68% of subjects at concentrations 1% to 2% respectively. Eiber et al., [41] found that BMI was affected by hedonic responses to sucrose solutions similar to the results of Drewnowski et al., [42]. Fushan et al., demonstrated that correlation with AUC and sucrose concentration was significantly associated with sweet taste perception in humans [27]. Veldhuizen et al., [43] showed that hedonic response was associated with the possibility of independent processing of intensity and liking. Duffy and Bartoshuk [44] determined that liking/disliking sweet taste was not associated with BMI.

Still there in no papers evaluating the discrimination of sweet taste differences to sucrose and dental caries. In the present study, we report that individuals tasting low (0.5 mg/dl) sucrose as “good” had significantly low DMFT and overall sweet taste sensitivity (AUC) in comparison to “normal” and “bad” tasters. In contrary, a similar significant association between tasting high sucrose (over 2.8 mg/dl) as “good” and either DMFT or AUC was not observed. We found that persons sensing sucrose concentrations over 2.8 mg/dl as “good” had higher BMI levels compared to sensing the same sucrose levels as “bad” or “normal”.

Limitations of this study include wide range of age in the study group and low reliability of DMFT score since the reason for the loss of teeth may well be by causes other than caries at this age groups. BMI also ignores variations in physical characteristics of the individual. Nevertheless these indices are widely used in human research. A recent study from our laboratory also showed the relation between dental caries and genetic background of sweet taste [45].

In conclusion, BMI greater than 20 seems to have a raising affect for taste discrimination at high sucrose levels

(>2.8 mg/dl). Individuals detecting low-level sucrose (0.5 mg/dl) as “good” taste have decreased overall sensitivity to sweet and express low dental caries risk.

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