RESEARCH PAPER

Evaluation of Taste Sensitivity in Type II Diabetic and Non-Diabetic Individuals - A Comparative Cross-Sectional Study

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ABSTRACT

Objective: Taste perception heavily influences dietary habits and metabolic regulation. In individuals with Type II Diabetes Mellitus (T2DM), chronic hyperglycemia may alter gustatory perception and result in changes in food consumption and glucose control. This study aimed to evaluate and compare taste sensitivity for sweet, salty, sour, and bitter tastes in individuals with T2DM and healthy volunteers and to correlate with their glycated haemoglobin (HbA1c) levels.

Materials and Methods: This comparative cross-sectional study evaluated 62 participants (31 with T2DM and 31 healthy volunteers). Taste detection thresholds were determined in a controlled setting using the standardised Triple Drop Method across five ascending serial concentrations of sucrose (sweet), sodium chloride (salty), citric acid (sour), and quinine sulphate (bitter).

Results: T2DM individuals exhibited significantly higher taste detection thresholds than healthy volunteers, expressed as the mean ± standard deviation. For sweet, 3.50 ± 1.06 vs 1.53 ± 0.56, $p<0.001$; for salt, 2.13 ± 1.09 vs 1.43 ± 0.5, $p=0.009$; and for sour, 2.40 ± 0.76 vs 1.40 ± 0.55, $p<0.001$. There was no statistically significant difference in bitter taste perception between the groups, 1.03 ± 0.18 vs 1.0 ± 0.0, $p=0.334$. Higher HbA1c levels were strongly correlated to higher taste thresholds for sweet ($r=0.612$, $p<0.001$), salt ($r=0.521$, $p=0.002$), and sour ($r=0.509$, $p=0.001$), but for bitter taste it was extremely low ($r=0.03$, $p=0.85$).

Conclusions: T2DM has a negative impact on sweet, salt and sour taste sensitivity, and this correlates directly with poorer HbA1C. This study may be a useful adjunct to dietary information.

Keywords: Sensation disorders, HbA1c, Sucrose, Gustatory Threshold, Glycemic Control.

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Introduction

Human taste perception is a critical determinant in dietary choices, nutritional habits, and systemic metabolic regulation. Taste perception occurs via specialised receptors on taste buds that elicit neural signals once a chemical signal reaches a specific detection threshold. Consequently, alterations in taste perception can significantly influence dietary patterns and individual metabolic health. Type 2 diabetes mellitus (T2DM) is characterised by insulin resistance, insufficient insulin production by pancreatic β-cells, and a progressive decline in β- cell function, impacting approximately 422 million adults globally[1]. Beyond classic microvascular and macrovascular complications such as diabetic neuropathy and nephropathy, T2DM can progressively disrupt oral sensory modalities, including gustatory acuity and salivary characteristics[2].

Recent psychophysical evidence indicates that sweet taste detection thresholds are often elevated in individuals with T2DM when compared with healthy persons[3]. This finding has been consistently replicated across various demographic cohorts, indicating a generalised reduction in sweetness sensitivity among T2DM individuals. There are multiple physiological mechanisms attributed to the high sweetness detection thresholds experienced by T2DM adults, including structural alterations to the morphology of taste buds caused by chronic hyperglycemia, gustatory nerve impairment as a consequence of diabetic neuropathy, imbalances of minerals such as zinc and varying levels of glycoproteins in the saliva[4]. Clinically, an inability to detect sweetness at low levels may promote an increased consumption of sugar, which can cause high glucose levels in the bloodstream and also contribute to continued dysregulation.

Despite these established paths, current research faces significant gaps. The majority of the literature available on this topic has focused on only one taste modality or examined one parameter related to salivation and has lacked a standardised methodology. Only a few studies have assessed each of the four main tastants (sweet, salt, sour, and bitter) within a representative sample of the Indian population. Psychophysical techniques such as the Triple Drop Method (TDM) provide a far greater level of reproducibility and sensitivity compared to most of the other methods for comparing all four taste modalities; however, not many researchers have used the TDM to evaluate all four primary taste modalities together in the same study. In addition, there is currently no literature that has examined the relationship between the taste threshold and long-term glycemic control or HbA1c in one population group; specifically, the Indian population that has a relatively high prevalence of T2DM and consumes a diet with a high carbohydrate content. We hypothesised that chronic hyperglycemia selectively elevates the gustatory threshold for sweet, salt, and sour tastes in proportion to the severity of glycemic dysregulation, while leaving bitter taste pathways relatively intact. Hence, this study was conducted to evaluate the four taste modalities by systematically determining the sensitivity to sweetness, saltiness, sourness and bitterness using the standardised triple drop method and to determine the correlation of HbA1c levels with taste threshold.

Materials and methods

This comparative cross-sectional study was conducted in the Endocrinology department of Sri Ramachandra Hospital, Chennai, India. All procedures involving human subjects were conducted in strict accordance with the ethical standards of the Institutional Ethics Committee of Sri Ramachandra Institute of Higher Education and Research (Reference No: CSP/25/JAN/156/33) and with the World Medical Association Declaration of Helsinki of 1975, as revised in 2000. Informed consent was obtained from all participants prior to enrolment, and confidentiality of all subjects was maintained.

The OpenEpi version 3 statistical software was used to calculate the sample size and was determined based on data from a previous study[5]. With a confidence interval of 95% (two-sided), power of 80%, and a sample size ratio of 1:1 between groups, a total of 62 participants (31 with T2DM and 31 healthy volunteers) was determined to be sufficient.

Participants with T2DM were recruited from the outpatient endocrinology department at Sri Ramachandra Hospital, while healthy individuals were selected from volunteers accompanying patients. All participants signed informed consent and were screened according to the selection criteria. Adults aged from 30 to 75 years with a diagnosis of T2DM for at least five years (i.e., for 5 or more consecutive years) were included in the study. Smokers, alcohol drinkers, people who consume betel nut, pregnant women or breast-feeding women, individuals who have had a recent upper respiratory or COVID-19 illness, and individuals who have any existing diseases of the oral cavity were excluded from the study. Subjects using medications that can influence their taste sensation (e.g., ACE inhibitors, antiepileptics) were also excluded from the study.

A structured questionnaire was used to assess eligibility, and a proforma was used to record data for each participant, such as a medical history, duration of diabetes, current medications, comorbidities and complications (like peripheral neuropathy and retinopathy). Individual glycemic status was determined by reviewing the participant's official laboratory records. For the patient group, HbA1c values were sourced from recent laboratory reports, documented within the preceding 3 months. Anthropometric measurements, such as height was measured using a calibrated stadiometer to the nearest 0.1 cm, and weight was measured using a digital scale to the nearest 0.1 kg. The body mass index (BMI) was calculated based on the formula,

$$BMI = \frac{\text{Weight (kg)}}{\text{Height (m}^2\text{)}}$$

Assessment of taste sensitivity (Triple Drop Method)

Taste threshold was determined for four of the primary taste modalities: sweet (sucrose), salty (sodium chloride), sour (citric acid), and bitter (quinine sulfate). To prepare the tastants, we used high- purity distilled water and calibrated electronic analytical. For the sweet modality, we prepared five ascending concentrations of sucrose by dissolving commercial-grade crystalline sucrose, mechanically grinding it into fine powder to ensure rapid and uniform dissolution. We dissolved 75 mg, 100 mg, 125 mg, 150 mg, and 175 mg of this sucrose powder into individual 10 mL of distilled water, preparing the final testing concentrations 0.75%, 1.00%, 1.25%, 1.50%, and 1.75% (Weight/ Volume). For salt modality, we used pure NaCl (table salt) dissolved in 10 mL of distilled water at specific masses of 10mg (0.10%), 20 mg (0.20%), 50 mg (0.50%), 70 mg (0.70%), and 100 mg (1.00%). The sour tastant was made using citric acid monohydrate powder, weighed out at 3 mg (0.03%), 5 mg (0.05%), 10 mg (0.10%), 20 mg (0.20%), and 30 mg (0.30%). For the bitter modality, we used anhydrous quinine sulfate powder at masses of 0.5 mg (0.005%), 1.0 mg (0.01%), 2.0 mg (0.02%), 5.0 mg (0.05%), and 10.0 mg (0.10%). The initial concentration ranges were adapted from the previously established psychophysical protocols, but preliminary piloting revealed that certain baseline values required fine-tuning[2].

We systematically modified and standardised these masses to ensure optimal baseline sensitivity and precise threshold tracking across all four taste modalities. All solutions were prepared fresh, labelled, and stored properly to maintain stability and avoid contamination. Prior to the testing, subjects had to abstain from any food or drink (except water) for at least 1 hour. Three drops of tastants were applied sequentially to the anterior tongue. Uniform drops of the tastant solutions were applied sequentially using a sterile dropper. The lowest concentration that

was accurately identified was recorded as the detection threshold, graded on a 1-5 scale (1 = most sensitive; 5 = least sensitive). A distilled water rinse was mandated between each test in order to prevent carryover effects. Data were anonymised and managed using Microsoft Excel for statistical evaluation. Statistics were performed using SPSS software version 26.0.

Results

Table 1 Demographic characteristics of the study participants.

Demographic	Variables	T2DM n (%)	Healthy volunteers n (%)	Total (n=62)	P value
Age (Years)	< 47 years	13 (41.94)	20 (64.52)	33 (53.23)	0.07
	≥ 47 years	18 (58.06)	11 (35.48)	29 (46.77)	
Gender	Male	15 (48.39)	15 (48.39)	30 (48.39)	1.00
	Female	16 (51.61)	16 (51.61)	32 (51.61)	
Education	Upto high school	23 (74.19)	22 (70.97)	45 (72.58)	0.77
	Graduate	8 (25.81)	9 (29.03)	17 (27.42)	
Socioeconomic status	< ₹ 50000/Month	21 (67.74)	24 (77.42)	45 (72.58)	0.53
	> ₹ 50000/Month	10 (32.26)	7 (22.58)	17 (27.42)	

Calculated using Chi-square (χ^2) test of independence.

The baseline characteristics of the study participants are detailed in Table 1. The two primary groups (T2DM and healthy volunteers) were comparable, showing no statistically significant difference across major demographic variables in Mean ± SD. The mean age in the T2DM group was 53.61 ± 12.77 years and 45.87 ± 11.38 years in the healthy individual group.

Table 2 Comparison of taste detection threshold among study participants.

Taste sensitivity	**Diabetic (Mean ± SD)**	**Non-Diabetic (Mean ± SD)**	**P value**
Sweet intensity	3.50 ± 1.06	1.53 ± 0.56	p<0.001
Salt intensity	2.13 ± 1.09	1.43 ± 0.50	0.009
Sour intensity	2.40 ± 0.76	1.40 ± 0.55	p<0.001
Bitter intensity	1.03 ± 0.18	1.00 ± 0.00	0.334

Using independent-sample t-test. Statistically significant at $p < 0.05$.

Similarly, an independent t-test revealed no statistically significant difference when anthropometric parameters were compared between T2DM and healthy volunteers, expressed as mean ± SD. Height was 159.97 ± 8.35 cms vs 163.29 ± 7.52 cms, p = 0.11; weight was 68.32 ± 10.02 kgs vs 69.45 ± 2.95 kgs, p = 0.70, and Body Mass Index was 27.12 ± 4.02 kg/m² vs 26.97 ± 5.94 kg/m², p = 0.91. These findings indicate that the groups were comparable in terms of demographic profile and anthropometric characteristics.

There were statistically significant differences found between T2DM individuals and healthy volunteers for sweet, salt and sour modalities using comparative analysis – independent sample t-test. These results show that T2DM individuals have significantly decreased sensitivity to these taste modalities. There was no statistically significant difference between

groups for the bitter taste modality, therefore indicating that perception of bitterness is intact in T2DM individuals, as shown in Table 2.

The Pearson correlation analysis showed that there was a statistically significant positive correlation between HbA1c levels and taste thresholds in individuals with T2DM. The correlation coefficient for the relationship between glycaemic control and sweet taste sensitivity was ($r = 0.612$, $R2 = 0.405$; $p < 0.001$), meaning approximately 40.5% of the variation in sensitivity to sweet taste is explained by adequate glycaemic control. There were significant positive correlations between glycaemic control in both salt ($r = 0.521$, $R2 = 0.313$; $p = 0.002$) and sour ($r = 0.509$, $R2 = 0.259$; $p = 0.001$) taste modalities, indicating a decrease in sensitivity for these tastes with poor glycaemic control. The correlation for bitter taste receptor preference was very weak ($r = 0.033$, $R^2 = 0.001$; $p = 0.850$), suggesting that glycemic status had no influence on bitter taste perception among this population.

Figure 1: Pearson linear correlation between HbA1c and sweet taste threshold

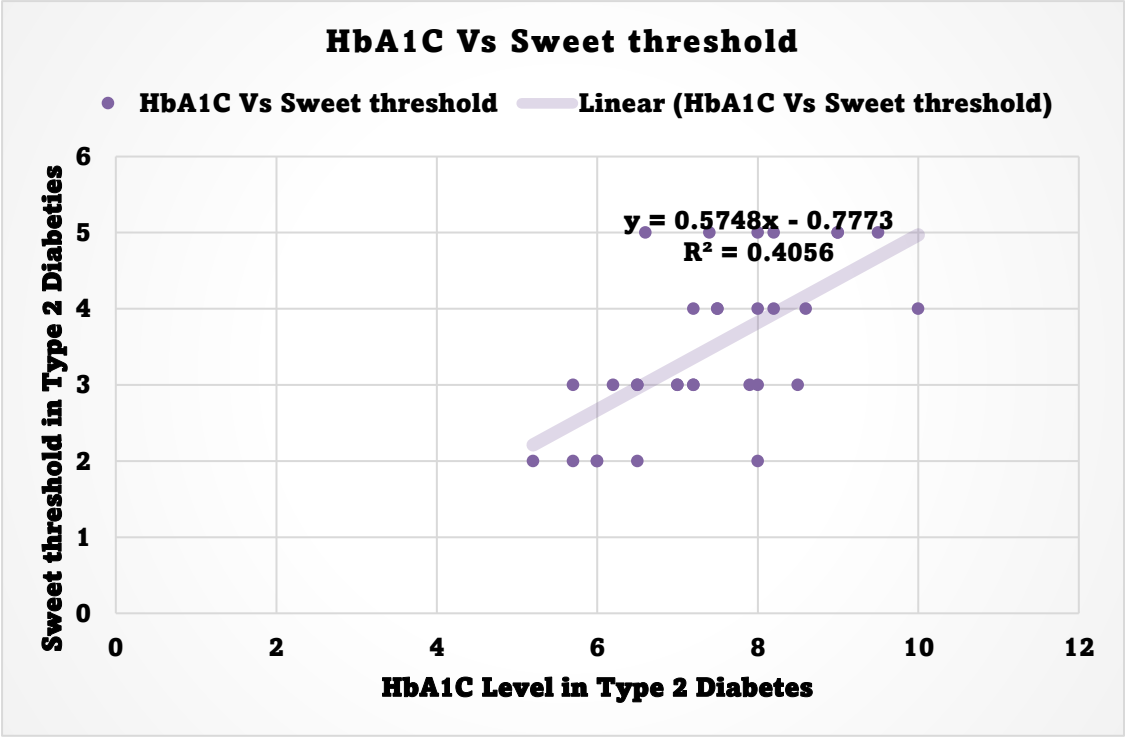


Figure 2: Pearson linear correlation between HbA1c and salt taste threshold

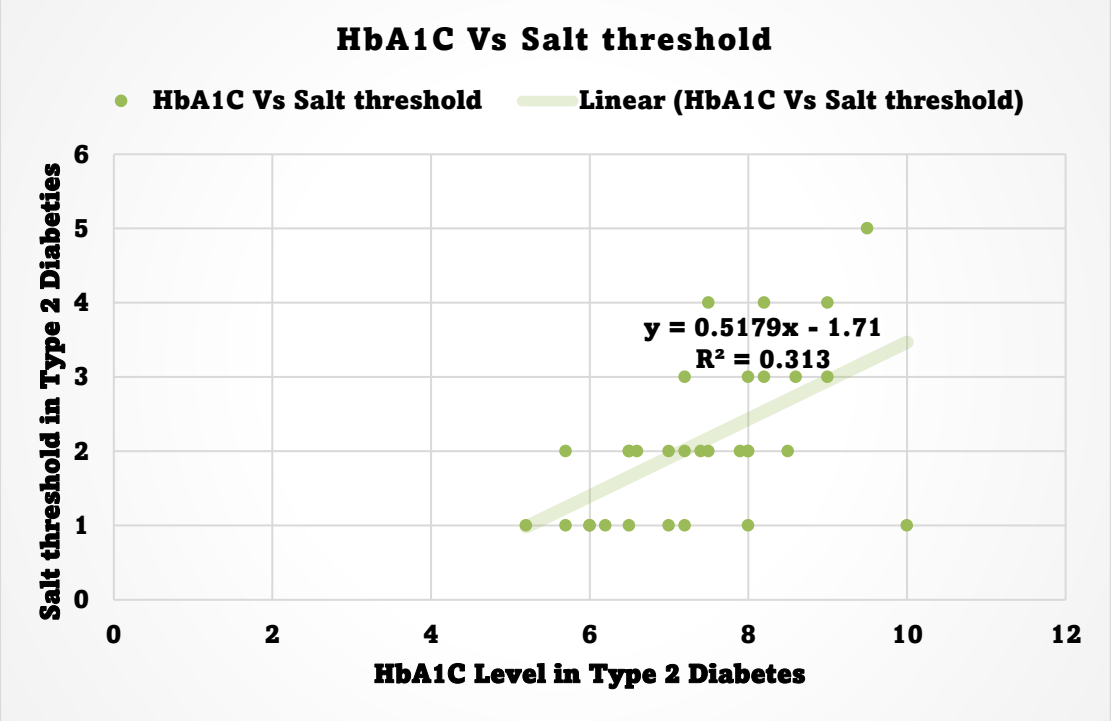
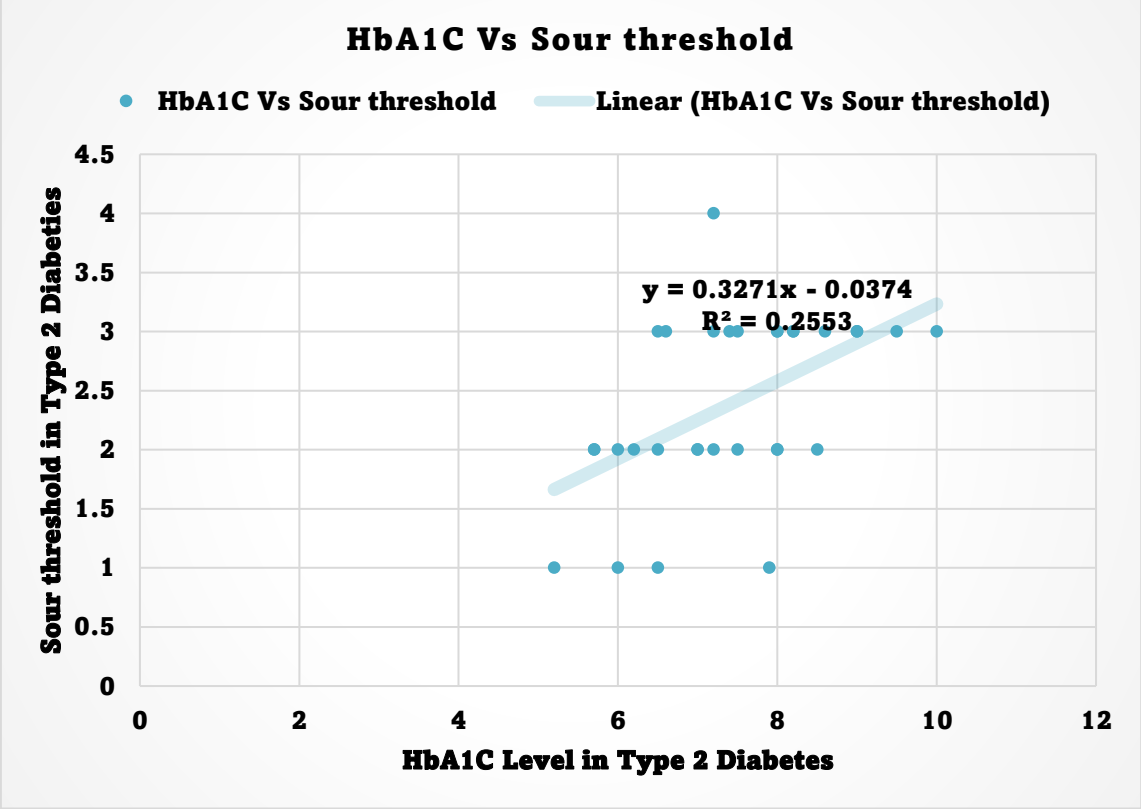


Figure 3 : Pearson linear correlation between HbA1c and sour taste threshold



Discussion

The present study evaluated the alterations in taste perception among T2DM and healthy volunteers, and examined the relationship between glycemic control and taste detection thresholds. Taste perception plays a critical role in dietary behaviour, and its impairment in diabetes may contribute to the altered food preferences and poor metabolic control.

The potential confounding variables were minimized which significantly strengthened the internal validity of our findings. The primary outcome measures revealed a notable elevation in taste identification thresholds for sweet, salt and sour modalities among the T2DM individuals, confirming our initial hypothesis that chronic metabolic dysregulation compromises specific oral sensory pathways. Conversely, the preservation of bitter taste perception across both groups highlights a selective vulnerability within the peripheral or generalised and uniform decline.

The sweet taste experience is mediated through the heterodimeric T1R2/T1R3 G-protein coupled receptor family located on Type II taste receptor cells. Chronic hyperglycemia may damage these receptors by causing microvascular damage, neuropathy and creating advanced glycation end products on the surface of the receptors[6]. In Addition, the systematic accumulation of advanced glycation end-products (AGEs) on cell surfaces, alongside local diabetic neuropathy affecting the chorda tympani or glossopharyngeal nerves, likely disrupts peripheral signal transduction[7]**.** Decreased sweet perception contributes to an increase in sugar consumption, which could further worsen glycemic control. Studies have consistently shown that people with Type 2 diabetes mellitus (T2DM) have less sensitivity to sweetness than healthy individuals [8,9].

Study results have also shown increased salt taste thresholds as well. Impairment of salt detection can occur through epithelial sodium channels (ENaC) or as a result of microvascular changes, neuropathy, and alterations in salivary composition [6]**.** Prior studies have established similar findings[8,9]. but others have not provided evidence of a difference, likely as a result of methodological differences. By increasing their salt intake, people with less sensitivity to salt may be predisposed at a risk for hypertension and cardiovascular complications.

A significant decrease in sour perception in T2DM was also found. This may be due to changes in proton-sensitive ion channels, diabetic neuropathy, and changes in pH levels and buffering capacity of saliva[6]. These findings were consistent with a few studies; however, some studies suggest no significant difference, possibly due to the variations in glycemic status and disease duration[3,8].

On the other hand, bitter taste perception was preserved with no statistically significant differences between the groups. Bitter taste is represented through a large group of T2R receptors, whose redundancy and sensitivity can help to protect against metabolic dysfunction[6]. A similar result was found by a study, indicating that diabetic subjects are likely less impaired in bitter taste perception[9].

A strong positive correlation was found between HbA1c levels and taste detection thresholds for the sweet, salty, and sour modalities. This result suggests that individuals with poor glycemic control have less sensitivity to taste, and these results are consistent with earlier studies[9,3]. However, several researchers did not find the same correlation, possibly due to differences in their sample characteristics.

These results have clinical implications. A decrease in taste perception may lead to an increase in sugar and salt consumption, which contributes to poor glycemic control and increases the risk for complications[9]**.**

Therefore, early identification of gustatory dysfunction may be beneficial for providing dietary education and subsequently better management of diabetes. In addition, taste dysfunction may help detect early signs of diabetic neuropathy or microvascular complications.

A key strength of this study lies in its strict methodology. Using the standardised, highly reproducible Triple drop method minimised the examiner bias. Our rigorous exclusion of active smokers, alcohol users, and individuals on confounding medications ensured that the observed threshold shifts were genuinely related to the underlying disease process.

Although the current study has given important insights into T2DM and taste modification, other limitations must also be considered. The cross-sectional design limits the ability to determine the cause of taste modification in T2DM and a longitudinal study needs to be done to establish the cause-and-effect. The perception of taste is subjective, and although we used standardised tests, subjective differences always exist for taste perception as a result of physiological variability among individuals. Future research should utilise other more objective methods of measuring taste (e.g., electrogustometry, gustatory evoked potentials) in addition to the psychophysical assessment.

Conclusion

Diabetes mellitus is a chronic metabolic disorder characterised by persistent hyperglycemia that has a detrimental effect on oral sensory functions. The present study revealed that individuals with T2DM have markedly reduced sweetness, saltiness, and sourness sensitivity compared to the healthy participants. These results emphasise a significant vicious cycle in which reduced sweet taste may contribute to increased preference for sweeter foods to achieve taste satisfaction, thus worsening glycemic control.

These findings support the need to consider taste sensory dysfunction as an under-recognised complication of diabetes (even though it is generally overlooked). Early identification of these changes in oral sensory function can help guide individuals into evidence-based dietary modifications[10]. Diabetics could be advised to use non-caloric alternatives that would help to improve the palatability of foods (e.g., enhancing the flavour of food with non-caloric herbs/spices such as cinnamon or cardamom) or adding sour flavour to foods to create a sweet perception through sensory interaction[7].

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