

A Survey on The Acceptance of Non-Nutritive Sweeteners among Diabetic Patients

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ABSTRACT

Background: The prevalence of Type 2 Diabetes Mellitus (T2DM) in Malaysia continues to rise, largely due to excessive sugar consumption. Non-nutritive sweeteners (NNS), such as stevia and erythritol, are increasingly used as alternatives due to their low caloric content and minimal impact on blood glucose. However, the acceptance of NNS among diabetic patients remains uncertain. This study aimed to assess the acceptance of a stevia-erythritol blend among hospitalised T2DM patients. **Methods:** A cross-sectional sensory evaluation was conducted among 69 T2DM patients hospitalised at one of the teaching hospital in east coast Malaysia. Participants consumed tea sweetened with a stevia-erythritol blend and rated its sweetness, aftertaste, and overall acceptability using a 5-point hedonic scale. Demographic data, body mass index (BMI), blood glucose levels, and length of hospital stay were also recorded. **Results:** Most of participants (66.7%) accepted the NNS-sweetened tea. Mean scores indicated positive responses for sweetness (3.71 ± 0.86), aftertaste (3.70 ± 0.85), and overall acceptability (3.86 ± 0.91). **Conclusion:** The findings indicate that diabetic patients generally accepted NNS, with sensory attributes such as sweetness and aftertaste playing a key role in their acceptance. These results support the inclusion of more palatable NNS-based options in hospital food services to promote better dietary adherence and glycaemic control in T2DM management.

Keywords:

non-nutritive sweeteners; stevia; erythritol; diabetes, sensory evaluation

INTRODUCTION

According to the International Diabetes Federation (IDF), approximately 537 million adults aged 20-79 are living with diabetes, and this number is expected to rise to 643 million by 2030 and 783 million by 2045. The IDF predicts that by 2045, the number of people with diabetes in the Southeast Asia (SEA) Region will increase by 68%, reaching 152 million, with a diabetes prevalence of 11.3%. In Malaysia specifically, the prevalence of diabetes is particularly concerning, as it has been reported that approximately over half a million or 2.5% of adults in Malaysia live with four non-communicable diseases (NCDs) which are diabetes, hypertension, high cholesterol, and obesity.

The rising prevalence of T2DM is concerning due to its often subtle symptoms, delaying early detection. The symptoms of T2DM take years to develop and become noticeable unlike type 1 diabetes, where the symptoms appear more obvious. Ministry of Health Malaysia (2012) emphasizes that the key strategy in achieving glycaemic control is by monitoring the total amount of carbohydrate intake including the sugar intake. Recent research has

proved that excessive sugar consumption is associated with the increasing trend in the prevalence of T2DM (Liu et al., 2023). According to the World Health Organization (WHO) guidelines on sugar intake for adults and children, it is strongly recommended to reduce the intake of free sugar throughout life. The WHO also recommends reducing free sugar intake to less than 10% of total energy, with further reductions to less than 5% for additional health benefits (WHO, 2015).

Health concerns over excessive sugar intake have increased NNS use, especially among individuals with obesity and diabetes. (Lohner et al., 2020). NNS offer sweetness without significant calories and are used as an alternative to nutritive sweetener to help lower energy intake and minimize carbohydrate-related health risks. Non-nutritive sweeteners are also often recommended for individuals with T2DM due to their minimal impact on glycaemic levels (Ministry of Health Malaysia., 2012). These sweeteners can serve as an alternative to regular sugar, helping diabetic patients manage their blood glucose more effectively. However, it is essential to ensure that their intake does not exceed the Acceptable Daily

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Intake (ADI) levels as recommended by The Food and Drug Administration (FDA) (Ministry of Health Malaysia., 2012).

In Malaysia, the use of stevia as a sugar alternative is increasingly promoted, particularly in response to rising health concerns like diabetes and obesity (Saharudin et al., 2020). Based on the study among health-educated individuals, a significant majority agreed stevia could substitute sugar and would recommend it for diabetic patients (Saharudin et al., 2020). However, the aftertaste of stevia influences the user's acceptance because it leaves a lingering unpleasant taste after drinking it. Erythritol which nearly 70% as sweet as sucrose, has a mild cooling effect in the mouth with no aftertaste (Mazi & Stanhope, 2023). It can increase volume and reduces the aftertaste associated with stevia, particularly its bitter and licorice-like notes (Myers et al., 2018). Therefore, stevia is often combined with erythritol to enhance the taste and usability of the sweetener blend while minimizing common drawbacks associated with pure stevia. Thus, this study aimed to determine the acceptance of NNS among diabetes patients.

MATERIALS AND METHODS

Participants

A cross-sectional sensory evaluation study was conducted among inpatients with T2DM in a tertiary hospital in Kuantan, Pahang, aged 18 years old and above. The data collection was done from February to May 2025. This study excluded T1DM patients, pregnant diabetic patients, patients on fluid restriction, patients in isolation, tube feeding patients and patients with cognitive impairments.

Sampling Strategy

Purposive sampling was used to recruit 105 T2DM patients warded in the hospital who are willing to participate. Participants could withdraw at any time. Written consent was obtained from each participant prior to their involvement in the study. The consent form, survey form and participant agreement were provided and required before the assessments were conducted. A list of patients receiving a diabetic diet was obtained from the hospital food service dietitians. From this list, patients with fluid restrictions, and those in isolation rooms were excluded from the study. The remaining eligible patients were then approached by the researchers to obtain their consent to participate.

Data Collection

In this study, the data collection form was prepared in Malay language to ease the communication with local

participants. The form included two components which was 1) participants' background information that consisted of demographic (age and gender), anthropometry (weight and height), blood glucose level (capillary blood glucose) and length of hospital stay, and 2) sensory evaluation that focus on aftertaste, sweet taste and overall acceptability of the tea with NNS.

Participants' Background Information

During the data collection process, participants were asked to complete a survey form that included background information on their hospital registration number (RN), age, gender, weight, height, and the number of days they had been hospitalised at the time they consumed the tea. Their registration number were used to access hospital's electronic medical record system. For participants who were unable to recall or provide their weight and height, the data were obtained from their medical records.

These measurements were then used by the researcher to calculate each participant's Body Mass Index (BMI). Then the value of BMI was categorized according to Malaysian Clinical Practice Guidelines for Obesity (2023) BMI based weight classification where underweight (less than 18.5 kg/m²), normal weight (18.5-22.9 kg/m²), overweight (23-27.4 kg/m²), and obese (27.5 kg/m² or greater) for participants ages less than 60 years old. For participants aged more than 60 years old, their BMI were classified according to Malaysian Dietary Guidelines for Older Persons (2023)' BMI classification where 24 to 27 kg/m² indicate normal range while below and above range indicate underweight and obese.

According to the Malaysian Clinical Practice Guidelines for T2DM (2020), the recommended 2-hour post-prandial blood glucose target range for patients with Type 2 diabetes is between 4.4 mmol/L and 8.5 mmol/L. Therefore, the reading between 4.4 mmol/L and 8.5 mmol/L is considered within the target range and higher and lower indicate below and above the target range respectively.

The measurement for blood glucose was capillary blood glucose, and all data were retrieved from the medical record to ensure consistency. All values were recorded between 12:00 p.m. to 1:00 p.m., before the tea was consumed. Following participants' discharge, the total length of hospital stay was retrieved from the medical record.

Sensory Evaluation

In this study, a sensory evaluation form was used to assess

participants' responses to the tea containing non-nutritive sweeteners (NNS). This method directly measured participants' preferences and satisfaction using a 5-point hedonic scale (Addo-Preko et al., 2023). The 5-point hedonic scale consisted of five levels of liking, ranging from 1 = "dislike very much" to 5 = "like very much," with 3 = "neither like nor dislike" representing the neutral point.

Table 1: Description for Sensory Evaluation Score

Score	Description
1	Dislike Extremely
2	Dislike Slightly
3	Neither Like nor Dislike
4	Like Slightly
5	Like Extremely

While some studies have defined a mean score of 4 or higher as indicating strong acceptability (Everitt, 2009), other researchers interpret mean scores above 3.0 as reflecting positive consumer acceptance, particularly when converted to an acceptance index exceeding 70% (Huey et al., 2023). In this study, the sensory attributes evaluated included aftertaste, sweetness, and overall acceptability. Therefore, in this study, the acceptance index approach was applied, and the results were interpreted based on whether the mean scores indicated an acceptable level of consumer preference. The sensory attributes evaluated included aftertaste, sweetness, and overall acceptability.

$$\text{Acceptance Index (AI)} = \frac{\text{Mean Hedonic Score}}{\text{Maximum Possible Score}} \times 100$$

A standard sachet of NNS weighs 2.5 g and is designed to provide sweetness equivalent to one teaspoon of sugar (EviaSweet, Fine Foods, Malaysia). It is a combination of erythritol and stevia (proportion not disclosed).

Tea was prepared by immersing a tea bag (Cameron Valley black tea, Malaysia) in 200 ml of boiling water for one serving. Tea was steeped for 3 minutes, allowing the leaves to release their full bouquet of flavor and aroma. Tea bag was then been taken out of the drink to avoid overpowering of taste. Then, one sachet of NNS (2.5 g) was added to the tea.

Research Flow

The tea sample preparation was carried out by the researcher in the hospital kitchen around 2:00 pm. The tea was then served during afternoon tea between 3.00 p.m

to 4.00 p.m., along with the data collection form. The completed forms were then collected around 4:30 pm.

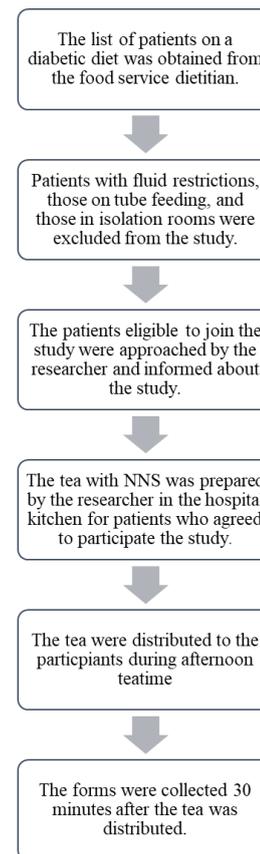


Figure 2: Participants' recruitment process and sensory evaluation protocol

Ethical Approval

This study received ethical approval from the Kulliyah Postgraduate and Research Committee (KPGRC) (KAHS 17/25), the International Islamic University Malaysia Research Ethical Committee (IREC) (IREC 2025-KAHS/DNS13), and the institutional hospital (IIR25-16).

RESULTS

There was a total of 69 participants who participated in this study. Despite 155 patients in a tertiary hospital were approached to be participant in this study, only 69 patients agreed to be the participants which resulted in low response rate (44.5%). However, only 49 participants with complete information on their anthropometric measurements.

Characteristics of the Participants

Table 2 demonstrates the sociodemographic characteristics of the total participants (N=69) with 60.9% were female (n= 42) and 39.1% were male (n=27). The age

group of 60-69 years old comprised the largest percentage of participants (39.1%, n=27) while those 39 years old and younger represent the lowest proportion (2.9%, n= 2). The ethnic composition of the participants was predominantly Malay (95.7%, n= 66) and only 3 participants with different race which were Chinese (1.4%, n=1) and Indian (2.9%, n=2). In terms of length of hospital stay, most participants were hospitalised for 1-7 days (47.8%, n=33), whereas the longest recorded length of stay was 40 days (1.4%, n= 1)

Table 2: Sociodemographic Characteristics of Participants (N=69)

Variables	n (%)	Mean ± SD
Age		64.74 ± 9.61
30-39 years	2 (2.9)	
40-49 years	3 (4.3)	
50-59 years	12 (17.4)	
60-69 years	27 (39.1)	
70-79 years	21 (30.4)	
≥80 years old	4 (5.8)	
Gender		
Male	27 (60.9)	
Female	42 (39.1)	
Race		
Malay	66 (95.7)	
Chinese	1 (2.9)	
Indian	2 (1.4)	
Length of Hospital Stay		10.32 ± 7.77
1-7 days	33 (47.8)	
8-14 days	20 (29.0)	
15-21 days	9 (13.0)	
22-28 days	5 (7.2)	
29-35 days	1 (1.4)	
36-42 days	1 (1.4)	

BMI Status of Participants

The anthropometry measurement of the 49 participants were presented in Table 3. The mean body mass index (BMI) was 27.35± 5.71 kg/m². According to Malaysian Clinical Practice Guidelines for Obesity (2023) and Malaysian Dietary Guidelines for Older Persons (2023), the majority of participants 51.0% (N=25) were obese, followed by 24.5% (N=12) normal, 22.4% (N=11)

underweight and 1.4% (N=1) overweight. Obesity was more predominant among females (53.8%) than males (47.8%). A higher proportion of males (30.4%) were in the normal weight range compared to females (19.2%).

Table 3: Anthropometric assessment and BMI categories of participants (N=49)

Variables	n (%)	Mean ± SD
BMI (kg/m²)		27.35 ± 5.71
Underweight	11 (22.4)	
Male	5 (21.7)	
Female	6 (23.1)	
Normal	12 (24.5)	
Male	7 (30.4)	
Female	5 (19.2)	
Overweight	1 (1.4)	
Male	0	
Female	1 (3.8)	
Obese	25 (51.0)	
Male	11 (47.8)	
Female	14 (53.8)	

Blood Glucose Level

Capillary blood glucose readings were obtained from all 69 participants to assess glucose control during hospitalization (Table 4). In this study, the mean capillary blood glucose was 8.17 ± 3.06 mmol/L. Among the participants, 3 (4.3%) had glucose levels below the target range, 43 (62.3%) were within the recommended target, and 23 (33.3%) had above-target glucose levels, indicating that a significant proportion of participants experienced suboptimal glucose control during hospitalization.

When comparing glucose control by gender, the distribution was generally similar. There were more male and female participants with normal blood glucose control (61.9% among males, 63% among females). Notably, participants with below-target glucose levels were all female (7.1% of all females) However, these findings suggest no apparent difference in glucose control status between gender in this study group.

Table 4: Capillary Blood Glucose Levels of Participants (N=69)

Variables	n (%)	Mean ± SD
Capillary blood glucose (mmol/L)		8.17 ± 3.06
Below Target <4.4 mmol/L)	3 (4.3)	
Male	0 (0.0)	
Female	3 (7.1)	

Within Target (4.4 – 8.5 mmol/L) 43 (62.3)
 Male 17 (61.9)
 Female 26 (63.0)
Above Target (> 8.5 mmol/L) 23 (33.3)

Male 10 (37.0)
 Female 13 (31.0)

Sensory evaluation of tea with non-nutritive sweeteners (NNS)

Table 5 shows the descriptive statistics from the 5-point hedonic scale showed that, for sweetness, the majority of participants (74%) neither like nor dislike it, with 21.7% liking it extremely and 31.9% slightly liking it. The mean sweetness score was 3.71 ± 0.86 , corresponding to an acceptance index (AI) of 74.2%, indicating that the product was within the acceptable range of sensory liking (AI \geq 70%)

A similar pattern was observed for aftertaste, where 20.3% of participants liked it extremely and 33.3% slightly liked it, resulting in a mean score of 3.70 ± 0.85 and an AI of 74.0%, also reflecting a generally acceptable level of sensory response.

The overall acceptability of the tea with NNS was the highest among the evaluated attributes. Most participants (40.6%) slightly liked it and 26.1% liked it extremely, with only 1.4% expressing extreme dislike. The mean overall acceptance score of 3.86 ± 0.91 corresponded to an AI of 77.2%, suggesting that participants were generally receptive to and satisfied with the taste and presence of non-nutritive sweeteners in the tea samples.

	0 (0)		
Dislike	3 (4.3)		
Extremely			
Dislike Slightly	29		
Neither like nor Dislike	(42.0)		
Like Slightly	23		
Like Extremely	(33.3)		
	14		
	(20.3)		
Overall Acceptance		3.86	\pm 77.2
		0.91	
	1 (1.4)		
Dislike	3 (4.3)		
Extremely			
Dislike Slightly	19		
Neither like nor Dislike	(27.5)		
Like Slightly	28		
Like Extremely	(40.6)		
	18		
	(26.1)		

Table 5: Mean hedonic scores for sensory evaluation taste of NNS (N=69)

Variables	n (%)	Mean SD	\pm	Acceptance Index (AI) (%)
Sweetness		3.71	\pm	74.2
		0.86		
	0 (0)			
Dislike	3 (4.3)			
Extremely				
Dislike Slightly	29			
Neither like nor Dislike	(42.0)			
Like Slightly	22			
Like Extremely	(31.9)			
	15			
	(21.7)			
Aftertaste		3.70	\pm	74.0
		0.85		

DISCUSSION

This study aims to evaluate the acceptance of non-nutritive sweeteners (NNS), specifically the combination of stevia and erythritol, among hospitalised diabetic patients. Conducted with a sample of 69 patients, the findings provide valuable insights into NNS acceptance within this population.

Recent studies have highlighted key factors influencing the acceptance of non-nutritive sweeteners (NNS), particularly stevia and erythritol, among various consumer groups, including individuals with diabetes (Hong et al., 2025; Mazi & Stanhope, 2023). While stevia is widely recognized for its health benefits, especially its non-glycaemic properties, its sensory qualities often present a barrier to acceptance. The most frequently reported concern is its lingering aftertaste, which many users find bitter or metallic. This aftertaste has been consistently cited as a factor that detracts from the overall sensory experience, especially when stevia is used as a standalone sweetener (Saharudin et al., 2020).

To improve consumer satisfaction, erythritol is often blended with stevia. Erythritol, a sugar alcohol with a clean, sweet taste and minimal aftertaste, helps to balance Stevia's more pronounced sensory attributes. According to Pourahmad and Khorramzadeh (2016), combining erythritol with stevia significantly improved the overall sensory acceptance of a soy-based beverage powder. Their study found that the formulation using 80% stevia and a 75:25 erythritol-to-isomalt ratio received the highest scores for sweetness, mouthfeel, sweetness aftertaste, and overall acceptability. The use of erythritol was shown to reduce the undesirable aftertaste often associated with stevia, resulting in a sweetness profile that more closely resembled that of sucrose.

These results are consistent with the findings of this study, where it indicates a favourable perception of NNS among the participants in terms of sweetness, aftertaste and overall acceptance. For sweetness, most participants expressed a positive or neutral response. The mean sweetness score was indicating a moderate level of liking. Based on the calculated Acceptance Index (AI), sweetness (74.2%), aftertaste (74.0%), and overall acceptance (77.2%) all exceeded the 70% threshold typically considered indicative of acceptable sensory quality (Huey et al., 2023), supporting that the NNS used in this study was well accepted by participant. The overall acceptance of non-nutritive sweeteners (NNS) was the highest among the evaluated attributes, indicating that most hospitalised diabetic patients were receptive to their taste. A similar positive response was seen for sweetness and aftertaste. The strong and significant associations between these taste attributes and overall acceptance suggest that the palatability of NNS, particularly sweetness and aftertaste, plays a key role in influencing their acceptance in this population.

Demographic factors such as age, gender, and BMI did not show a significant association with NNS acceptance. This indicates that sensory experience, especially taste and aftertaste, was more decisive than individual characteristics (Farhat et al., 2021; Moreira et al., 2025). The predominance of older adults in this study may have positively influenced acceptance, as previous research has shown that older Malaysians generally favor natural, plant-based products (Kim Sooi & Lean Keng, 2013). Given that stevia is a plant-derived sweetener, this demographic's preference for natural health alternatives may have enhanced their openness toward the stevia-erythritol blend.

When compared with a previous study conducted at Universiti Kuala Lumpur Royal College of Medicine Perak, which specifically evaluated the use of pure stevia, our

findings indicate a notably higher level of acceptance among hospitalised diabetic patients. In the earlier study, while a significant proportion of participants (66.7%) liked the taste of stevia and 95.1% were willing to recommend it for diabetic patients, a substantial number (74.1%) reported an unpleasant aftertaste and 65.4% perceived a noticeable change in the taste of their drinks (Saharudin et al., 2020). In contrast, our study reported a moderately positive perception, with the aftertaste receiving an average score approaching 3.7 and overall acceptance nearing 3.9 on the hedonic scale. Notably, only a minimal proportion of participants, approximately 1%, expressed strong disapproval. This suggests that the non-nutritive sweetener used in our study, stevia-erythritol blend, provided a more favourable sensory experience. The combination of stevia and erythritol has been shown to effectively reduce the bitterness and lingering metallic aftertaste typically associated with pure stevia, resulting in a sweeter taste profile (Mazi & Stanhope, 2023; Pourahmad & Khorramzadeh, 2016). Therefore, the improved acceptance observed in our study may be attributed to the enhanced palatability of this blend, reinforcing its potential as a suitable and well-tolerated sugar substitute for diabetic individuals in clinical settings.

Taken together, these findings suggest that while NNS like stevia and erythritol may not perfectly replicate the taste of sugar, they are generally well-accepted when appropriately formulated. Our results align with the broader literature in indicating that both the sweetness level and aftertaste are significantly associated with overall acceptance. Thus, given the strong acceptance observed, this NNS has the potential to support dietary adherence while enhancing the palatability of low-sugar diets (Huey et al., 2023).

Stevia, while popular for its zero-calorie benefits and glycaemic neutrality, is often criticized for its lingering bitter or metallic aftertaste. Erythritol, on the other hand, offers a sweetness profile and can mask the aftertaste of stevia effectively. By combining these two sweeteners, the study assessed a more consumer-acceptable alternative that more closely mimics the sensory qualities of sugar. This is especially relevant for hospital food services, where taste acceptability plays a crucial role in ensuring patients compliance with dietary prescriptions.

Beyond sensory perception, health awareness and motivation also appear to influence the acceptance of NNS among participants. Many hospitalised diabetic patients in this study were already familiar with sugar restriction as part of their dietary management, which may enhance their openness toward NNS as a healthier sugar substitute. This aligns with the recommendations of the American

Diabetes Association (ADA, 2022), which emphasize the use of low- or non-caloric sweeteners to aid glycaemic control and support dietary compliance. The finding also supports WHO's guideline stating that NNS can be used as a tool to reduce free sugar intake, especially among populations at risk of non-communicable diseases such as diabetes (WHO, 2023). This suggests that participants' cognitive acceptance, derived from awareness of health benefits, may have reinforced their sensory acceptance toward the stevia-erythritol blend. This is consistent with previous findings that diabetic individuals who are aware of the health implications of sugar intake tend to show greater acceptance of NNS as part of dietary management (Farhat et al., 2021).

Overall, these findings emphasize that incorporating acceptable NNS formulations into hospital food services may serve as a practical dietary strategy to enhance compliance without compromising taste or nutritional goals. Conducting this study within a real hospital environment adds clinical relevance, as it reflects the actual context of diabetic dietary management. Such an approach not only supports dietary adherence but also aligns with public health recommendations promoting the reduction of added sugar intake for chronic disease prevention and management.

Strength and Limitation

This study on the acceptance of NNS, specifically a blend of stevia and erythritol, among hospitalised diabetic patients present several strengths that enhance the credibility and practical relevance of the findings. By focusing on hospitalised diabetic patients, the study provides insights that are highly applicable to hospital-based dietary practices and nutritional care. This translational health research allowed for the assessment of NNS acceptance in a realistic context where patients were already engaged in medical nutrition therapy, thereby increasing the ecological validity of the research. Another key strength is the use of a stevia-erythritol blend rather than relying on single sweeteners.

For further research, it is also important to recognize that external variables among the participants such as current medication, illness severity, taste alterations due to malnutrition, and psychological factors could have influenced the sensory evaluation results. Many hospitalised patients experience altered taste perception due to their medical condition or treatment regimen, which may have impacted their ability to accurately assess the sweetness or aftertaste of the NNS.

CONCLUSION

This study indicates that NNS, specifically a blend of stevia and erythritol, are generally acceptable among hospitalised diabetic patients. The majority of participants rated the tea containing NNS positively in terms of sweetness, aftertaste, and overall acceptance. This indicates that NNS can serve as a suitable alternative to sugar in diabetic diets without compromising taste satisfaction.

These results can be used to inform hospital food service practices, particularly in designing diabetic-friendly meals. The positive reception of the stevia-erythritol blend supports its potential inclusion in hospital menus as healthier alternative to sugar, helping improve the palatability of meals and encouraging better dietary compliance among diabetic patients.

In conclusion, this study provides valuable evidence supporting the use of blended nonnutritive sweeteners as a practical strategy to enhance hospital meals and support effective dietary management in patients with T2DM.

Recommendation

Future studies should consider using a broader and more diverse of participants to enhance the generalizability of the result. Including diabetic patients from various hospital, regions, and cultural backgrounds would provide a more accurate reflection of overall acceptance of non-nutritive sweeteners. It is also recommended that future research include a more comprehensive assessment of participants' nutritional status. This will help to identify whether malnutrition plays a role in taste perception, which could affect the way NNS are received and rated during the sensory evaluation.

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