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ORIGINAL ARTICLE

Umami and Other Taste Perceptions in Patients With Parkinson's Disease

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ABSTRACT

Objective Studies of taste perceptions in Parkinson's disease (PD) patients have been controversial, and none of these studies have assessed umami taste. This study aimed to assess umami, along with the other 4 taste functions in PD patients.

Methods Participants were tested for gustation using the modified filter paper disc method and olfaction using the modified Sniffin' Stick-16 (mSS-16) test (only 14 culturally suitable items were used). A questionnaire evaluated patients' subjective olfactory and gustatory dysfunction, taste preference, appetite, and food habits.

Results A total of 105 PD patients and 101 age- and sex-matched controls were included. The body mass index (BMI) of PD patients was lower than that of controls (PD = 22.62, controls = 23.86, $p = 0.028$). The mSS-16 score was 10.7 for controls and 6.4 for PD patients ($p < 0.001$) (normal ≥ 9). Taste recognition thresholds (RTs) for sweet, salty, sour, bitter and umami tastes were significantly higher in PD, indicating poorer gustation. All taste RTs correlated with each other, except for umami. Most patients were unaware of their dysfunction. Patients preferred sweet, salty and umami tastes more than the controls. Dysgeusia of different tastes in patients was differentially associated with poorer discrimination of tastes, an inability to identify the dish and adding extra seasoning to food. BMI and mSS-16 scores showed no correlation in either patients or controls.

Conclusion PD patients have dysgeusia for all five tastes, including umami, which affects their appetite and diet. Patients preferred sweet, salty and umami tastes. This information can help adjust patients' diets to improve their nutritional status.

Keywords Body mass index; Dysgeusia; Olfaction; Parkinson; Taste; Umami.

Parkinson's disease (PD) is a neurological disorder that involves many systems. Olfactory loss, one of the earliest and premotor symptoms, is highly prevalent in patients with PD.[1,2] Dysgeusia or abnormal taste is also a well-known controversial phenomenon in PD. Taste loss has also been reported as a premotor symptom[1] that might result from a loss of smell or taste itself.[3]

Olfactory function can be evaluated by assessing odor identification, discrimination, detection threshold, recognition threshold (RT), memory, hedonics, and intensity using various available tools.[4] In patients with PD, the two most common tests used are the University of Pennsylvania Smell Identification Test (UPSIT) and Sniffin' Sticks-16 (SS-16). The UPSIT is a self-adminis-

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tered 40-item odor identification test that uses microencapsulated odorants that are released by scratching standardized odor-impregnated test booklets.[5] Sniffin' Sticks are pen-like odor dispensing devices that have been used to evaluate odor identification, discrimination, and thresholds.[6] SS-16 consists of 16 test items.[6]

Gustatory function has been evaluated by assessing the taste threshold, identification and intensity.[4] Two primary methods are used to assess gustation−chemogustometry (applying chemical stimuli) and electrogustometry (applying electrical stimuli).[4,7] In chemogustometry, different taste solutions (tastants) are applied to the tongue, either regionally or to the whole mouth, and the taste is identified.[4,8] Tastants can be delivered in different ways, such as using a cup, micropipette, taste strips, filter paper disks, or cotton swabs.[4] In electrogustometry, an electrode is placed on a tongue region, and the tongue is electrically stimulated regionally. Both chemo- and electrogustometry require a subjective response by the patients.[7] Gustatory evoked potentials can provide an objective assessment but are rarely performed.[7]

While the evidence for olfactory dysfunction is quite robust in patients with PD, gustatory dysfunction remains controversial. The gustatory system consists of 5 categories of taste buds−sweet, sour, bitter, salty, and umami tastes. These taste buds are generally distributed throughout the tongue.[8] Some studies examining gustation in patients with PD have revealed dysfunction of some or all tastes, while they are normal in others.[9-17] One of the explanations may be a difference in the testing methodology and different demographic characteristics of participants between studies. Most of the studies have tested only sweet, sour, bitter, and salty tastes in patients with PD, but not umami.

Umami is the taste imparted by a number of substances, predominantly glutamate and 5'-ribonucleotides such as inosinate and guanylate.[18] It gives the food its rich, savory taste. It is also described as inducing a meaty, mouth-watering, tongue coating, earthy, musty or a pleasant after taste.[18] Some of the foods with a high umami taste are *kombu*, the seaweed *nori*, aged cheese, dried shiitake mushroom, fermented products, fish sauce and soy sauce.[19] The global scientific community needed approximately one hundred years to accept umami as one of the basic tastes.[18]

This study investigated gustatory function for all 5 tastes, including umami, and whether patients expressed any taste preference, which might help in improving their nutrition. Additionally, we aimed to study the correlation between olfaction, gustation, and body mass index (BMI) in patients with PD.

MATERIALS & METHODS

This study was conducted in compliance with guidelines on human experimentation and approved by the Institutional Review Board of Faculty of Medicine, Chulalongkorn University (IRB no. 211/57). The study was conducted at King Chulalongkorn Memorial Hospital, Chulalongkorn University from 2015 to 2018. All the participants had a Thai Mental State Examination[20] (TMSE) score of at least 23 and provided informed consent. PD was diagnosed according to the United Kingdom Parkinson's Disease Society Brain Bank (UKPDSBB) criteria.[21] Participants were excluded from the study if they had atypical parkinsonism, allergic rhinitis, upper respiratory tract infection, chronic sinusitis, chronic alcoholism, postoperative status, a history of severe traumatic brain injury or base of skull injury, a history of malignancy, chronic kidney disease, or hypothyroidism or a history of chemotherapy.

Participants were asked about their perception of their sense of smell and taste. If they had abnormal perception, then they were further asked to identify whether the perception was decreased, absent or altered and whether the abnormalities were present only sometimes or all the time. Participants were asked to provide detailed information on food and taste preferences and appetite using a 25-item questionnaire. Participants' weight and height were measured, and smell identification and gustatory tests were performed in both patients and controls.

Smell identification test

Patients and controls were tested with SS-16. We previously validated the SS-16 test kit in our patients with PD (unpublished data by T Kitjawijit and P Jagota, 2015). Only 14 odors were identified by more than 50% of the healthy controls and thus were considered culturally suitable. The cutoff score for olfactory dysfunction in patients with PD was identified as 9. For this study, we used only those 14 significantly relevant odors to test all the participants (turpentine and clove were not used), henceforth the test was designated the modified SS-16 (mSS-16).

Gustatory (taste) identification test

The filter paper disc method[22] (FPD) was modified by using cotton swabs to transfer the tastants instead of filter paper discs. In the FPD method, the filter paper discs are transferred to the tongue using forceps, where the examiner must ensure that the filter paper discs have been dropped onto the tongue and not moved elsewhere. Patients with PD experience rigidity and might have difficulty opening their mouths for a long time. Cotton swabs with the same bud size as filter paper discs (0.5 cm diameter) were used to ensure that an adequate amount of tastants transferred to overcome this problem.

Solutions were prepared to test sweet, salty, sour, bitter, and umami tastes. A sucrose solution was used for sweet, sodium chloride for salty, tartaric acid for sour, quinine for bitter, and monosodium glutamate (MSG) for umami tastes. The concentrations of the solutions for sweet, sour, salty and bitter were prepared at 5 levels based on the FPD method.[22] For umami taste, 6 concentrations of MSG solutions were prepared using the method developed by Satoh-Kuriwada et al.[23] (Table 1).

Participants had to refrain from smoking 1–2 hours before the test and refrain from eating, drinking, and chewing gum at least 30 minutes prior. They were tested by first applying the solution of a randomly selected taste with the lowest concentration (level 1), except for bitter, which was tested last to avoid unpleasantness. A cotton swab was dipped into the solution and then applied for 3 seconds onto the anterior (near the tip) part of the tongue. Then, the cotton swab was removed, and subjects were asked to swallow their saliva once to disperse the taste substance. Subsequently, the participants responded whether they had felt any taste and the name of the taste. If the taste was not identified, the next concentration of the same taste solution was tested using a new cotton swab until the taste was correctly identified or until the highest concentration of that taste solution was reached (level 5 for sweet, salty, sour, bitter and level 6 for umami). The concentration level at which the taste was identified was defined as the taste RT. If the taste was not identified, it was simply defined as "cannot be identified." Then, the participants rinsed their mouth with water several times until no previous taste remained to avoid interference between tastes. The process was then repeated for other tastes in random order ending with bitter taste, as mentioned above. The same process was performed for both patients and controls. The total time for testing all the tastes in a participant was approximately 15 minutes.

Statistical analysis

The chi-square test and Fisher's exact test were used for categorical data, the Mann–Whitney U test was used for ordinal data, and the independent *t* test was used for continuous data to test for significant differences between groups. Spearman's rank correlation, point biserial correlation and Pearson's correlation coefficients were calculated to study the correlations between variables. A p-value < 0.05 was considered statistically significant, except where a significant p-value was derived from the Benjamini-Hochberg procedure to adjust for multiple comparisons.

Table 1. Concentration levels of different solutions used for the gustation test

Level	Concentration of solution (mmol/L)				
	Sucrose (sweet)	Sodium chloride (salt)	Tartaric acid (sour)	Quinine (bitter)	Monosodium glutamate (umami)
1	8.76	51.3	1.33	0.025	1
2	73.0	214	13.3	0.500	5
3	292	856	133	2.52	10
4	584	1,710	267	12.6	50
5	2,340	3,420	533	101	100
6	-	-	-	-	200

RESULTS

One hundred five patients with PD and a total of 101 age- and

Table 2. Demographic data

Demographic data	PD (n = 105)	Control (n = 101)	p-value
Age (yr)	63.3 ± 10.5	61.07 ± 11.1	0.141†
Sex			
Male	50 (47.6)	41 (40.6)	0.310‡
Female	55 (52.4)	60 (59.4)	
Weight (kg)	58.57 ± 12.9	60.66 ± 12.5	0.279†
Height (cm)	160.48 ± 8.8	159.01 ± 8.8	0.276†
BMI	22.62 ± 3.9	23.86 ± 4	0.028*†
Smoking			
Never	83 (79)	82 (81.2)	0.009*‡
Current smokers	2 (1.9)	10 (9.9)	
Past smokers	20 (19)	9 (8.9)	
Alcohol drinking			
Never	73 (69.5)	86 (85.1)	0.006*‡
Current drinkers	10 (9.5)	9 (8.9)	
Past drinkers	22 (21)	6 (5.9)	
Age at PD onset (yr)	53.9 ± 12.3	NA	
Current symptoms			
Tremor	61 (58.1)	NA	
Rigidity	57 (54.3)	NA	
Bradykinesia	73 (69.5)	NA	
Postural instability	34 (32.4)	NA	
Gait problem	50 (47.6)	NA	
Motor complications			
Wearing off	38 (36.2)	NA	
Dyskinesia	24 (22.9)	NA	
H&Y§			
1	1 (1)	NA	
1.5	5 (4.8)	NA	
2	20 (19)	NA	
2.5	61 (58.1)	NA	
3	16 (15.2)	NA	
4	2 (1.9)	NA	

Values are presented as n (%) or mean ± standard deviation unless otherwise indicated. *p < 0.05; †independent t test; ‡chi-square test; §during the motor "on" stage. Median H&Y stage = 2.5. H&Y, Hoehn and Yahr stage; NA, not applicable; PD, Parkinson's disease; BMI, body mass index.

sex-matched controls were included. Some of the controls did not answer some parts of the questionnaires; therefore, the number of controls is different for different parts. Demographic data are provided in Table 2. Weight and height were not different between patients with PD and controls, but the BMI was significantly higher in controls (PD = 22.62, controls = 23.86, $p = 0.028$), as well as smoking and drinking history ($p = 0.009$ and $p = 0.006$, respectively). The median Hoehn and Yahr (H&Y) stage was 2.5 (range 1–4). The prevalence of diabetes mellitus (DM) in patients and controls was 14.29% and 11.88% ($p = 0.761$), and hypertension (HT) was 25.71% and 37.62% ($p = 0.091$), respectively.

Table 3. Results of smell identification, taste and odor perception, preferred taste and dry mouth

Parameters	PD ($n = 105$)	Control ($n = 101$)	*p*-value
Mean modified Sniffin' Stick-16 score (total 14 odors)‖	6.4	10.7	< 0.001*†
Is your smell sensation normal?			
Yes	78 (74.3)	61 (98.4) ($n = 62$)	< 0.001*‡
No	27 (25.7)	1 (1.6)	
Olfaction abnormality			
Decreased	23 (85.2)	1 (100)	
Absent	2 (7.4)	0 (0)	
Altered	2 (7.4)	0 (0)	
Persistence of olfaction abnormality			
Present all the time	12 (44.4)	1 (100)	
Present sometimes	15 (55.6)	0 (0)	
Is your taste sensation normal?			
Yes	90 (85.7)	60 (98.4) ($n = 61$)	0.008*‡
No	15 (14.3)	1 (1.6)	
Gustatory abnormality			
Decreased	13 (86.7)	1 (100)	
Absent	1 (6.7)	0 (0)	
Altered	1 (6.7)	0 (0)	
Persistence of gustatory abnormality			
Present all the time	7 (46.7)	1 (100)	
Present sometimes	8 (53.3)	0 (0)	
Preferred taste			
Sweet	54 (51.4)	29 (28.7)	0.001*‡
Salty	35 (33.3)	16 (15.8)	0.004*‡
Sour	36 (34.3)	42 (41.6)	0.280‡
Bitter	1 (1)	2 (2)	0.616§
Umami	6 (5.7)	0 (0)	0.029*§
Dry mouth	8 (7.6)	8 (10.8) ($n = 74$)	0.461‡

Values are presented as *n* (%) unless otherwise indicated. Some of the controls did not answer some parts of the questionnaires, therefore, the number of controls is different for different parts. *$p < 0.05$; †independent *t* test; ‡chi-square test; §Fisher's exact test; ‖validation of the smell test in the Thai Parkinson's disease (PD) population shows that only 14 items are useful for the test (turpentine and clove were omitted from the test).

Patients were more likely to perceive themselves as having abnormal smell and taste sensations than controls ($p < 0.001$ and $p = 0.008$, respectively) (Table 3). Most patients identified themselves as having decreased olfaction and gustation, with abnormalities present all the time in approximately 45% of the patients. Patients significantly preferred sweet ($p = 0.001$), salty ($p = 0.004$), and umami ($p = 0.029$) tastes compared to controls. The prevalence of dry mouth in both groups was not different ($p = 0.461$).

Of the 25 items on the food and appetite questionnaire (Table 4), 3 items were significantly different between patients and controls after adjusting for multiple comparisons using the Benjamini-Hochberg procedure with a false discovery rate of 0.2. Patients felt that they had lost appetite ($p = 0.001$). Food taste was more important to the patients than controls ($p = 0.001$), and they had to add sugar or other sweet ingredients to their food more frequently than the controls ($p = 0.012$).

The mean mSS-16 score (14 items) was 10.7 for controls and 6.4 for patients with PD ($p < 0.001$) (cutoff score for normal is 9) (Table 3). The gustatory RT test revealed that patients identified the correct tastes at a significantly higher concentration level for all tastes (Figure 1). The mode (highest frequency) of recognition for each taste in patients was level 3 for sweet, 2 for salty, 3 for sour, 3 and 4 for bitter and 6 for umami. In controls, it was level 2 for sweet, 2 for salty, 3 for sour, 2 for bitter and 4 for umami.

Spearman's correlation tests showed no correlation between the BMI and mSS-16 score in either patients or controls, or between the BMI and H&Y stage, and H&Y stage and mSS-16 in patients. In patients with PD, BMI exhibited a small but significant ($p = 0.037$, $\rho = 0.204$) correlation with the salty taste RT, and small correlations were observed between the H&Y stage with bitter ($p = 0.030$), and umami ($p = 0.021$) taste RTs ($\rho = 0.212$ and $\rho = 0.258$, respectively), indicating that a poorer salty taste sensation was associated with an increased BMI and poorer bitter and umami taste sensations were associated with more severe disease stages. In the control group, the bitter taste RT exhibited a small but significant inverse correlation with the mSS-16 score ($p = 0.026$, $\rho = -0.258$). Thus, a poorer bitter taste sensation was associated with a poorer olfactory score in controls.

Spearman's correlation analysis was conducted to study whether the five taste RTs had any correlations. All the tastes correlated positively with each other in both patients and controls, with moderate to large effect sizes (Table 5), except for umami and sweet RTs in patients with PD ($p = 0.486$), and umami and sweet ($p = 0.059$), umami and bitter ($p = 0.055$) and umami and sour ($p = 0.369$) RTs in controls.

Regarding Pearson's correlation coefficients between the 25 items on the food and appetite questionnaire (Table 4) and the five taste thresholds, the salt RT was negatively and mildly cor-

Table 4. Percentage of 'yes' to food and appetite questionnaire

No.	Questions	PD (*n* = 105)	Control (*n* = 74)	*p*-value*
1	You feel that you eat less than before.	36.2	23	0.059
2	Do you feel that you experience the taste of food less than before?	32.4	18.9	0.045
3	You feel that your food is not as tasty as before.	39	25.7	0.062
4	You have lost your appetite.	34.3	12.2	0.001†
5	You have lost weight.	34.3	20.3	0.041
6	You must add extra seasoning to every food.	25.7	23	0.675
7	You feel that your taste sensation has changed.	26.7	13.5	0.034
8	When eating food, you must add fish sauce, salt, soy sauce, or other salty ingredients.	29.5	20.3	0.163
9	When eating food, you must add lemon, vinegar, or other sour ingredients.	26.7	31.1	0.519
10	When eating food, you must add sugar or other sweet ingredients.	29.5	13.5	0.012†
11	When eating food, you must add monosodium glutamate or other ingredients to make the food taste better.	13.3	16.2	0.590
12	When eating food, you must add chili.	34.3	40.5	0.393
13	The taste of food is very important to you.	67.6	43.2	0.001†
14	You can discriminate between different tastes of food, e.g., salty, sweet, sour, and bitter.	86.7	82.4	0.436
15	When you start eating, you can determine the taste of the food.	92.4	82.4	0.042
16	When you start eating, you can identify what dish it is.	88.6	81.1	0.161
17	You can determine how spicy the food is.	86.7	82.4	0.436
18	You have oral health problems, such as tooth decay, broken teeth or oral ulcers.	51.4	45.9	0.470
19	Your financial difficulties limit your food choices.	12.4	17.6	0.332
20	Your depression causes a loss of appetite.	18.1	10.8	0.180
21	Your nausea or vomiting causes a loss of appetite.	9.5	5.4	0.312
22	You feel that your medication causes nausea and loss of appetite.	9.5	12.2	0.573
23	You feel that you want to eat more when you add extra seasoning.	41.9	32.4	0.199
24	You cook yourself.	61.9	59.5	0.741
25	You like to eat what you or your family cook rather than ready-to-eat food.	74.3	78.4	0.528

*chi-square test; †significant *p*-values were adjusted for multiple comparisons using the Benjamini-Hochberg procedure with a false discovery rate (FDR) of 0.20. PD, Parkinson's disease.

related with question 14 in patients with PD ($p = 0.041$, $r = -0.20$). The umami taste RT was also negatively and mildly correlated with question 14 ($p = 0.019$, $r = -0.263$) in the patients. Based on these results, higher salt and umami RTs, i.e., poorer salt and umami taste sensations, tend to be associated with a poorer ability of patients with PD to discriminate between different tastes of food. Umami was additionally mildly and negatively correlated with questions 15, 16 and 17 in patients ($p = 0.026$, $r = -0.248$; $p = 0.012$, $r = -0.281$; $p = 0.026$, $r = -0.249$, respectively). Therefore, a poorer umami taste sensation in patients with PD tends to be associated with a lower ability to discriminate the taste of food (e.g., sweet, salty, bitter, and sour), what dish it is and how spicy the food is. The sour taste RT was mildly correlated with question 5 in controls ($p = 0.029$, $r = 0.253$) and mildly and negatively correlated with question 20 in patients with PD ($p = 0.029$, $r = -0.214$). Based on this finding, a poorer sour taste sensation tends to be associated with weight loss in controls, and patients with PD are less likely to lose their appetite because of depression. The bitter taste RT was mildly correlated with question 6 in patients with PD ($p = 0.029$, $r = 0.213$). Thus, a poorer bitter taste sensation tends to be associated with the addition of extra seasoning to food by patients with PD. The sweet RT was not correlated with any of the questions in either patients or controls.

The point biserial correlation analysis was conducted for the 25-item questionnaire and BMI and mSS-16. In patients with PD, BMI was negatively correlated with questions 5 and 19 ($p = 0.029$, $r_{pb} = -0.24$ and $p = 0.021$, $r_{pb} = -0.25$, respectively). BMI was positively correlated with question 25 ($p = 0.027$, $r_{pb} = 0.24$). These results indicate that weight loss and financial difficulties tend to be associated with lower BMI values in patients with PD. Liking to eat what the patient or the patient's family cooks rather than ready-to-eat food tends to be associated with higher BMI values. mSS-16 scores for both the patients and the controls and BMI of the controls were not correlated with any of the questions.

DISCUSSION

Our study showed a significantly lower BMI in patients than in controls, consistent with previous studies,[24,25] although their

BMI was within the normal category. As reported in the literature, patients have impaired olfactory function. The present study showed that patients also have impaired gustatory function for all tastes, including umami, compared to controls. Previous studies have tested sweet, salty, sour, and bitter tastes.[9-17] They did not test umami taste. This study, to our knowledge, is the largest study testing taste sensation in patients with PD and is the only study that has tested umami taste sensation in patients with PD. Hypogeusia for all tastes was present, where patients identified all the tastes at higher concentration levels than the controls. One patient could not identify sweet taste, 2 could not identify salty taste, and 9 could not identify umami taste. All patients could identify sour and bitter tastes. Hence, the level of taste loss in patients may be unequal for different tastes. Cecchini et al.[26] showed that sour and salty taste identification was worse in patients with PD presenting a mild cognitive impairment and executive dysfunction. Another study in Asia by Kim et al.[15] found that female patients with PD had taste impairment, as identified by lower filter paper taste strip test (TST) scores, which tested sweet, sour, salty and bitter tastes (not umami). However, the impairment was attributable to a lower Mini-Mental State Examination (MMSE) score.[15] Therefore, differential taste loss might be the result of differential anatomical dysfunction. Regardless, all the patients in this study could still taste some of the tastants, although at higher concentrations.

The loss of various tastes is correlated significantly and positively with each other. Hence, the loss of one taste will be associated with the loss of another taste, although they may be at different levels, as mentioned above. The exception for this is the umami taste. The umami taste threshold was not correlated with

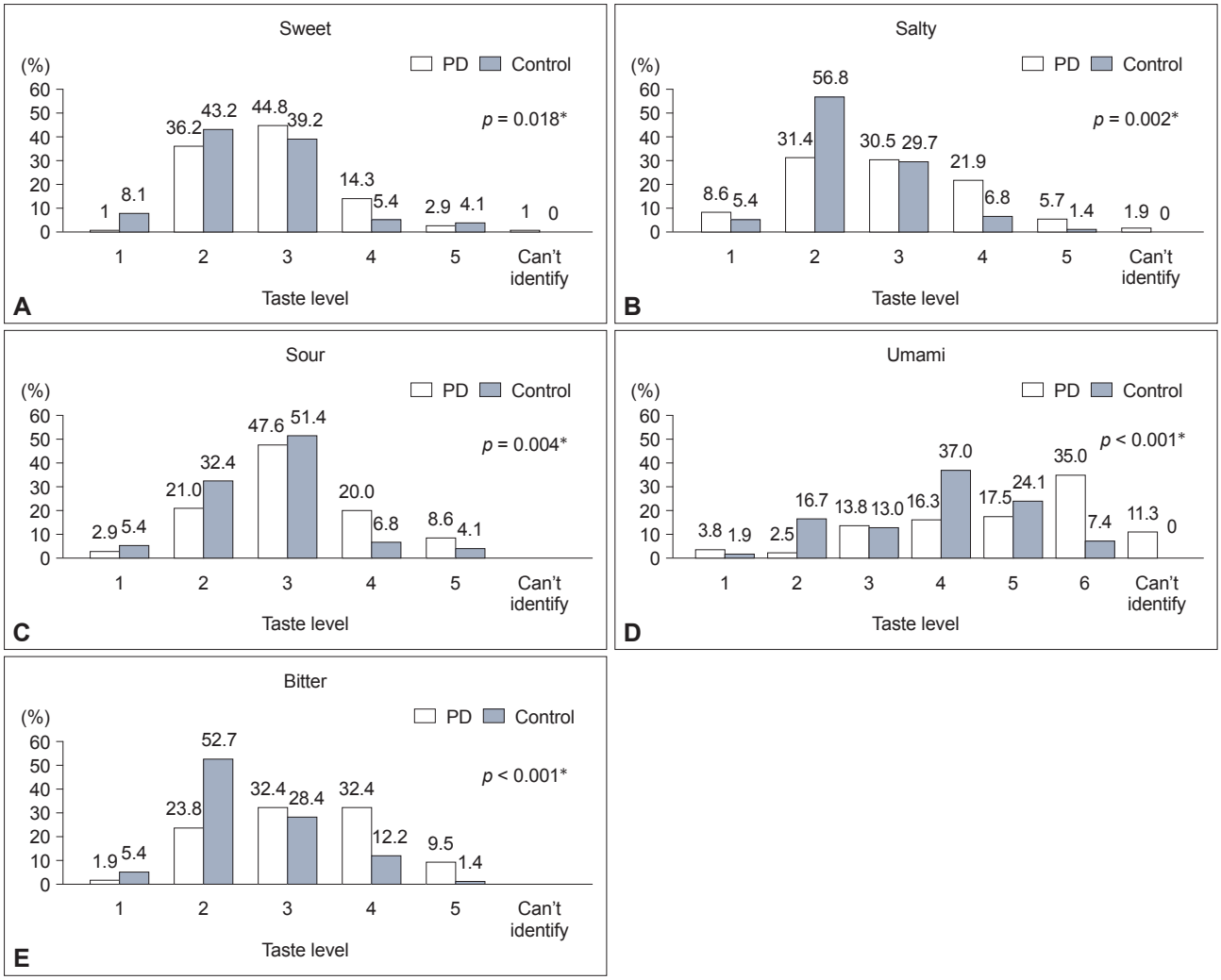

Figure 1. Results of the taste recognition threshold. Gustatory results showing a significantly higher taste recognition threshold (RT) in patients with Parkinson's disease (PD) than in controls for all tastes, implying poorer gustation in PD. A: PD patients' mode (highest frequency) for sweet RT is 3, while it is 2 for controls. B: PD patients' mode for salty RT is 2 as in controls but > 50% of the patients have RT > 2. C: Mode for sour RT is 3 for both PD and controls, but more PD patients have RT of 4 and 5. D: Mode for umami RT is 6 in PD and 4 in controls. E: Modes for bitter RT are 3 and 4 in PD and 2 in controls.

Table 5. Results of the correlation analysis between various taste recognition thresholds in patients with PD and controls

Combination	PD		Control	
	p-value*	ρ†	*p*-value*	ρ†
Sweet recognition threshold & salt recognition threshold	< 0.001*	0.38	0.023*	0.31
Sweet recognition threshold & bitter recognition threshold	< 0.001*	0.38	< 0.001*	0.70
Sweet recognition threshold & sour recognition threshold	0.011*	0.28	< 0.001*	0.45
Sweet recognition threshold & umami recognition threshold	0.486	0.08	0.059	0.26
Salt recognition threshold & bitter recognition threshold	0.002*	0.34	0.002*	0.42
Salt recognition threshold & sour recognition threshold	< 0.001*	0.38	0.024*	0.31
Salt recognition threshold & umami recognition threshold	0.007*	0.30	0.016*	0.33
Bitter recognition threshold & sour recognition threshold	< 0.001*	0.36	0.009*	0.35
Bitter recognition threshold & umami recognition threshold	0.026*	0.25	0.055	0.26
Sour recognition threshold & umami recognition threshold	< 0.001*	0.37	0.369	-0.12

*Holm corrections were used to adjust *p*-values. $p < 0.05$ is considered significant; †Spearman's rank correlation coefficient. PD, Parkinson's disease.

the sweet RT in patients or with the sweet, bitter or sour thresholds in controls. Moreover, more umami nonidentifiers were observed than any other taste. The level of the umami RT was also the highest (level 6 in patients and 4 in controls). It may explain the lack of a correlation. Previous studies have also reported a higher RT for umami than for other tastes in the elderly.[27]

Thai people consume more MSG per day than Japanese people (3.6 g/day vs. 1.2–1.7 g/day).[27] Regular consumption of a larger amount of a tastant may increase its RT.[28] For the umami nonidentifiers (as with other tastes) in this study, we do not know whether they have a RT that is higher than the maximum level in this study or whether they are ageusic for the taste. A study with a higher concentration of tastants may provide insights into this issue.

Patients significantly perceived their abnormal olfaction and gustation. However, although the number of patients who perceived that their olfactory and gustatory functions were impaired was significantly higher than that of the controls, the majority of the patients still perceived them to be normal. This finding confirms previous reports that subjective taste and smell impairment identification is low.[29,30]

Based on the responses to the questionnaire, patients had to add sugar or other sweet ingredients to their food. Overall, the food and appetite questionnaire showed that dysgeusia in patients is associated with a poorer appetite, poorer ability to discriminate the taste of food and its spiciness, and a poorer ability to identify the dish. These limitations may have resulted in patients adding extra seasoning to their food. Losing weight and having financial difficulties were associated with a lower BMI, while eating home-cooked food was associated with a higher BMI in patients. On the other hand, the mSS-16 score was not associated with any of the questions. Their ageusia may have been attributed to their loss of appetite and rendered the taste of food more important to them. Hence, education on home-cooked, nutritious food with appropriate seasoning may be provided to patients and their caregivers to improve the patients' appetite and nutrition and reduce their financial burden.

In the present study, BMI did not correlate with olfactory function (mSS-16 score) in either patients or controls. It showed a small correlation with salty taste. The severity of the disease, as represented by H&Y staging, showed a small correlation with bitter and umami tastes but not with BMI and mSS-16 scores. Interestingly, in the controls, bitter taste exhibited a small inverse correlation with mSS-16 scores. Therefore, the poorer the olfactory function, the less participants can identify bitter taste. Correlation results vary from study to study. In contrast to this study, Roos et al.[11] found a small correlation between olfactory function and BMI but not gustatory function and BMI. Shah et al.[13] did not observe effects of age, disease severity or duration on gustation in patients with PD. In contrast, De Rosa et al.[10] identified a correlation between gustation and disease severity and stage. Kim et al.[15] found no significant correlations between the TST score and age, H&Y stage, disease duration, MMSE score, MoCA score, or smell test score, even when their data were analyzed separately according to sex.

Taste preference in humans has developed since childhood. The body usually prefers particular tastes to obtain the nutrients it needs–sweet for energy (carbohydrates), salty for minerals and umami (savory) tastes for proteins.[31] A bitter taste represents toxic food, and sour represents acids, and thus these foods are usually avoided.[31] Patients in this study preferred sweet, salty, and umami tastes more than the controls. Increased energy and nutritional requirements from motor symptoms and malnutrition may explain these preferences.[24,32] Patients added significantly more sweet ingredients to their food. The sweet preference in humans is evident beginning in the prenatal period.[33] Some studies have shown that, unlike other tastes' RT, sweet RT does not significantly increase with aging.[30,34,35] Meyers et al.[36] reported an

increased sweet preference, sweet consumption, and ice cream preference in patients with PD compared to controls. However, in another study by Sienkiewicz-Jarosz et al.,[37] pleasantness ratings of sucrose solutions did not differ between patients and controls. However, this study involved only 20 patients.

Malnutrition is more prevalent in the later stages of PD.[32] As patients with a low BMI have a poorer survival prognosis,[38] malnutrition prevention should be initiated early in the course of the disease to maintain a normal BMI. Knowledge of patients' preferences for food taste and type can help relieve this issue. Flavor has sometimes been confused with taste. Olfaction, gustation, and mechanosensation of the tongue together send signals to the orbitofrontal cortex where the pleasantness or unpleasantness of food is perceived. This perception constitutes flavor. The smell or taste of the food along with the texture, sight, and anticipation of the food affect flavor. Therefore, studies aiming to improve nutrition or quality of life (QoL) related to food intake may need to consider factors other than olfaction and gustation.

This study has a few limitations. First, the validation of SS-16 in patients with PD by our group is unpublished (by T Kitjawijit and P Jagota, 2015). Second, although the BMI of patients was lower than that of the controls, patients with PD included in the present study had a normal BMI. Hence, the result may be different in malnourished or low BMI patients. As the study showed impaired gustation in this group with an almost high BMI, the impairment may be more pronounced in the lower BMI group. Further studies will be needed to validate this assumption. We did not study the effects of medications on tastes, which is another limitation of this study, although a previous study has shown that the taste test score was not associated with the levodopa equivalent dose.[9] Some small correlations between some tastes and the H&Y stage and BMI were observed in patients. As stated above, correlation studies remain controversial. More extensive studies are needed to investigate this issue further.

Conclusions

This study confirms olfactory and gustatory dysfunction for all tastes, including umami, in patients with PD. Most of the patients are unaware of them. They may unconsciously add extra seasoning or sweet ingredients to overcome taste dysfunction.

Patients have a preference for sweet, salty, and umami tastes. Increased sweet consumption is evidenced by adding extra sweet ingredients to their food. This information may be of use when providing counseling or adjusting patients' diets to treat or prevent malnutrition. Adjustments in the diet must counterbalance increased risks of DM, HT, and other acquired disorders in patients. The addition of artificial sweeteners, food enhancers and seasonings, an understanding of food combination types according to ethnicity, or other strategies may need to be used to improve the "flavor" of food and QoL of patients.

Conflicts of Interest

The authors have no financial conflicts of interest.

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