Identification and enjoyment of food items is reduced in dysosmic subjects: a pilot study *

Jordan J. Allensworth, Rodney J. Schlosser, Zachary M. Soler

Department of Otolaryngology - Head & Neck Surgery, Medical University of South Carolina, Charleston, SC, USA

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Abstract

Background: Although dysosmia affects a significant proportion of the adult population, there are a paucity of studies addressing its impact on flavor perception and food enjoyment. This study aimed to assess flavor perception and food enjoyment in subjects with and without dysosmia, comparing performance of items considered olfactory-dominant or trigeminal-dominant.

Methods: Adult subjects prospectively underwent Sniffin' Sticks olfactory testing from which threshold, discrimination, and identification (TDI) scores were used to identify dysosmic (TDI < 31) and normosmic subjects (TDI >31). Forced-choice, blinded flavor identification testing was performed using 8 flavor extracts and 8 real-food purees of either trigeminal- or olfactory-dominant flavor profile. Food enjoyment was quantified using visual analog scales.

Results: Forty-one subjects were enrolled, including 20 dysosmics and 21 normosmics, with no difference in age or gender. Compared with normosmics, dysosmic subjects had significantly lower identification of extracts and purees. Among dysosmics, overall identification of trigeminal-dominant extracts and foods was higher than olfactory-dominant extracts and foods. Compared with normosmics, dysosmic subjects reported significantly reduced enjoyment of olfactory-dominant extracts and foods; however, there was no significant difference in enjoyment of trigeminal-dominant extracts or foods.

Conclusions: Identification and enjoyment of food items is reduced in dysosmic subjects, with the greatest impact in olfactory items. These findings suggest that diet modification might lead to greater enjoyment in those with dysosmia.

Key words: olfaction disorders, taste, smell, quality of life, olfactory perception, patient reported outcome measures

Introduction

Olfactory impairment has been found to impact a significant proportion of adults with higher rates in the elderly and those with inflammatory conditions of the upper aerodigestive tract including allergic rhinitis (AR) and chronic rhinosinusitis (CRS) [1-8]. Dysosmia is an established contributor to reduced quality of life, and has been linked with mood changes, decreased perception of hygiene, inability to detect spoiled foods or toxic vapors, and even mortality [9-11]. Patients with olfactory loss also frequently report altered flavor perception, typically complaining that food is bland and no longer enjoyable.

Despite the high population prevalence of olfactory dysfunction, investigations into flavor perception and enjoyment remain limited. Prior studies investigating dysosmia and taste have focused on gustatory input alone, and are limited largely to the addition of salt or monosodium glutamate (MSG) [12]. These studies do not fully reflect the composite flavor perception experienced in daily life, consisting of combined olfactory, gustatory and trigeminal sensation [13]. Specifically, it is known that cutaneous trigeminal nerve endings, including those innervating mucosal surfaces, detect chemicals and modulate taste through a process known as chemesthesis or cutaneous chemosensation [14,15]. The aim of this study was to determine if subjects with dysosmia identify or enjoy food items differently when compared with normosmic controls. Within this framework, we additionally sought to determine if trigeminal- or olfactory-dominant flavor profiles are experienced differently by dysosmic subjects when compared with normosmic controls.

Materials and methods

Recruitment and study population

Adults ≥18 years were enrolled prospectively into a cross-sectional, case-control study from the community around the Medical University of South Carolina (MUSC, Charleston, SC, USA) prior to the COVID-19 pandemic. Exclusion criteria included current or previous dysphagia, parenteral nutrition dependence, head or neck radiation, traumatic brain injury, chemotherapy, Alzheimer's Disease, Parkinson's Disease, multiple sclerosis, current pregnancy, sinus surgery within 6 months, and olfactory or gustatory impairing medications [16]. Demographic information including age, gender, body mass index (BMI), and highest education level was collected. Comorbidities including depression, diabetes mellitus, smoking history, chronic rhinosinusitis with (CRSwNP) or without polyposis (CRSsNP), and allergic rhinitis were noted. The diagnosis of CRSwNP or CRSsNP was made previously in subjects using Clinical Practice Guideline of the American Academy of Otolaryngology–Head and Neck Surgery, the European Position Paper on Rhinosinusitis and Nasal Polyps (EPOS2012), and the International Consensus Statement on Allergy and Rhinology [17-20]. Presence of nasal polyps was determined based on nasal endoscopy. The presence of allergic rhinitis was determined based on prior physician's diagnosis and confirmation with previous positive objective testing. The study was reviewed and approved by the MUSC Institutional Review Board and written informed consent was obtained for all participants.

Patient-reported assessments

Subjects completed a validated and abbreviated version of the Questionnaire of Olfactory Disorders, (QOD-NS), an olfactory-specific quality of life survey which uses Likert-scale responses to measure 17 negative statements. Responses indicated: 0="I agree" to 3="I disagree". In this survey lower scores were considered reflective of better QOL and subjectively determined olfactory function (total score range: 0-51). Subjects also completed the Patient Health Questionnaire-9 (PHQ-9), a 9-item depression screening module from the Patient Health Questionnaire [21]. In this module, scores ≥5 are concerning for depression.

Psychophysical olfactory testing

Orthonasal olfactory testing was performed using the "Sniffin' Sticks" test (Burghardt, Wedel, Germany). This examination evaluated three separate domain items of olfactory function including: odorant threshold (T, score range: 1-16), odorant discrimination (D, score range: 0-16), and odorant identification (I, score range: 0-16). Correct responses are summarized into a composite TDI total score (score range: 1-48) with higher scores reflecting superior olfaction. For the purposes of this study, dysosmia was defined as a TDI score ≤31, while normosmia was defined as TDI score>31. These cutoffs were established based on normative data and correspond to the 10th percentile for age 15-35 years [22].

Food extracts testing

Objective flavor testing was performed using commercially available flavor extracts from the manufacturer McCormick Company (Hunt Valley, MD, USA) [23]. Flavor extracts were selected based on prior development for commercial alimentary use and approval by the Food and Drug Administration (FDA) and subsidiary US Flavor and Extract Manufacturers Association (FEMA) in the United States. Flavor extracts consisted of extract, water and alcohol. Flavor testing was conducted in accordance with previously described protocols [24,25]. Flavors extracts were selected based on previously established olfactory or trigeminal dominant profiles, with olfactory extracts including vanilla, raspberry, banana and chocolate, and trigeminal-dominant extracts including anise, cinnamon, peppermint, and lemon [15,24]. Distilled water was included as a control item. Extracts were diluted in distilled water, and concentrations were established by pretesting with normosmic subjects separate from study participants to determine easily detectable concentrations. Extract selection and concentrations can be found in Table 1. Subjects were blindfolded and provided with 5mL aliquots of each flavor or control. Subjects were instructed to either swallow or swish and spit each extract preparation. Subjects then rinsed with distilled water twice between sample items, allowing at least 30 seconds or additional time if any taste lingered. Following administration, subjects were asked to identify each tastant from 5 possible choices in a forced-choice paradigm. A 100mm Visual Analogue Scale (VAS) was used to assess enjoyment, with no marks and the left and right limits being identified (i.e. lowest enjoyment vs highest enjoyment), consistent with contemporary food and sensory research [26,27]. In addition, subjects were provided with a blank comments section to enter any comments on tested items as desired.

Food purees testing

Food-based flavor testing was performed using standardized, commercially available food purees with complete ingredient lists readily available (Table 1). Purees were applied in ½ teaspoon portions to a 1.5 x 1.5 cm square piece of white bread from a single large-scale producer. Subjects were blindfolded, and the food item and carrier were placed on the anterior tongue and then chewed and swallowed. Similar to flavor extract testing, subjects rinsed with distilled water twice between sample items, attempted to identify each food item from 5 possible choices in a forced-choice paradigm, completed a VAS rating food enjoyment (100mm), and were provided a blank section to enter comments if desired. Enjoyment was scaled by subtracting each subject's rating of control items, including distilled water alone for extracts and plain bread for purees, such that scores

Table 1. Flavor extracts and food items used.

Sensory category (predominant)	Flavor Extract	Drops in 5 mL*	Concentration (volume %)	Food item/ Puree
Olfactory	Vanilla	4	4	Vanilla
	Raspberry	4	4	Peach
	Banana	4	4	Banana
	Chocolate	4	4	Carrot
Trigeminal	Anise	2	2	Ginger
	Cinnamon	2	2	Garlic
	Peppermint	0.5	0.5	Mustard
	Lemon	3	3	Lemon
Control/ Carrier	Water (alone)	n/a	n/a	White bread

*1 drop = 0.05 mL

could range from -100 to +100.

Statistical analysis

Statistical analysis was completed using Statistical Package for Social Sciences (SPSS) version 24.0 software (IBM Corporation, Armonk, NY, USA). Across all statistical analysis, a p value of ≤0.050 was considered statistically significant. To assess demographic data, descriptive statistics were employed including mean, standard deviation and percentage values (%). When comparing normosmic and dysosmic subjects, including mean differences in demographic and comorbidity data, independent samples t-tests were employed. When comparing categorical data, Chi-squared ($\chi 2$) and Fishers exact tests were utilized.

Results

Study cohort

There were 41 total subjects in the study cohort, including n=20 classified as dysosmic (TDI=21.4 ± 8.1) and n=21 classified as normosmic (TDI=33.6 ± 2.3) (Table 2). There was no significant difference between groups regarding gender, age, or educational level. As expected, the dysosmic group had worse olfactory-specific QOL as determined by the QOD-NS (12.1 ± 11.5 vs 5.4 ± 6.6; p=0.03). With regard to comorbidities, subjects with dysosmia were more likely to have CRSwNP (40.0% vs 9.5%; p=0.02) and prior positive allergy testing (50.0% vs 14.3%; p=0.01). The prevalence of other comorbid conditions was not significantly different between groups, including depression, tobacco abuse, and diabetes mellitus among others.

Identification of food extracts and purees

The ability of study subjects to successfully identify food extracts and purees is displayed in Table 3 and Figure 1. Dysosmic subjects performed significantly worse at identifying olfactory-dominant food extracts (43.7 ± 29.1% vs. 84.5 ± 20.1%, p < 0.01) and purees (52.5 ± 24.2 % vs. 75.0 ± 17.7 %, p < 0.01). Similarly, dysosmic subjects performed significantly worse at identifying trigeminal-dominant food extracts (67.5 ± 33.5% vs. 97.6 ± 7.5%, p < 0.01) and purees (76.3 ±25.0% vs. 94.1 ± 10.9 %, p < 0.01). Subjects were better able to identify trigeminal-dominant food extracts and purees as compared to olfactory-dominant items (Table 4), with effects most pronounced for dysosmic subjects.

Table 2. Demographics and comorbidities.

		Dysosmic N (%) or Mean ± SD	Normosmic N (%) or Mean ±SD	p
Total (N)		20	21	
Sex	Male	9 (45.0)	9 (42.9)	0.89
	Female	11 (55.0)	12 (57.1)	
BMI		27.3 ±6.0	27.2 ±4.6	0.98
Age in years		62.0 ± 13.2	57.3 ±10.7	0.22
Education in years		15.6 ±2.0	16.3 ±2.1	0.16
QOD-NS		12.1 ±11.5	5.4 ±6.6	0.03*
PHQ-9		4.3 ±0.9	2.9 ±0.8	0.25
		Dysosmia N (%)	**Normosmia N (%)**	**p**
Asthma		7 (35.0)	3 (14.3)	0.12
GERD		6 (30.0)	5 (23.8)	0.66
Depression		3 (15.0)	3 (14.3)	0.95
Diabetes mellitus		2 (10.0)	3 (14.3)	0.21
OSA		4 (20.0)	5 (23.8)	0.94
CRSwNP		8 (40.0)	2 (9.5)	0.02*
CRSsNP		3 (15.0)	4 (19.0)	0.73
Past or present smoker		9 (45.0)	6 (28.6)	0.62
Allergic rhinitis		12 (60.0)	11 (52.4)	0.62
Allergy testing history		10 (50.0)	3 (14.3)	0.01*
Immunotherapy		4 (20.0)	0 (0.0)	0.11

Scaled enjoyment outcomes

The impact of dysosmia on scaled enjoyment outcomes is detailed in Table 5 and Figure 1. When tasting olfactory-dominant foods, dysosmic subjects reported significantly lower enjoyment scores compared with normosmic control subjects (4.7 ± 15.4 vs. 16.6 ± 16.3, p = 0.02). Notably, there was no significant difference in enjoyment of trigeminal-dominant foods between dysosmic and normosmic subjects. In dysosmic subjects, the highest enjoyment scores were reported for trigeminal-dominant purees (10.3 ± 20.8 vs. 5.2 ± 30.5), although this difference was not statistically significant (p = 0.38) (Table 4).

Table 3. Identification outcomes.

		Normosmic, % correct, mean (SD)	Dysosmic, % correct, mean (SD)	p
Olfactory Identification	Extract	84.5 (20.1)	43.7 (29.1)	<0.01*
	Puree	75.0 (17.7)	52.5 (24.2)	<0.01*
	Total	79.8 (16.0)	46.3 (23.3)	<0.01**
Trigeminal Identification	Extract	97.6 (7.5)	67.5 (33.5)	<0.01**
	Puree	94.1 (10.9)	76.3 (25.0)	<0.01*
	Total	95.8 (6.0)	71.9 (25.3)	<0.01**
Overall Identification	Extract	91.1 (10.6)	55.6 (12.5)	<0.01**
	Puree	84.5 (10.4)	64.4 (18.8)	<0.01*
	Total	87.8 (8.0)	60.0 (9.38)	<0.01**

Table 4. Outcomes within dysosmic and normosmic grouped subjects.

			Normosmic, % correct, mean (SD)	Dysosmic, % correct, mean (SD)	p
Dysosmic	Identification, (% correct)	Flavors	43.8 (29.1)	67.5 (33.5)	0.02*
		Purees	52.5 (24.2)	76.3 (25.0)	<0.01*
		Total	46.3 (23.3)	71.9 (25.3)	<0.01*
	Enjoyment	Flavors	4.3 (18.8)	6.9 (22.7)	0.69
		Purees	5.2 (14.5)	10.3 (20.8)	0.38
		Total	4.7 (15.4)	8.6 (19.6)	0.49
Normosmic	Identification, (% correct)	Flavors	84.5 (20.1)	97.6 (7.5)	0.40
		Purees	75.0 (17.7)	94.1 (10.9)	<0.01**
		Total	79.8 (16.0)	95.8 (6.0)	<0.01**
	Enjoyment	Flavors	18.0 (17.8)	15.4 (25.7)	0.71
		Purees	15.2 (21.6)	14.6 (27.1)	0.94
			16.6 (16.3)	15.0 (23.5)	0.80

* $p < 0.05$, significant difference between normosmic and dysosmic subjects. ** $p < 0.001$, significant difference between normosmic and dysosmic subjects.

Subjective commentary

Participation in the comments section for each item was noted primarily in dysosmic subjects. Representative commentary for trigeminal items includes "Now this one I know is mustard," (mustard puree), "I can sense a difference and tingle with this one," (peppermint extract), "This one I can actually taste," (anise extract), "For this one I feel something," (ginger puree), "This one is finally clear to me," (garlic puree), and "This one feels cool," (peppermint extract). All but one comments were reserved for trigeminal items.

Discussion

In this prospective study of flavor perception including identification, enjoyment, and commentary in community-dwelling adults, we found that the experience of flavor was significantly impacted by olfactory ability as well as the flavor profile of the item tested. As expected, identification of olfactory-dominant extracts and purees was significantly worse among dysosmic subjects when compared with normosmic subjects. In general, identification of trigeminal-dominant flavors was significantly better compared with olfactory-dominant flavors in

Table 5. Scaled enjoyment outcomes.

		Normosmic, mean (SD)	Dysosmic, mean (SD)	p
Olfactory	Extract	18.0 (17.8)	4.3 (18.8)	0.02*
	Puree	15.2 (21.6)	5.2 (14.5)	0.09
	Total	16.6 (16.3)	4.7 (15.4)	0.02*
Trigeminal	Extract	15.4 (25.7)	6.9 (22.7)	0.27
	Puree	14.6 (27.1)	10.3 (20.8)	0.57
		15.0 (23.5)	8.6 (19.6)	0.35

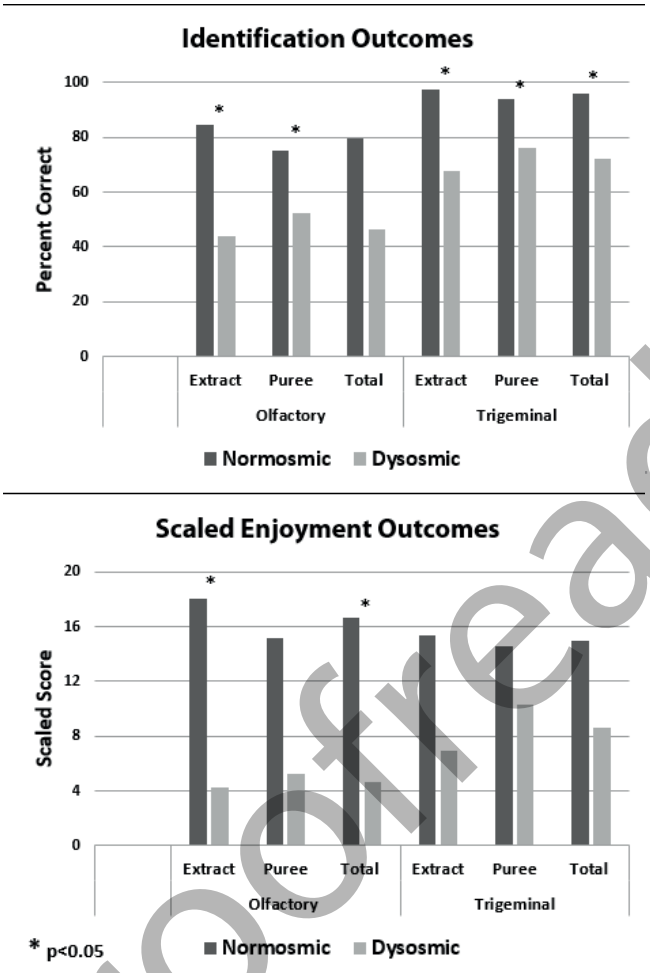

Figure 1. Differences in identification and enjoyment between dysosmic and normosmic subjects. Identification outcomes reported as the percentage correct. Enjoyment scores are scaled by subtracting control scores and can range from -100 to +100.

both normosmic and dysosmic subjects. Notably, the effect of dysosmia on flavor identification appeared to be attenuated for trigeminal-dominant flavors. Similar effects were seen for food enjoyment scores. Normosmic subjects enjoyed olfactory-dominant items significantly more than dysosmic subjects. However, there was no significant difference in enjoyment of trigeminal-dominant food items between dysosmic and normosmic subjects. Within dysosmic subjects, trigeminal-dominant food items received the highest enjoyment scores and also elicited the most subjective commentary.

Despite high population prevalence of olfactory loss in aging and patients with inflammatory sinonasal disease, flavor perception in these groups has received relatively little attention. Although perhaps intuitive, data from this study suggests that impacts of olfactory loss on food flavor are not homogenous across food items. Instead, flavor perception and enjoyment are likely to vary based on the nature of the stimulus and could be maximized with foods that have higher trigeminal stimulation. Traditionally, diet modification for patients with olfactory loss has focused on adding salt or monosodium glutamate (MSG), which represents a focus on gustatory inputs. However, this study suggests that dietary modifications could also focus on trigeminal stimulation. This may mean that individuals intentionally alter their food choices and recipes to minimize olfactory-dominant foods in exchange for items and spices that stimulate the trigeminal system.

This study intentionally used purees and food extracts suspended in liquid to remove chemosensory inputs related to food texture and temperature. Furthermore, patients were blindfolded to remove visual input. However, texture, temperature, and visual appeal may all enhance flavor perception and enjoyment and are aspects of the culinary arts. Therefore, a comprehensive approach to diet modification for patients with OD might include minimizing olfactory flavors, enhancing trigeminal flavors, and focusing on pleasurable chemosensory inputs to enhance texture, temperature, and visual appeal.

These findings may be of particular interest for individuals or populations with gradual olfactory loss over time, including older adults and some patients with inflammatory disease. It is not uncommon for older individuals to express that food

is bland and that eating is no longer pleasurable. The "tea and toast syndrome" describes those older adults whose diet dwindles in scope and can lead to nutritional deficiency [28,29]. Such deficiencies may be particularly relevant in the setting of a growing body of research demonstrating associations between OD and mortality [10,11,30-33]. Of particular interest is whether such patients are less likely to beneficially alter their diet over time, in contradistinction to patients with rapid-onset olfactory loss (i.e. post-viral or traumatic) who are suddenly faced with changes in flavor perception and might intentionally experiment with dietary choices. Recent findings of olfactory loss in association with COVID-19 have led to the emergence of new strategies and discussion aimed at addressing disproportionate nutritional impacts on elderly patients recovering from infection [34]. Although these concepts are speculative, population data clearly shows that up to 62.5% of aging adults have olfactory loss with the majority being chronic-onset in nature [2,4]. As such, the potential exists for formal and standardized dietary recommendations formulated specially to maximize food enjoyment for those with OD and thus increased risk for nutritional deficiencies.

Strengths of this study include utilization of standardized food extracts and commercially available food items, which should enhance reproducibility of findings. However, several issues should be kept in mind. Although water was swished between items and time allowed to transpire, numerous flavors were tested consecutively which could impact saturation of receptors. Because standardized methods do not exist for this type of flavor testing, some choices needed to be made with regard to testing methods. This included distractor questions for identification testing and utilization of bread as a "control" carrier for purees. Although the data is internally consistent, absolute results would be hard to compare to studies that choose different testing methods. Additionally, mean age of the study population was roughly sixty years. Because smell loss is more common in older individuals, results may not reflect the general population, particularly younger individuals. Although psychophysical olfactory testing was used to categorize subjects regarding olfactory ability, we did not concurrently measure gustatory or trigeminal function. Certainly, simultaneous measurements of olfaction, gustatory function, and trigeminal sensation would be ideal for future studies on flavor perception and food enjoyment, and these studies would require much larger sample sizes than this pilot study to allow for subgroup analysis. Lastly, as a pilot study, requisite data was not available for a priori power calculations and sample size determinations. However, future studies with similar methods can utilize this data to design comparison groups with larger sample size and power to minimize type 2 error.

Conclusion

Food identification and enjoyment appears to be decreased in subjects with olfactory dysfunction, particularly with regard to olfactory-dominant food items. Subjects with dysosmia are more likely to identify and enjoy trigeminal-dominant food items. Dietary modification could be part of a comprehensive approach to maximizing food enjoyment for individuals and groups with known olfactory loss.

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Authorship contribution

JJA:
RJS:
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Conflict of interest

JJA: None; RJS: Consultant for GSK, Optinose, Sinusonic, and Stryker; ZMS: Consultant for GSK, Lyra, Optinose, Novartis, and Sinusonic.

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Zachary M. Soler, MD, MSc
135 Rutledge Ave
Charleston, SC 29425
USA

Tel: +1-843-792-7165
E-mail: solerz@musc.edu