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Wine Flavor Perception in a Person with Isolated Congenital Aglossia, Naïve Wine Taster, and Sommelier

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Abstract

Objective: This study aimed to augment previous research that investigated flavor perception in isolated congenital aglossia by a whole food/beverage approach. Isolated congenital aglossia is the rare condition of absence of a tongue at birth without the presence of other symptoms. Previous studies confirmed taste perception in isolated congenital aglossia using single taste solutions including sour, salty, sweet, bitter, and umami.

Methods: The current randomized, double-blinded study age- and sex-matched a naïve wine taster and sommelier to the 46 year-old female with isolated congenital aglossia. A Nose and Palate Survey with 54 variables created based on the Court of Master Sommeliers Deductive Tasting Format was used to evaluate flavor perception. All of the five red wines were tested in triplicate in random order, for a total of 15 separate samples per subject.

Results: There was a significant difference in overall nose ratings among the participants $F(2,42)=63.461$, $p<0.001$, with post hoc analysis revealing differences in overall nose ratings between the person with isolated congenital aglossia and sommelier ($p<0.001$), as well as between the naïve wine taster and sommelier ($p<0.001$). There was a significant difference in overall palate ratings among the participants $F(2,42)=48.651$, $p<0.001$, and post hoc analysis revealed differences in overall palate ratings between the person with isolated congenital aglossia and sommelier ($p<0.001$), as well as between the naïve wine taster and sommelier ($p<0.001$). There were no significant differences between the person with isolated congenital aglossia and naïve wine taster with a tongue for either overall nose or palate ratings.

Conclusion: These results support previous findings that individuals with isolated congenital aglossia can discern various taste and flavor stimuli and suggest that absence of tongue does not greatly affect wine flavor perception among naïve wine tasters.

Keywords: Congenital aglossia; Wine; Flavor; Taste; Sommelier; Tongue; Gustation; Olfaction

Introduction

Taste buds, composed of taste cells that contain the sensory receptors for taste, are largely found on the surface of the tongue, but are also present on the surface of the soft palate and epiglottis [1]. Despite being in different locations and having distinct innervations, taste buds are uniform in their function and no portion of the tongue perceives one type of taste stimuli over another. Taste plays a major role in flavor perception, along with olfaction.

It would be reasonable to assume that the absence of the tongue would affect the sensory perception of taste. Isolated congenital aglossia (ICA) is the absence of a tongue without the presence of other syndromes or symptoms [2]. However, taste awareness has been reported in those with ICA. Since it was first described in 1718 by de Jussieu, twelve reports of ICA have been published [2], four of which go into detail regarding taste perception in ICA.

For points of comparison, research shows that normal populations detected taste stimuli on average at 0.22 g/L sucrose (sweet), 0.06 g/L sodium chloride (salty), 0.007 g/L acetic acid (sour), 0.097 g/L caffeine (bitter), and 0.085 g/L monosodium glutamate (umami) [3]. One male congenital aglossia subject was found to be able to discern concentrations of solutions of sweet, salty, sour, and bitter brushed on the small palate of 3% (30 g/L) cane sugar, 1% (10 g/L) sodium chloride, 0.1% (1 g/L) sulfuric acid, and 0.01% quinine (0.1 g/L), respectively [4]. Taste was reported in another male with the condition of 5% (5 g/L) cane sugar, 10% (100 g/L) sodium chloride, 0.1% (1 g/L) quinine, and 1% (10 g/L) acetic acid in the sublingual and anterior faucial pillers when solutions were brushed onto various mucous membranes [5]. In studying a female minor with the congenital aglossia, it was found that taste stimuli of sour, bitter, sweet, and salty were discerned at 0.015 g/L sulfuric acid, 0.012 g/L quinine, 8 g/L sucrose, and 0.75 g/L sodium chloride, respectively [6]. The fourth subject with the condition who had reported taste perception is the same subject for the current study. She was found to have best detected salty, sour, sweet, bitter, and umami at 5.8 g/L sodium chloride, 0.66 g/L and 0.066 g/L acetic acid, 171 g/L sucrose, 0.1 g/L and 0.02 g/L anhydrous caffeine, and 0.85 g/L, and 0.085 g/L monosodium glutamate, respectively [2]. This was the first report of umami taste perception in a person with ICA [2].

Though these previous studies investigated taste using single sample solutions, there is no existing literature examining the perception of combined, complex tastes or flavors in ICA. This is of importance because in a real-world setting food and beverages usually contain multiple compounds that are associated with different taste and flavor sensations. The aim of this study was to augment previous research that investigated taste perception in a case of ICA by a real-world, whole food/beverage approach. Wine offers complex flavors containing varying levels of compounds that are responsible for sweet, salty, sour, bitter, and possibly umami tastes [7]. While limited research exists using an objective approach to investigate wine tasting, the tasting of wine does employ a standardized protocol, as well as specific flavor characteristics to evaluate.

Materials and Methods

Participants

This study was part of an ongoing line of research examining taste perception in the same subject with ICA as reported by McMicken et al. in 2014 [2]. The subject of comparison was a 46 year-old female with ICA who volunteered to participate as part of this research. Due to the rarity of congenital aglossia, the prevalence is unknown and the participating subject is one of 12 individuals reported in research literature since 1718 [2]. Her flavor perception was compared to a naïve wine taster with a tongue and professional sommelier. These two subjects were recruited using contacts in the community and selected based on availability and qualifying criteria to be sex- and age-matched to the ICA subject. With the scarcity of people with ICA and female sommeliers that met the age and availability criteria in the region, the aforementioned sample size was appropriate for this study.

Instrumentation

The researchers developed the data collection instrument referred to as the Nose and Palate Survey. After conducting an extensive search, no detailed wine tasting surveys were found in previous research. This survey was created using the Court of Master Sommeliers Deductive Tasting Format [8] and validated by a sommelier who did not participate in the study. The survey was pilot tested in this study.

The Nose and Palate Survey consisted of two main sections, the Nose section to measure the smell from orthonasal olfaction and the Palate section to measure the flavors of the wine samples from gustation and retronasal olfaction. The sections and elements evaluated were derived from the Court of Master Sommeliers Deductive Tasting Format [8]. The survey used a Likert-type rating scale from 0 to 5 to measure the subjects' perception of the elements in the wine, with 0 representing none detected, 1=very weak, 2=weak, 3=clear but not intense, 4=intense, and 5=very intense. Flavor components (e.g. "Non-fruit Floral") were listed with the rating scale beside each one. All subjects received definitions of the flavor elements to allow them to recognize if they were in fact experiencing those flavors. The survey also included other wine characteristics, but due to the parallel content in both the nose and palate sections, this article only examines the fruit type, fruit character, non-fruit, organic earth, and inorganic earth results.

Procedure

This study was approved by the California State University, Long Beach (CSULB) Institutional Review Board (IRB). The wine tasting was performed a private area located at a wine tasting bar in Long Beach, California. The owner of the wine bar was present and poured each sample into identical standard red wine glasses prior to the subjects' arrival. This allowed for the wines to reach room temperature and breathe for the same amount of time before the subjects tested them. The three-digit, randomized sample numbers that corresponded to the different wines were recorded and the standard red wine glasses were labeled with these numbers. A separate researcher served the wine to the subjects to adhere to the double blind design (Figure 1).

Figure 1: Wine Samples. Five red wine varietals were sampled in triplicate by each of the subjects.

Total testing time was three hours. Each sample took approximately 10 minutes from start to finish, which provided adequate time for the subjects to sense the smell and taste and complete the Nose and Palate Survey. Breaks lasting 10 minutes were provided between every five samples to avoid respondent fatigue.

Five types of wine were sampled that fell within the same category of dry, medium-bodied red. The wine bar owner used his expertise to choose wines which had the same appearance but are of different varietals per the researchers' specifications. All wines were tested in triplicate in random order, for a total of 15 separate samples per subject. Each subject received the wines in the same order. Both the researchers and subjects were blinded to the type of wine in the sample. Samples were delivered in amounts of 75 mL, of which only 15 mL was imbibed for a total of 225 mL or 1.5 glasses of wine consumed by each subject. This amount of wine consumed over three hours did not exceed the amount of wine the female subjects would consume in a non-study setting.

On the day of the testing the subjects were briefed on the wine taste testing procedure. They were randomly seated at three separate tables in the wine bar. Each table was set up with a bottle of water, unsalted crackers, expectoration container, and two glasses, one for water and one to spit the wine into after tasting prior to emptying it into the expectoration container (Figure 2).

The subjects followed the wine tasting procedure described in the Certified Specialist of Wine Study Guide [9]. This involved sniffing the wine and then recording their impressions of the scent on the Nose and Palate Survey. The subjects tasted the wine by placing a small amount of wine (15 mL) in their mouth and moving it all over the

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tongue and/or inside of the mouth, and then drawing some air into their mouths to taste further.

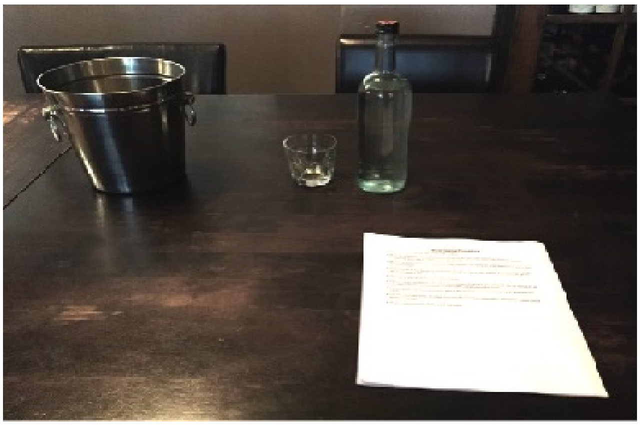

Figure 2: Wine Tasting Set-up. Subjects were randomly seated at three separate tables containing bottle of water, unsalted crackers, expectoration container, and two glasses, one for water and one to spit the wine into after tasting prior to emptying it into the expectoration container.

This was done twice, with the first taste being disposed (i.e. expectorated) and the second taste swallowed. The subjects recorded their impressions of the flavor on the Nose and Palate Survey. They then rinsed their mouth out twice with water and could choose to eat a cracker in order to help cleanse the palate. The tastings continued in this manner until all 15 samples were tested.

At the conclusion of the study, the subjects were debriefed and informed of the five wines they sampled. The researchers ensured that each subject had a safe mode of transportation upon their departure.

Data Analysis

The data were analyzed using IBM SPSS Statistics 22. One-way independent analysis of variance (ANOVA) with post hoc analysis were performed. Results were presented as means with standard errors (Mean ± SE). Significance was set at $p<0.05$. Post hoc comparison p-values were reported using Tukey honest significant difference (HSD) unless Levene's statistic was found to be significant, in which case Games-Howell was used to report p-values for post hoc analysis and the Welch p-value and statistic was reported for the ANOVA analysis.

Results

Three female participants completed the study, with a mean age of 47 years (SD ± 1) and the results were divided into nose and palate categories. The overall nose means ± SE for the person with ICA, naïve wine taster, and sommelier were 1.441 ± 0.056, 1.282 ± 0.050, and 0.683 ± 0.043, respectively (Table 1). There was a statistically significant difference in nose ratings among the participants $F(2.42)=63.461$, $p<0.001$. Post hoc analysis (Table 1) revealed that there were significant differences in overall nose ratings between the person with ICA and the sommelier ($p<0.001$), as well as between the naïve wine taster and the sommelier ($p<0.001$). There was no significant difference in overall nose ratings between the person with ICA and the naïve wine taster with a tongue ($p=0.075$).

The overall palate means ± SE for the person with ICA, naïve wine taster, and sommelier were 1.510 ± 0.058, 1.360 ± 0.060, and 0.750 ± 0.055, respectively (Table 2). There was a statistically significant difference in palate ratings among the participants $F(2.42)=48.651$, $p<0.001$. Post hoc analysis (Table 2) revealed that there were significant differences in overall palate ratings between the person with ICA and the sommelier ($p<0.001$), as well as between the naïve wine taster and the sommelier ($p<0.001$). There was no significant difference in overall palate ratings between the person with ICA and the naïve wine taster with a tongue ($p=0.180$).

	Mean (± SE)			F-Statistic/ Welch Statistic[c]	ANOVA/Welch p-value[c]	Post hoc p-value[b,c]		
	ICA	Naïve w/Tongue	Sommelier			ICA vs. Sommelier	ICA vs. Naïve w/Tongue	Sommelier vs. Naïve w/Tongue
Nose Overall	10.44 (0.056)	10.28 (0.050)	00.68 (0.043)	630.46	<0.001	<0.001	0.075	<0.001
Fruit Type	20.69 (0.161)	20.02 (0.119)	10.94 (0.107)	90.718	<0.001	0.001	0.002	0.908
Red	20.60 (0.214)	20.00 (0.338)	20.21 (0.482)	10.179[c]	0.324[c]	0.749[c]	0.309[c]	0.930[c]
Black	20.67 (0.270)	20.53 (0.256)	20.53 (0.435)	00.071[c]	0.931[c]	0.963[c]	0.932[c]	10.000[c]
Blue	20.80 (0.145)	10.53 (0.322)	00.92 (0.309)	180.147[c]	<0.001[c]	<0.001[c]	0.005[c]	0.372[c]
Fruit Character	20.14 (0.087)	10.70 (0.078)	00.79 (0.086)	680.36	<0.001	<0.001	0.002	<0.001
Baked	20.07 (0.228)	20.33 (0.303)	20.33 (0.361)	0.259	0.773	0.808	0.808	1
Stewed	20.33 (0.270)	20.27 (0.248)	00.43 (0.173)	200.36	<0.001	<0.001	0.978	<0.001
Dried	20.13 (0.165)	10.36 (0.248)	00.20 (0.107)	490.375[c]	<0.001[c]	<0.001[c]	0.041[c]	0.001[c]
Peels	20.07 (0.316)	10.40 (0.335)	00.00 (0.000)	Welch N/A[d]	Welch N/A[d]	<0.001[c]	0.331[c]	0.003[c]
Desiccated	10.93 (0.228)	00.93 (0.195)	00.00 (0.000)	Welch N/A[d]	Welch N/A[d]	<0.001[c]	0.007[c]	0.001[c]

Tart	20.07 (0.267)	10.53 (0.350)	00.79 (0.300)	40.297	0.02	0.015	0.438	0.215
Jammy	20.40 (0.289)	20.07 (0.396)	10.86 (0.361)	0.603	0.552	0.528	0.777	0.908
Non-Fruit	10.13 (0.140)	10.37 (0.088)	00.31 (0.069)	470.027[c]	<0.001[c]	<0.001[c]	0.352[c]	<0.001[c]
Floral	00.87 (0.192)	10.87 (0.413)	00.27 (0.118)	90.007[c]	0.001[c]	0.036[c]	0.096[c]	0.005[c]
Vegetal	00.53 (0.215)	10.80 (0.243)	00.20 (0.145)	150.666[c]	<0.001[c]	0.417[c]	0.002[c]	<0.001[c]
Herbal	10.93 (0.267)	10.53 (0.256)	00.67 (0.225)	60.044	0.005	0.004	0.489	0.06
Spice	10.73 (0.300)	20.07 (0.358)	10.00 (0.234)	20.694	0.081	0.266	0.717	0.068
Animal	00.87 (0.291)	00.20 (0.145)	00.08 (0.277)	30.448[c]	0.049[c]	0.046[c]	0.125[c]	0.736[c]
Fermentation	00.87 (0.256)	00.73 (0.182)	00.00 (0.000)	Welch N/A[d]	Welch N/A[d]	0.011[c]	0.906[c]	0.003[c]
Organic Earth	10.12 (0.153)	00.97 (0.070)	00.32 (0.092)	180.628[c]	<0.001[c]	<0.001[c]	0.665[c]	<0.001[c]
Forest Floor	10.73 (0.300)	00.93 (0.228)	00.64 (0.169)	50.464	0.008	0.008	0.058	0.677
Compost	00.00 (0.000)	00.67 (0.187)	00.07 (0.071)	Welch N/A[d]	Welch N/A[d]	0.590[c]	0.008[c]	0.021[c]
Mushrooms	10.07 (0.267)	00.80 (0.262)	00.40 (0.163)	20.031	0.144	0.124	0.705	0.459
Potting Soil	10.53 (0.336)	10.60 (0.190)	00.07 (0.067)	350.045[c]	<0.001[c]	0.002[c]	0.984[c]	<0.001[c]
Barn	10.27 (0.248)	00.87 (0.215)	00.27 (0.182)	50.392	0.008	0.006	0.4	0.136
Inorganic Earth	00.12 (0.055)	00.34 (0.063)	00.06 (0.034)	80.091	0.001	0.682	0.013	0.001
Mineral	00.60 (0.289)	00.47 (0.119)	00.21 (0.114)	10.259[c]	0.301[c]	0.446[c]	0.916[c]	0.432[c]
Limestone	00.00 (0.000)	00.93 (0.267)	00.00 (0.000)	Welch N/A[d]	Welch N/A[d]	-e	0.009[c]	0.009[c]
Chalk	00.00 (0.000)	00.00 (0.000)	00.07 (0.067)	Welch N/A[d]	Welch N/A[d]	0.589[c]	-[e]	0.589[c]
Slate/Petrol	00.13 (0.133)	00.67 (0.187)	00.08 (0.077)	40.163[c]	0.028[c]	0.929[c]	0.071[c]	0.023[c]
Flint	00.00 (0.000)	00.00 (0.000)	00.00 (0.000)	-[e]	-[e]	-[e]	-[e]	-[e]
Volcanic	00.00 (0.000)	00.00 (0.000)	00.00 (0.000)	-[e]	-[e]	-[e]	-[e]	-[e]

[a]Statistical significance set at p<0.050.

[b]Post hoc comparison p-values are reported using Tukey HSD unless otherwise noted.

[c]Welch p-value and statistic reported if Levene's found to be significant and Games-Howell reported for p-values for post hoc comparison analysis.

[d]Levene's found to be significant; however robust tests of equality of means could not be performed because at least one group had 0 variance.

[e]Tests could not be performed because at least two groups had 0 variance.

Table 1: Nose components means (± standard error) with independent one-way ANOVA and post hoc analysis results.

	Mean (± SE)			**F-Statistic/ Welch Statistic[c]**	**ANOVA/Welch p-value[c]**	**Post hoc p-value[b,c]**		
	ICA	**Naïve w/Tongue**	**Sommelier**			**ICA vs. Sommelier**	**ICA vs. Naïve w/Tongue**	**Sommelier vs. Naïve w/Tongue**
Palate Overall	10.51 (0.058)	10.36 (0.060)	00.75 (0.055)	480.651	<0.001	<0.001	0.18	<0.001
Fruit Type	20.71 (0.121)	20.00 (0.108)	10.87 (0.446)	150.615	<0.001	<0.001	<0.001	0.692
Red	20.80 (0.223)	20.13 (0.322)	20.21 (0.494)	10.655[c]	0.212[c]	0.537[c]	0.223[c]	0.990[c]
Black	20.60 (0.190)	20.47 (0.322)	20.40 (0.456)	00.119[c]	0.888[c]	0.914[c]	0.932[c]	0.992[c]
Blue	20.73 (0.118)	10.40 (0.273)	00.86 (0.312)	220.126[c]	<0.001[c]	<0.001[c]	0.001[c]	0.402[c]

Fruit Character	20.32 (0.073)	10.90 (0.312)	00.93 (0.389)	650.461	<0.001	<0.001	0.005	<0.001
Baked	20.00 (0.253)	20.21 (0.408)	20.13 (0.307)	00.116[c]	0.891c	0.940[c]	0.897[c]	0.986[c]
Stewed	20.46 (0.291)	20.00 (0.210)	00.47 (0.192)	200.975	<0.001	<0.001	0.356	<0.001
Dried	20.85 (0.191)	10.57 (0.228)	00.33 (0.126)	460.517	<0.001	<0.001	<0.001	<0.001
Peels	20.23 (0.166)	20.23 (0.411)	00.07 (0.067)	800.236[c]	<0.001[c]	<0.001[c]	10.000[c]	0.001[c]
Desiccated	20.08 (0.309)	10.33 (0.225)	00.07 (0.071)	300.938[c]	<0.001[c]	0.001[c]	0.150[c]	<0.001[c]
Tart	20.85 (0.249)	20.43 (0.441)	10.60 (0.363)	30.908[c]	0.033[c]	0.024[c]	0.693[c]	0.331[c]
Jammy	10.77 (0.231)	10.43 (0.309)	10.86 (0.361)	0.548	0.582	0.978	0.72	0.585
Non-Fruit	10.08 (0.117)	10.57 (0.109)	00.36 (0.064)	370.041	<0.001	<0.001	0.003	<0.001
Floral	10.07 (0.182)	10.13 (0.376)	00.00 (0.000)	Welch N/A[d]	Welch N/A[d]	<0.001[c]	0.986[c]	0.024[c]
Vegetal	00.40 (0.190)	10.60 (0.306)	00.13 (0.133)	90.445[c]	0.001[c]	0.494[c]	0.008[c]	0.001[c]
Herbal	10.67 (0.287)	20.27 (0.267)	00.14 (0.097)	350.889[c]	<0.001[c]	<0.001[c]	0.292[c]	<0.001[c]
Spice	10.67 (0.211)	20.67 (0.252)	10.67 (0.319)	40.773	0.014	1	0.028	0.028
Animal	10.00 (0.218)	00.60 (0.214)	00.21 (0.214)	30.281	0.048	0.037	0.389	0.427
Fermentation	00.67 (0.211)	10.13 (0.274)	00.00 (0.000)	Welch N/A[d]	Welch N/A[d]	0.018[c]	0.381c	0.003[c]
Organic Earth	10.05 (0.164)	10.05 (0.135)	00.27 (0.094)	150.131[c]	<0.001[c]	0.001[c]	10.000[c]	<0.001[c]
Forest Floor	10.47 (0.256)	10.40 (0.273)	00.47 (0.133)	80.712[c]	0.001[c]	0.006[c]	0.983[c]	0.016[c]
Compost	00.07 (0.067)	00.73 (0.248)	00.00 (0.000)	Welch N/A[d]	Welch N/A[d]	0.589[c]	0.049[c]	0.026[c]
Mushrooms	10.00 (0.218)	10.00 (0.258)	00.40 (0.235)	20.124	0.132	0.187	1	0.187
Potting Soil	10.73 (0.300)	10.33 (0.252)	00.14 (0.097)	190.62[c]	<0.001[c]	<0.001[c]	0.571[c]	0.001[c]
Barn	10.00 (0.218)	00.80 (0.223)	00.33 (0.232)	20.324	0.11	0.102	0.804	0.315
Inorganic Earth	00.27 (0.078)	00.21 (0.057)	00.04 (0.020)	60.841[c]	<0.005[c]	0.035[c]	0.834[c]	0.035[c]
Mineral	10.27 (0.267)	00.47 (0.192)	00.13 (0.091)	80.379[c]	0.002[c]	0.002[c]	0.056[c]	0.281[c]
Limestone	00.00 (0.000)	00.40 (0.163)	00.00 (0.000)	Welch N/A[d]	Welch N/A[d]	-[e]	0.068[c]	0.068[c]
Chalk	00.00 (0.000)	00.00 (0.000)	00.07 (0.067)	Welch N/A[d]	Welch N/A[d]	0.589[c]	-[e]	0.589[c]
Slate/Petrol	00.33 (0.232)	00.27 (0.118)	00.07 (0.067)	10.461[c]	0.252[c]	0.526[c]	0.965[c]	0.322[c]
Flint	00.00 (0.000)	00.00 (0.000)	00.00 (0.000)	-[e]	-[e]	-[e]	-[e]	-[e]
Volcanic	00.00 (0.000)	00.13 (0.133)	00.00 (0.000)	Welch N/A[d]	Welch N/A[d]	-[e]	0.589[c]	0.589[c]

[a]Statistical significance set at p<0.050.

[b]Post hoc comparison p-values are reported using Tukey HSD unless otherwise noted.

[c]Welch p-value and statistic reported if Levene's found to be significant and Games-Howell reported for p-values for post hoc comparison analysis.

[d]Levene's found to be significant, however robust tests of equality of means could not be performed because at least one group had 0 variance.

[e]Tests could not be performed because at least two groups had 0 variance.

Table 2: Palate components means (± standard error) with independent one-way ANOVA and post hoc analysis results.

Post hoc analysis of the characteristics measured showed that the person with ICA and the sommelier had statistically significant differences for fruit type, fruit character, non-fruit, and organic earth for both nose and palate ($p<0.05$). However, there was no significant difference between them for inorganic earth for the nose category only ($p=0.682$). Post hoc analysis between the person with ICA and naïve wine taster revealed statistically significant differences for the fruit type and fruit character for both the nose and palate categories ($p<0.05$).

However, there were no significant differences between the non-fruit (p=0.352) and organic earth (p=0.665) for the nose, and the organic earth (p=1.000) and inorganic earth (p=0.834) for the palate. Post hoc analysis between the naïve wine taster and the sommelier showed significant differences for the fruit character, non-fruit, organic earth, and inorganic earth characteristics, but was not significantly different for the fruit type for both the nose (p=0.908) and the palate (p=0.692).

Discussion

Comparison of flavor perception between naïve wine taster and person with ICA

The results of this study suggest that the absence of a tongue does not greatly affect wine flavor perception in naïve wine tasters. There was a negligible difference between the mean ratings for both the nose and palate wine characteristics among the person with ICA and naïve wine taster with a tongue. In addition, there were no significant differences between the person with ICA and the naïve wine taster with a tongue for overall nose and palate ratings in the post hoc analysis. These findings support previous research that taste and flavor perception does exist in those with ICA [2,4-6].

These flavor perception similarities between the naïve wine tasters with and without a tongue, as in the case of ICA, could be due to the various taste receptor cell locations throughout the oral cavity and the role olfaction plays in wine tasting. Instead of using the tongue as the main site for taste buds, the person with ICA could be relying on those located on soft palate and epiglottis and the ability to smell the wine, which is resulting in the ability to perceive the flavor similarly to the naïve wine taster with a tongue.

While there were no significant differences in the overall nose and palate ratings between the person with ICA and the naïve wine taster, it is interesting to note that there were differences between some of the characteristics comprising these categories. The nose and palate ratings for the fruit type and fruit character were significantly different, while there were no significant differences for the organic earth category. This may suggest flavor perception differences exist more with tastes and flavors related to fruits and less with those related to earthy tastes and flavors between naïve wine tasters with and without a tongue. Another possible explanation in the difference in compensation for detecting different flavors in ICA could be that the detection of fruity flavors relies more on taste whereas earthy flavors are contributed more by olfactory sense.

Differences in flavor perception between expert and naïve wine tasters

Findings from this study also support previous research in wine tasting, which demonstrated that trained wine experts and naïve wine tasters evaluate wine differently. A study investigating perceived wine complexity and aging ability among professional wine experts and naïve wine consumers found differences between the groups' representations of complexity. The wine experts used learned factors including oenology and viticulture (e.g., use of oak, soil) to represent wine complexity, whereas the wine consumers used inherent factors relating to their experience of the wine (e.g., perceived smell, taste, enjoyment), which were personalized and subjective [10].

Previous studies involving neural activity during wine tasting also suggest that wine knowledge plays a role in the neural processing that occurs while imbibing the wine samples. The literature suggests that those more highly trained in wine tasting, such as sommeliers, have more brain activity in the frontal lobes [11]. Trained wine professionals have higher bilateral activation in the dorsolateral prefrontal cortex involved in high-level cognitive processes, while naïve wine drinkers with no formal wine education experienced activation in areas of the brain responsible for emotional processing [12].

Study limitations

While the findings from this study support previous research, it was not without limitations. The numbers of trials in this study were restricted by the subjects' time availability and the amount of alcohol that can be safely consumed during one event. To increase the accuracy of the measurements and gain additional statistical power, it would be ideal to have the subjects wine taste on other days as well, which would allow for additional samples and wine types to be evaluated. Although breaks were built into the study and all subjects tasted the wines in the same order, the subjects may have become fatigued over the duration of the study affecting their responses for the samples towards the end of the study. In addition, the facility at which the study was held opened for business during the last hour of the tastings and aroma from food cooking, among other distractions, could have affected the responses during that time. Another limitation was that all three subjects were female, which may have altered the findings since no data regarding wine tasting perceptions in males were available due to the study design. Though this study aimed to increase knowledge in taste and flavor perception in a person with ICA, the findings may not be generalizable to populations who have lost their tongues or sense of taste as a result of other medical conditions.

Future Research

ICA represents a rare situation that allows researchers to investigate flavor perception and taste function without the tongue, a major taste structure. Future research should focus on continuing to gain knowledge of taste and flavor perception in those with ICA, as well as increase the understanding of taste to allow for generalization to other populations. To better understand the taste mechanisms in those with ICA, studies on both the taste structures and neural activities during gustation with this condition would be recommended. This could be achieved through mapping the taste structures within the oral cavity of a person with ICA. Another research avenue to pursue would be to investigate areas of neural activity of a person with ICA during tasting sessions using functional magnetic resonance imaging (fMRI) technology.

Findings involving taste and flavor perception in ICA could aid other populations with taste or tongue loss, including those with Alzheimer's disease, autism spectrum disorder, and head and neck cancers, as well as aging populations. As previously mentioned, training in wine tasting can affect how professionals perceive wine taste and flavors, which suggests alterations in their neural activities during the wine tasting. Therefore, it would be reasonable to explore the possibility of using taste training for taste rehabilitation in populations with tongue or taste loss in future studies.

There is precedence for using taste stimuli for oral rehabilitation. Sasano, Satoh-Kuriwada, and Shoji in 2015 saw positive results using a drink high in monosodium glutamate, which produces the umami taste, to overcome hypogeusia [13]. In addition, sour taste has been found to stimulate swallowing in patients with dysphagia [14,15]. By better understanding the function of taste in those with ICA, the field of taste rehabilitation may be expanded at the benefit of those who have lost their tongue or sense of taste.

Conclusion

In conclusion, this study supports the findings of previous research that individuals with ICA have the ability to discern and identify various taste and flavor stimuli. The results of this study suggest that the absence of a tongue does not greatly affect wine flavor perception in naïve wine tasters. To our knowledge, this is the first study to report that an individual without a tongue identifies flavors similarly to one with a tongue using wine to stimulate a real-world gustation experience with multiple, complex tastes and flavors. Through future research further knowledge on taste and flavor could be gained that may aid in developing taste rehabilitation methods to use with individuals who have lost their tongue or developed altered taste to improve their health outcomes.

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