Original Article

Taste perception and diet in people of Chinese ancestry

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Background and Objectives: Taste perception plays a key role in consumer acceptance and food choice, which has an important impact on human health. Our aim was to examine the relationship between taste intensities and preferences of sweet (sucrose), salty (sodium chloride and potassium chloride), sour (citric acid), and bitter (quinine and phenylthiocarbamide) in relation to dietary intake and dietary patterns in people of Chinese ancestry. **Methods and Study Design:** This cross-sectional study included 100 adult Singaporean Chinese (50 women). A validated taste methodology was used with taste solutions provided by Monell Chemical Senses Center. Dietary intake and patterns were assessed by dietary recalls. **Results:** There was little relationship between taste intensity and tastant preference in regard to background dietary intake or pattern. Tastant differentiation was reliable, but there was some confusion in regard to the rating of saltiness as sourness. **Conclusions:** There was a salty-sour confusion among Singaporean Chinese unlike the bitter-sour confusion reported for Caucasians. Most sodium came from sauces and was added during food preparation. In programs to address sodium: potassium ratio excess among Chinese prone to hypertension and stroke, sour as well as salty taste may need to be considered.

Key Words: taste intensities, dietary patterns, Chinese, sodium, phenylthiocarbamide (PTC)

INTRODUCTION

Taste perception plays a key role in consumer acceptance and food choice, which has an important impact on human health. Food choices are made based on a variety of factors such as cultural influences, taste, smell, appearance, mood, environment, health, allergies, hunger levels and pregnancy.[1] Taste perception has been studied with reference to age[2] and diseases.[3] If taste influences food choice and intake, it may be possible to manage chronic disease by making simple changes to the tastes and foods consumed regularly. Previous work has highlighted that simple modifications to dietary behaviors can help Asians in the management of Type II Diabetes Mellitus.[4] A previous study had reported that pleasantness ratings for sodium chloride (NaCl) and sucrose were higher in Chinese participants compared to participants of European ancestry.[5] However there is little research conducted on taste qualities (four of which are sweet, salty, sour and bitter, with umami recognized among East Asians) in terms of taste perception and dietary intake.[6] This is especially so in relation to taste perception by people of Chinese ancestry, which applies to some 20% of the world's population[7] to whom many study findings on other ethnicities may not be generalizable. The present study investigates relationships between taste and diet in people of Chinese ethnicity.

Taste perception is associated with dietary intake.[8] Individual differences in taste perception may influence dietary intake and in turn may relate to nutritional status and susceptibility to chronic disease.[9] Studies have usually examined sweetness[6] or saltiness[10,11] alone. The Chinese diet as a whole has not been assessed in regard to individual taste differences, with little emphasis placed on meal patterns such as the amount of energy eaten at breakfast, lunch, dinner and snacks. Differences in dietary intake have been proposed to be a major modifiable risk factor for chronic diseases such as diabetes and cardiovascular diseases.[12] The basic taste of sweetness is thought to be closely related to dietary habits.[13] Previous studies have suggested that some Chinese prefer saltier solid foods compared with Europeans;[5] however, this may be due to differences in rated taste intensity or dietary behavior. This present study explores differences in rated taste intensities in relation to dietary behavior. Excess intake of dietary sodium is positively associated with hypertension and adverse cardiovascular health.[14] This is often a Chinese health problem.[15] In Singapore, the prevalence of hypertension in Chinese (systolic pressure ≥140 mmHg or diastolic pressure ≥90 mmHg) was 23.4% in

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2010.[16] Recent studies in Chinese populations have examined the acceptability of salt substitutes such as potassium chloride (KCl) in food products and these studies have found that the overall acceptability of salt substitute (a mixture of NaCl, KCl and magnesium sulphate) was not different to normal NaCl in a standard salty soup.[17,18] Another study carried out in America showed that adding KCl not only increases saltiness slightly, but also increases off-tastes such as bitter, chemical and metallic tastes.[19] However, no study to date has investigated the taste perception of KCl and its relation to background diet. To the authors' knowledge, this is the first study to investigate the relationships between tastes (sweet, salty, sour, and bitter) and diet among Chinese.

The relationship between phenylthiocarbamide (PTC) and the chemically similar compound 6-n-propylthiouracil (PROP) taste effects and health was explored by Fischer and colleagues in the 1960s.[20] Genetic variation in PTC and taster status: non- and super-taster groups had been linked with basic tastant properties such as the ability of super-tasters to perceive salt,[21] sugar, acid and bitter substances at a greater intensity than non-tasters.[22] Some studies also relate PROP taster status to an individual's food preference and diet. The liking of sweet and high-fat food and beverage groups decreases with increasing perceived bitterness of PROP in women, but an opposite trend is seen in men.[23] However, another study of PROP and sugar and fat has not found any PROP association with diets lower in sugar and fat intake.[24] These aforementioned studies have been mainly carried out among Caucasians with more recent studies to do with PROP and taste intensity or food liking,[25] and PROP and energy intake[26] among Asians. The current study aims to determine whether the PTC findings in Caucasians can be generalized to an Asian population.

METHODS

Participants

In order to provide 90% power to detect a mean difference of 5mm (estimated from Zandstra et al. 2000[27] and Carter et al. 2011[28]) in NaCl intensity and acceptance ratings between the groups using a two-sided significant level of 5%, 95 participants were required to have complete data. Allowing for 10% attrition and unusable data, 105 participants were to be recruited. Data analyses were performed with the statistical package for the social sciences (SPSS). It was possible to recruit 103 Chinese Singaporeans without exclusion criteria. However, three women did not complete all tests. A total of 100 participants (50% women) had complete data for statistical analysis. This sample size is similar to a recent study which investigated the association between taste and diet in young adults (n=85).[6]

Participants were apparently healthy, non-smoking adults, aged between 21 and 55 years, with Chinese ethnicity defined by both parents and all 4 grandparents being Chinese. They were recruited through advertisement or by word of mouth from the Singaporean general public. Exclusion criteria were allergies or intolerance of any of the tastants; use of medication known to alter taste function; and pregnancy. The study was approved by the Domain Specific Review Board A of the National Healthcare Group, Singapore (Study Reference Number: 2013/01136). The study complied with the Declaration of Helsinki for medical research involving human participants. Written informed consents were obtained from all participants.

Procedures

Participants were required to attend one test session between 0900 to 1800 h. Fifty percent of participants (n=50) were asked to attend another session and to complete the same taste tests 7-14 days after the first test session in order to determine the reliability of the taste tests. They were asked to avoid any food and beverages, except for plain drinking water, for at least an hour before the tests. Standing height and weight were measured using a stadiometer and electronic scales (SECA 764, United Kingdom).[29] The body mass index (BMI) was calculated using weight (kg) divided by the height squared (m^2). Percent body fat was measured by bioelectric impedance (TANITA BC-418). Blood pressure was measured using a digital blood pressure monitor (OMRON HEM-907). All measurements were carried out in duplicate and the average used.

Taste tests

Taste solutions were prepared at the Monell Chemical Senses Center in Philadelphia, PA, dispensed into glass vials, tightly capped, and air freighted to Singapore. Participants followed the procedures described as per Knaapila et al. 2012.[30] All solutions tested were similar to those in Knaapila et al. 2012[30] except ethanol, which was not tested. Taste solutions were rated in this order: 1. water, 2. sucrose (12% w/v), 3. citric acid (0.12% w/v), 4. NaCl (1.5% w/v), 5.KCl (1.5% w/v), 6.PTC (1.8 X 10-4 M) and 7.quinine hydrochloric acid (0.003% w/v). A plastic tray was provided with taste solutions arranged in the order of testing, along with a paper ballot on which responses were rated. Potable tap water was used for mouth rinses, nose clips were applied, and then solutions were tasted and rated. They were presented in single-use glass vials, using the "sip and spit" method. Water used to prepare the taste solutions was obtained from Millipore (Billerica, MA).

Participants were asked to answer the following question: "How does it taste?" and to rate sweetness, saltiness, sourness, bitterness, and burn for each solution on a 7.7cm visual analogue scale anchored with "Not at all" on the left and "Extremely" on the right. The word "burn" refers to a somatosensory sensation, not a taste, but the term "taste" is used here for simplicity. "How much do you like it?" was also asked and rated on a similar scale, anchored on the left with the phrase "Not at all", in the middle with "Neutral", and on the right with "Like extremely".[30]

Dietary intake

Dietary intake was assessed using two 24-hour recalls, based on estimates of household measures, one weekday and one weekend day. A prompted 24-hour recall template ensured comprehensiveness of the diet recorded. Time of day, food or drink consumed, brand name as appropriate, and estimated quantity were documented. Nutrient intakes were ascertained with Dietplan6 (Forestfield Software Ltd, West Sussex, UK) and a local food database.[31] Dietary total energy, macronutrients (carbohydrate, fat, and protein), sodium, potassium, dietary fiber and total sugars were identified. Dietary variety and meal patterns were calculated and shown in EXCEL (adapted from Savige et al. 1997).[32]

Statistical analysis

Data were analyzed with SPSS, version 22.0 (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp). Independent sample t-tests were used to compare baseline characteristics, taste intensities and preferences, and diet by gender. Pearson correlation analysis was used to assess the relationships between taste intensities, preferences, and diet. All tests were evaluated at the 2-sided 0.05 level.

RESULTS

Participant characteristics and body composition

A total of 100 participants (50% women) with complete data were analyzed. Their characteristics are summarized in Table 1. Men were taller, heavier, with a higher BMI and systolic blood pressure compared to women (all $p \leq 0.01$), while women had a higher percent of fat mass ($p<0.01$).

Taste intensities and preferences

A test-retest correlation of more than 0.40 was considered to be reliable.[30] For this study, all the test-retest correlations were greater than 0.40 and were significant except for the sourness of citric acid, which had a test-retest correlation of 0.26 (p=0.07) (data not shown). The mean and SD of the taste traits are reported in Table 2. Each tastant was correctly identified; that is, 98% of participants rated sucrose as sweet, 96% rated NaCl as salty, 91% rated citric acid as sour and 97% rated quinine as bitter. Some gave mixed ratings for the different tastant. Thus, sucrose rated as salty (5%), as sour (2%) and as bitter (2%); NaCl rated as sweet (4%), as sour (13%) and as bitter (5%); and citric acid rated as sweet (11%), as salty (18%) and as bitter (7%).

From Table 2, we noted that both women and men rated KCl to be more bitter (women 3.38±1.81; men 3.59±2.41) than salty (women 1.36±1.88; men 1.27±1.85). There were no significant differences by gender for different taste traits or taste preferences (all $p \geq 0.05$). As expected, sucrose was very much liked (women 4.60±1.21; men 4.62±1.48) compared to citric acid (women 3.07±1.25; men 2.64±1.70), NaCl (women 2.40±1.40; men 2.54±1.68), quinine (women 1.65±1.09; men 1.74±1.46), and KCl (women 1.29±1.77; men 1.58±1.38).

Diet

As shown in Table 3, men had higher energy intakes compared to women ($p<0.01$) as for fat, carbohydrate and protein (all $p \leq 0.03$). Although the absolute amount of energy and macronutrients were higher in men compared to women, no significant differences were observed in the percent energy distributions between macronutrients' contribution (Figure 1A). Likewise, dietary fiber, sodium and potassium intakes did not differ by gender (all $p \geq 0.10$). We also examined meal patterns by gender in regard to breakfast, lunch, dinner and snacks. No differences were observed insofar as percentage of energy contribution by eating episode and gender (Figure 1B).

We also considered dietary variety. The dietary variety score was calculated by scoring one point for each different food over the 2-day food recall, by a method adapted from Savige et al. 1997.[32] An example is given in Table 4. The mean±SD dietary variety score was 8.4±2.5 food items per day (Table 3), with no difference by gender (p=0.97).

By comparison with the Singaporean dietary guidelines of 2010, the percent energy contribution from macronutrients was fat (33.7%) and protein (17.0%), both slightly above the figures recommended, namely fat (25-30%) and protein (10-15%), with carbohydrate (48.7%) lower than the recommended (55-65%)[33] (Table 3). The mean±SD sodium intake (3000±130 mg) exceeded the Singapore dietary guidelines for adults, which recommends less than 2000mg per day.[33] The sources of sodium intake are shown in Figure 2 (categories adapted from Liem et al. 2011).[34] The main sources of sodium were sauces and salt added during cooking; the next were fish, poultry and meat.

Associations between taste and diet

There was a negative correlation between rated bitterness intensity and liking (r=-0.501). There were no correlations observed between rated taste intensities (sweetness for sucrose, saltiness for KCl and bitterness for quinine) and diet (nutrient intake, energy contribution or dietary variety) (Table 5). However, there were weak negative correlations between NaCl intensity and intakes of total sugar and potassium. Moreover, for citric acid intensity there were weak negative correlations with protein and potassium intakes (Table 5).

Table 1. Participant characteristics

	Total(n=100)		Women(n=50)		Men(n=50)		p-value
	Mean	SD	Mean	SD	Mean	SD	
Age (years)	25.7	4.6	25.7	5.1	25.7	4.2	0.10
Height (cm)	166.1	8.1	160.0	6.0	172.1	4.9	<0.01
Weight (kg)	61.4	11.7	54.5	9.1	68.4	9.8	<0.01
BMI (kg/m^2)	22.2	3.6	21.3	3.7	23.1	3.2	0.01
Fat mass (%)	23.1	8.4	28.8	6.8	17.4	5.5	<0.01
Systolic blood pressure (mmHg)	108.5	12.7	99.8	7.4	117.1	10.9	<0.01
Diastolic blood pressure (mmHg)	65.3	8.4	63.6	7.0	66.9	9.4	0.05

SD: standard deviation; cm:centimeter; m: meter; kg: kilogram; BMI: body mass index.

Table 2. Average rating of taste measures (intensities and preferences) by gender (7.7cm line scale)

Item	Measure	Women (*n*=50)		Men (*n*=50)		*p*-value
		Mean	SD	Mean	SD	
Sucrose	Sweetness[a]	4.65	1.46	4.99	1.76	0.30
	Saltiness	0.07	0.17	0.29	0.76	0.05
	Sourness	0.07	0.18	0.20	0.75	0.25
	Bitterness	0.09	0.20	0.18	0.67	0.40
	Burn	0.07	0.18	0.20	0.64	0.19
	Liking	4.60	1.21	4.62	1.48	0.94
NaCl	Sweetness	0.10	0.26	0.15	0.43	0.54
	Saltiness[a]	5.07	1.53	5.09	1.87	0.95
	Sourness	0.30	0.81	0.58	1.03	0.14
	Bitterness	0.10	0.23	0.17	0.44	0.31
	Burn	0.17	0.35	0.29	0.72	0.30
	Liking	2.40	1.40	2.54	1.68	0.64
KCl	Sweetness	0.12	0.24	0.16	0.62	0.67
	Saltiness[a]	1.36	1.88	1.27	1.85	0.83
	Sourness	0.26	0.80	0.55	1.07	0.13
	Bitterness[a]	3.38	1.81	3.59	2.41	0.63
	Burn	0.43	0.77	0.37	1.04	0.75
	Liking	1.29	1.17	1.58	1.38	0.27
Citric acid	Sweetness	0.28	0.59	0.38	0.77	0.47
	Saltiness	0.77	1.56	0.81	1.34	0.91
	Sourness[a]	3.44	1.41	3.99	2.15	0.13
	Bitterness	0.19	0.44	0.50	1.03	0.06
	Burn	0.27	0.53	0.28	0.74	0.91
	Liking	3.07	1.25	2.64	1.70	0.15
Quinine	Sweetness	0.09	0.17	0.14	0.49	0.51
	Saltiness	0.18	0.29	0.25	0.67	0.50
	Sourness	0.19	0.71	0.39	0.93	0.23
	Bitterness[a]	3.68	1.79	3.85	2.60	0.71
	Burn	0.38	0.61	0.57	1.24	0.34
	Liking	1.65	1.09	1.74	1.46	0.71
PTC	Sweetness	0.08	0.23	0.14	0.47	0.43
	Saltiness	0.16	0.38	0.20	0.63	0.76
	Sourness	0.20	0.68	0.36	0.95	0.34
	Bitterness[a]	4.85	2.40	4.86	2.62	0.98
	Burn	0.64	1.22	0.76	1.50	0.66
	Liking	1.16	1.25	1.27	1.49	0.69

SD: standard deviation.
[a] The main taste quality to be tested for the tastant.

Table 3. Nutrient intake, energy contribution and dietary variety in Chinese women and men

Nutrient	Total (*n*=100)		Women (*n*=50)		Men (*n*=50)		*p*-value
	Mean	SD	Mean	SD	Mean	SD	
Energy (kcal)	1830	431	1670	323	2000	462	<0.01
Fat (g)	68.5	20.4	64.1	18.5	73.0	21.4	0.03
SFA (g)	26.2	8.6	24.2	7.7	28.2	9.1	0.02
MUFA (g)	24.0	8.4	22.8	7.9	25.3	8.7	0.13
PUFA (g)	11.2	4.1	10.6	3.4	11.9	4.7	0.13
Energy from Fat (%)	33.7	7.2	34.6	8.1	32.7	6.2	0.20
CHO (g)	223	64.5	201	55.3	245	66.2	0.01
Total sugars (g)	60.8	32.0	54.6	27.8	67.0	34.9	0.05
Energy from CHO (%)	48.7	9.7	48.2	9.6	49.3	9.7	0.59
Prot (g)	78.4	33.4	67.5	16.9	89.4	41.4	0.01
Energy from Prot (%)	17.0	4.8	16.4	3.3	17.7	5.8	0.16
Fiber (g)	15.3	5.9	14.4	5.0	16.3	6.6	0.10
Sodium (mg)	3000	1030	2890	1013	3110	1040	0.29
Potassium (mg)	1640	731	1640	638	1640	820	0.98
Dietary variety score per day	8.4	2.5	8.7	2.5	8.1	2.5	0.97

SD: standard deviation; SFA: saturated fat; MUFA: monounsaturated fat; PUFA: polyunsaturated fat; CHO: carbohydrate; Prot: protein.

No correlation was observed between rated preferences for any tastant except citric acid with fat and carbohydrate; and PTC with dietary fiber intake (Table 6).

DISCUSSION

Taste instensities and preferences

No significant differences were observed in taste intensities and preferences between women and men for

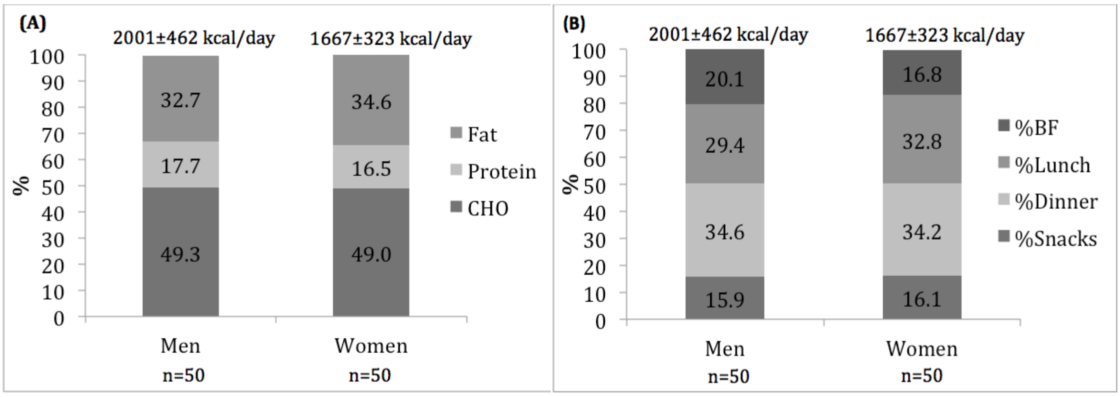

Figure 1. Dietary pattern: Percentage energy contributed by (A) macronutrients and (B) eating episodes by gender.

Table 4. Sample 2-day food recall (criteria adapted from Savige et al.1997)[32]

	Weekday	DV score	Weekend-day	DV score
Breakfast	Steamed sweet potato (1 medium)	1	Steamed pork bun (3 pc)	1
	Cheerios (1 cup)	1	Soon kueh – Turnip dumpling (1 pc)	1
	Soy milk (1 cup)	1		
Snack	NIL		NIL	
Lunch	Prawn noodle soup (1 bowl)	1	White rice (1 bowl)	*
	Buah Long Long fruit juice (1 cup)	1	Stir fried mushrooms (2 Tbsp)	1
	Yoghurt with fruits (1 cup)	1	Stir fried bokchoy (2 stalks)	1
			Green curry chicken breast (2 Tbsp)	1
			Lemon (1 pc)	1
			Water	*
Snack	NIL		Baked chicken wing (3 pc)	1
			Chocolate biscuit (2 small pc)	1
Dinner	Teow chew rice porridge -plain (1 bowl)	1	White rice (0.5 bowl)	*
	Stir fried beansprouts (4 Tbsp)	1	Sliced fish soup (0.5 bowl)	1
	Minced pork in black bean sauce (3 Tbsp)	1	Stir fried broccoli (2 Tbsp)	1
	Rocket salad with sesame sauce (1 cup)	1	Green curry chicken breast (2 Tbsp)	*
	Steamed sweet potato (0.5 medium)	*	Steamed pork bun (2 pc)	*
	Stir fried spinach (1 Tbsp)	1		
	Papaya (1 slice)	1		
	Coke zero	1		
	Water	*		
Snack	NIL		NIL	
Total		13		10

DV score: Dietary variety score (*Repeated food item or water: no score).
Dietary variety score for 2 days=23.

anytastant tested (Table 2). This is in agreement with findings among non-Chinese (Caucasians) for ratings of sweetness of sucrose, sourness of citric acid and bitterness of quinine.[30] Tastants were correctly identified; that is, sucrose was rated as sweet; NaCl rated as salty, citric acid as sour, and quinine as bitter. The numerical ratings in the present study compared to one conducted largely among Caucasians, which used the same tastants, concentrations and 7.7cm visual analog scale,[30] were lower for women and higher for men.[30] The comparisons are: sweetness of sucrose, 4.65 vs 4.68 for women, 4.99 vs 4.66 for men; sourness of citric acid, 3.44 vs 3.62 for women, 3.99 vs 3.84 for men; and bitterness of quinine, 3.68 vs 3.99 for women, 3.85 vs 3.78 for men. These ratings were all less than 1cm different between Chinese andCaucasians. However, the trend was different between women and men. In addition, liking ratings for both women and men were higher in this present study compared to the Knaapila et al. 2012 study.[30] That is, for sucrose, women and men respectively, 4.60 and 4.62 vs 4.55 and 4.33; for NaCl, 2.40 and 2.54 vs 1.69 and 1.62; for citric acid, 3.07 and 2.64 vs 1.47 and 1.78. The bitterness rating of the different tastants was rated much lower in the present study compared to the Knaapila et al. 2012 study.[30] That is for bitterness of NaCl: women and men respectively, 0.10 and 0.17 vs 1.10 and 1.86; and for bitterness of citric acid: 0.19 and 0.50 vs 3.00 and 2.58. Similar to a study conducted in 1988, for both women and men, KCl was perceived as more bitter than salty, which can be attributed to the cation, K^+.[35] Potassium salts are used as salt substitutes to replace sodium intake in the diet.[36] However, due to the bitter and metallic taste of KCl, a mixture is commonly used.[37,38] A study conducted in a Chinese population reported that there were no differences observed for overall acceptability between salt substitute and normal NaCl after the intake of a mixed salt substitute (65% NaCl, 25% KCl and 10% magnesium sulphate) over a period of 12 months.[18] However, the findings for a mixture of KCl may not apply to KCl on its own.

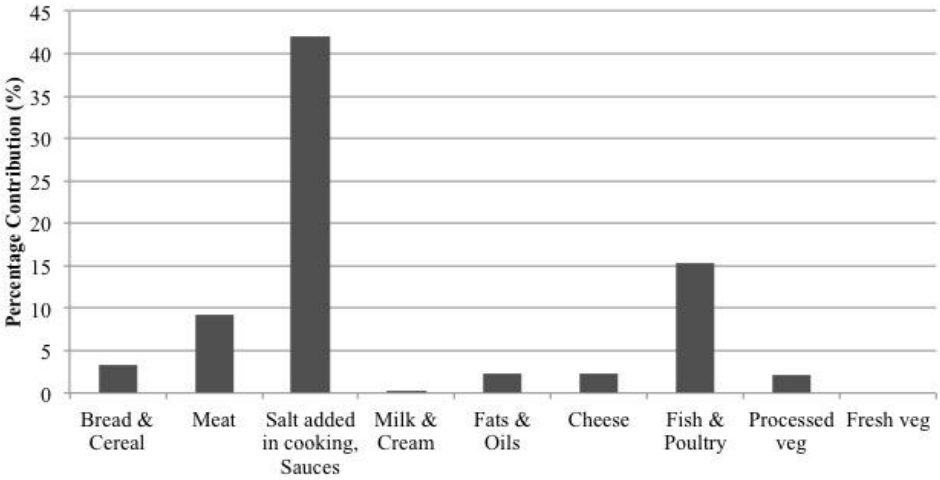

Figure 2. Percentage contribution of food types to average daily intake of sodium from Chinese study participants (categories adapted from Liem et al 2011).[34]

Table 5. Correlations (r) between taste intensities and nutrient intakes or dietary pattern

Nutrient/ Dietary pattern	Sucrose Intensity	NaCl Intensity	KCl Intensity	Citric acid Intensity	Quinine Intensity	PTC Intensity
Energy (kcal)	0.00	-0.13	0.03	-0.08	-0.14	-0.06
Fat (g)	0.01	-0.10	0.08	-0.02	-0.10	-0.06
SFA (g)	0.10	-0.01	-0.07	0.04	-0.08	-0.06
MUFA (g)	-0.05	-0.11	-0.14	-0.06	-0.13	-0.05
PUFA (g)	-0.03	-0.06	-0.06	-0.03	0.03	0.01
Energy from Fat (%)	0.00	0.01	-0.07	0.05	0.01	-0.01
CHO (g)	0.09	-0.05	0.05	0.02	-0.08	0.03
Total sugars (g)	-0.03	-0.24*	0.02	-0.13	-0.14	-0.08
Energy from CHO (%)	0.10	0.06	0.09	0.09	0.02	0.07
Prot (g)	-0.12	-0.14	-0.07	-0.22*	-0.13	-0.13
Energy from Prot (%)	-0.09	-0.03	-0.09	-0.19	-0.01	-0.06
Fiber (g)	0.03	0.07	0.06	-0.04	-0.05	0.19
Sodium (mg)	-0.08	-0.09	-0.12	0.02	-0.08	-0.03
Potassium (mg)	-0.19	-0.26*	-0.07	-0.26*	-0.14	-0.05
Dietary variety score per day	-0.02	-0.10	0.16	-0.06	-0.08	-0.00

SD: standard deviation; SFA:saturated fat; MUFA:monounsaturated fat; PUFA:polyunsaturated fat; CHO:carbohydrate; Prot:protein; NaCl: sodium chloride; KCl: potassium chloride; PTC: phenylthiocarbamide.
*Correlation is significant at the 0.05 level.

Diet
The average energy intake for men (2001±462 kcal/day) was significantly higher than women (1667±323 kcal/day) (Figure 1A). When compared to another study which looked at 13 Chinese women's energy intake using a 3-day food record, the average energy intake was comparable at 1544±370 kcal/day.[39] The percentage of energy contributed by macronutrients in our study was about 49% from CHO, 17% from protein and 34% from fat. These percentages are consistent with the Singapore's National Nutrition Survey 2010 which reported 52.1% from CHO, 15.3% from protein and 31.4% from fat, which reflects a decreasing trend for CHO, observed since 1998.[33]

Overall, the average dietary variety was found to be 8±3 (mean±SD) food items per day (Table 3). There have been few studies which characterize Chinese diets in this way to provide indices of dietary quality, since most focus on macro- and micro-nutrient intakes. A diet that is high in total food variety score is essential in order to achieve nutrient adequacy.[32] A score of >30 per week is classified as very good dietary adequacy, 25-29 per week as good, 20-24 per week as fair, <20 per week as poor and <10 per week as very poor dietary adequacy.[32] A dietary variety score of more than 12 foods per day would indicate good dietary adequacy.[32] As the average dietary variety score was less than 12, the diet of this study population was not found to have good dietary adequacy. However, indices of food variety among Chinese in Australia indicate that Chinese diets have among the greatest potential to achieve diversity.[40] When they do, as in Taiwan, they also confer relative longevity.[41] Therefore, understanding their tastant characteristics is of considerable interest.

In this present study, participants' dietary sodium intake was approximately 50% higher than the Singapore dietary guidelines for adults. Excess sodium intake over a prolonged period of time has been linked to increased risk of cardiovascular diseases and hypertension.[42] Hence, we looked at the dietary contributors of sodium intake. Comparing the United States (US), United Kingdom (UK) and Japan,[34] the Singaporean Chinese dietary sources of sodi-

Table 6. Correlations (r) between taste preferences and nutrient intakes or dietary pattern

Nutrient/ Dietary pattern	Sucrose Preference	NaCl Preference	KCl Preference	Citric acid Preference	Quinine Preference	PTC Preference
Energy (kcal)	0.11	0.04	0.06	-0.07	0.17	-0.12
Fat (g)	0.12	0.14	0.12	0.22*	0.19	-0.01
SFA (g)	0.09	0.14	0.06	0.17	0.19	0.05
MUFA (g)	0.06	0.14	0.12	0.17	0.18	-0.03
PUFA (g)	0.07	0.05	0.14	0.12	0.18	-0.03
Energy from Fat (%)	0.08	0.14	0.10	0.41*	0.07	0.09
CHO (g)	0.11	-0.07	-0.09	-0.20	0.07	-0.10
Total sugars (g)	0.13	-0.07	-0.09	-0.08	0.10	0.06
Energy from CHO (%)	0.00	-0.15	-0.17	-0.27*	-0.06	0.00
Prot (g)	0.03	0.09	0.17	-0.13	0.12	-0.17
Energy from Prot (%)	-0.04	0.10	0.15	-0.07	-0.02	-0.16
Fiber (g)	0.02	-0.11	-0.16	-0.18	0.00	-0.30*
Sodium (mg)	0.06	0.11	-0.03	-0.16	0.08	-0.02
Potassium (mg)	0.08	-0.12	0.04	-0.04	0.10	-0.10
Dietary variety score per day	0.12	-0.06	-0.04	0.00	0.03	-0.10

SD: standard deviation; SFA:saturated fat; MUFA:monounsaturated fat; PUFA:polyunsaturated fat; CHO:carbohydrate; Prot: Protein; NaCl: sodium chloride; KCl: potassium chloride; PTC: phenylthiocarbamide.
*Correlation is significant at the 0.05 level.

um are similar to Japan with the main contributor being sauces and salt added during cooking (Figure 2). In Japan, sodium comes mainly from soy sauce, salted vegetables and miso soup.[43] In Singaporean Chinese diets, salt added in home cooking and soy sauce are the greatest contributors. This is different to the UK and US where the main contributors are from bread, grains, cereals, red meats, poultry, and eggs, along with salt from restaurants and fast foods.[43] In Singapore, the prevalence of hypertension in Chinese was 23.4% in 2010.[16] Since the molar ratio of sodium to potassium is regarded as an important factor in both hypertension and stroke among Chinese, ways to reduce it are important.[44] Thus, public health messages emphasize the importance of reducing salt added during cooking and in sauces as an effective way to cut down sodium from the diet.

Associations between taste and diet

Overall, there is no correlation between the rated intensities of sweet, salty, sour and bitterness with the diet (Table 5). We also found no correlation between the preferences for sweet, salty, sour and bitterness with dietary characteristics (Table 6). A recent study which looked at association of sweet taste function with anthropometry and dietary intake in adults found that, compared to detection and recognition thresholds, intensity measures were the most suitable for assessment of associations between taste and food consumption.[45] Although associations have been found between sweet taste intensity and energy intake from Food Frequency Questionnaires, sweet taste did not appear to have a robust influence on dietary intake.[45] A study by Cicerale et al.,[6] also reported that sweetness intensity did not appear to play a role in adult dietary intake.[6] Yet another recent study also found that preference for sweetness does not significantly affect self-reported carbohydrate and sugar intake.[46] Dietary intake only seems important for salt taste acuity when assessed in older European adults,[47] but in general diet does not appear to be a predictor of taste acuity. In a large study (n=2371) looking at the intensity of salt taste and prevalence of hypertension, the taste perception of salt was not related to mean blood pressure.[48] Most evident in our study was the preference for citric acid compared to the other tested tastants (Table 6). Citric acid was rated as sour, bitter and salty, but the ratings of citric acid as salty (r=0.82) and bitter (r=0.38) were more reliable compared to sour (r=0.26). For the NaCl rating, 12% also rated the taste as sour. There seems to be salty-sour confusion among Chinese. This is different from the Caucasian population where there appears to be bitter-sour confusion.[30] Sourness is also rated as a taste for quinine and KCl (Table 2). The acceptability of sour taste among infants has also been of interest in regard to fruit intake;[49] however, the more general dietary association between diet, citric acid and macronutrient intake is unknown. Even more interesting is taste preference programming during fetal life through maternal exposure.[50]

PTC or PROP tasters and non-tasters in relation to diet[51-54] may,[51-53] or may not be evident.[54] The present study shows no evident correlation between PTC intensity and preference in relation to dietary intake and dietary pattern, except for PTC preference with lower intakes of dietary fiber. Most studies have classified participants as tasters and non-tasters based on PTC intensity, but not on preference for PTC.

Strengths and limitations

One of the strengths of this study was its ability to evaluate taste perception and diet with people of similar ethnicity. It has examined the association between taste perception and Chinese diet. Test-retest reliability was established in a sub-set. A limitation was that two 24-hour recalls to assess dietary intake may not have taken sufficient account of day-to-day variations in consumption. Another limitation is that a single concentration of each tastant was used to measure intensity and preference; differing doses of tastant may have been more discriminating. Other factors which may affect dietary intake, such as nutrigenomics (single nucleotide polymorphisms), eating behaviors and food choices need to be taken into account. Comparisons between Chinese in different geographical and socio-economic settings and with other ethnic groups, such as Indian and Malay Singaporeans are warranted.

In summary, meal pattern and degree of dietary variety had little bearing on the relationship between taste intensity and preference for of sucrose, NaCl, KCl, citric acid, quinine or PTC. However, there was a salty-sour confusion among Singaporean Chinese unlike the bitter-sour confusion reported for Caucasians.

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