Food neophobia and its association with taste threshold and food liking among adults

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Summary

This study was designed to determine the relationship between taste threshold (sweet, bitter, sour, salt, fat), food neophobia and food liking. A total of 51 non-smoking and healthy individuals were recruited in Ankara, Turkey. The taste threshold was assessed using the 3-alternate forced choice methodology. Food neophobia score was applied to determine whether there was a fear of trying new foods. The food liking questionnaire had 50 items (sweet foods, salty foods, sour foods, bitter foods, fatty foods) based on taste classification. The subjects indicated their level of liking on a 10-point scale that ranged from 1 ("strongly disliking") to 10 ("strongly liking"). The results showed that the sweet threshold and fat threshold of neophobics were higher than those of neophilics and neutral adults ($p < 0.05$). There was no correlation between food liking scores and either taste thresholds or food neophobia scores. However, food neophobia scores positively correlated with sweet and fat taste thresholds ($p < 0.05$). The findings suggest that food neophobia may be linked to some tastes, while food liking may depend on further factors, such as habits, food environment and any factor related to the food choice of the individuals.

Keywords

taste threshold; food neophobia; food liking; adult

Food neophobia is one's reluctance to try unfamiliar foods, with genetic and environmental determinants [1]. This food behaviour is an inherited tendency that has been passed down from generation to generation, causing some individuals to be excessively choosy about food, probably to avoid the toxicity of an unknown food source [1, 2]. Despite this possible benefit, food neophobia was also found to be associated with low diet quality, more disliked foods generally (even if familiar) and reduced intention to try new foods [3, 4]. According to recent research, food neophobia is negatively related to fruit and vegetable consumption in adults and to diet variety in general [5]. It is important to consider the possibility of unpleasant sensory properties when evaluating novel food refusal. In this context, it is possible that taste responsiveness may have an essential role in moderating this effect [2, 6].

Taste has a significant impact on food choice. As individuals' taste perceptions vary, this can be critical to food choice, personal nutrition and quality of life. Therefore, it is necessary to examine individual motivations for food choices to promote a diet with positive effects on health [7]. Taste quality is related to various nutritional or physiological needs or signifies a potential dietary risk. Sweet taste represents carbohydrates, salty taste represents electrolytes, bitter and sour tastes represent potentially harmful compounds and are generally associated with innate aversion [8]. Fat taste is associated with acids in the oral cavity [9]. Taste receptors of taste buds on the tongue papillae recognize a substance in the mouth so that taste sensation is experienced [10]. It is known that sensitivity to taste qualities varies among individuals and polymorphisms of the genes encoding for taste are assumed to be among

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the multifactor reasons for these inter-individual differences [11].

Taste sensitivity is defined as one's ability regarding taste stimuli. It is assessed by various methods such as detection threshold (which signifies the lowest concentration of a tastant detected), recognition threshold (which signifies the lowest concentration of a correctly identified tastant), taste intensity rating (which signifies the intensity of sensation elicited by a tastant at a certain concentration level), fungiform papillae density (small, mushroom-shaped structures density of which varies largely among individuals) and 6-*n*-propylthiouracil taster status (related to genotype TAS2r38) [12]. Contemporary evidence regarding the association between taste sensitivity and food neophobia is inconsistent, indicating higher taste sensitivity in neophobic people [13, 14], while some studies suggested no association at all [2, 15].

Food liking is a crucial factor in eating behaviour. It is defined as the pleasantness of the taste of food in the mouth and is related to the liking of main taste qualities (sweet, sour, bitter, salty, umami and fat) [16]. Food liking refers to the perceptual outcome that combines the flavour of food, previous experience with the food and health state. These factors contribute to an individual's response to food that is multidimensional and dynamic [17]. The relationship between taste sensitivity and food liking has been explored over the decades, but it is still unclear how individual taste sensitivity measures relate to each other and to food liking. Furthermore, different methods for testing taste sensitivity may lead to varied results, making it difficult to compare results across studies [18]. In a study involving 9 000 participants from USA, United Kingdom, Australia, Germany and Denmark, foods with high arousal characteristics were found to have the strongest negative associations between food phobia and liking [19]. A review by Cox et al. [20] revealed the need to assess the correlation between taste sensitivity and food liking.

Although the sense of taste is thought to significantly affect food-related behaviour, its effect on food neophobia and food liking is unclear. In this context, the present study aimed to assess the correlation between taste threshold (sweet, bitter, sour, salt, fat), food neophobia, and food liking in adults. It was hypothesized that taste thresholds would be associated with food neophobia but not with food liking. Based on understanding the role of taste thresholds in food-liking and neophobia, insight into food choice can be provided. To the authors' knowledge, this is the first study to examine the relationship between taste thresholds and food neophobia with a food liking questionnaire based on taste classification.

MATERIALS AND METHODS

Subjects

Healthy persons aged 19–44 years and having agreed to participate in the study were from the university through public advertisement in Ankara, Turkey. The exclusion criteria were determined as follows: being aged over 44 years, smoking, being pregnant or lactating, suffering from ageusia, receiving a treatment that could modify taste perception, or having a body mass index (*BMI*) of < 18.5 kg·m^{-2} or > 30.0 kg·m^{-2}. All subjects were invited to all five laboratory sessions over three days (two sessions per day with a one hour break between) to assess their taste thresholds. Also, a questionnaire for food neophobia and food liking was administered to the participants. Tab. 1 shows the characteristics of the participants. The present study was carried out based on the Declaration of Helsinki principles and the study protocol was approved by the Local Research Ethics Committee (protocol number, GO19/1060).

Taste threshold assessment

Ascending series 3-alternate forced choice methodology was adopted to detect taste threshold [21, 22]. Saccharose, caffeine, sodium chloride, citric acid and oleic acid were used to determine sweet, bitter, salty, sour and fat taste thresholds, respectively. The solutions for four tastes (sweet, salty, bitter, sour) were prepared in accordance with the ISO standard 3972:2011 [23]. Thirteen concentrations (0.02, 0.06, 1.0, 1.4, 2.0, 2.8, 3.8, 5.0, 6.4, 8.0, 9.8, 12.0 and 20.0 mmol·l^{-1}), which are stated in the literature [22, 24], were used to determine fat taste threshold. Details of the taste threshold procedures were published in another study [25]. Participants were asked to rinse their mouths with water before starting and between each set of samples in testing sessions. To avoid visual cues, testing was conducted at 20–22 °C in a room with curtains drawn and with minimal lighting. Participants wore nose clips during sessions to eliminate any possible conflicting non-taste sensory inputs.

Food neophobia assessment

The food neophobia score (*FNS*) [26] was used to assess individuals' tendency to avoid or try new foods. *FNS* has ten items rated using a seven-point scale ranging from "strongly disagree" (score 1) to "strongly agree" (score 7). A half of the items

(items 1, 4, 6, 9, and 10) are reversely scored. The total score of *FNS* score ranges between 10 and 70 points. Higher scores signify higher food neophobia. Cronbach's alpha internal consistency was 0.81. The participants were divided into three groups based on the 33rd and 66th percentile [27, 28]. Those who scored 10–16 were considered food neophilic, those who scored 17–39 were considered neutral and those who scored 40–65 were considered food neophobic.

Food liking assessment

A food liking questionnaire on sweet foods, salty foods, sour foods, bitter foods and fatty foods was applied to all the participants based on the taste classification [29]. They marked their level of liking on a 10-point scale. On this scale, 1 referred to "strongly disliking" and 10 referred to "strongly liking".

In order to calculate the liking mean score for each taste, the average of the liking scores of the foods included in the related taste classification was used. High scores mean liking foods, low scores mean disliking foods. The sweet food classification includes candy bar, jams, chocolates, cola, other sugar-carbonated beverages, doughnut, sweet roll, Hawaiian punch, pie, brownies, cookies, cake and ice cream. In the bitter food classification, grapefruit juice, mustard greens, coffee, grapefruit, kale greens, chard greens, lemonades, brussels sprouts, mustard, liquor, beer and red wine were examined. The salty food classification includes potato chips, salt, maize chips, french fries, popcorn, processed meat, crackers, nuts, tomato juice and hot dogs. The sour food classification includes grapefruit, grapefruit juice, lemonade, mustard, red wine, sour cream, dressing with oil and vinegar, yoghurt, oranges, orange juice, cider and white wine. The fatty food classification includes doughnuts, processed meat, potato chips, french fries, butter, margarine, cream, turkey with skin, chicken with skin, hot dogs, mayonnaise, beef and hamburger.

We first validated the food liking questionnaire in Turkey for this research, the results of that study are currently under review for publication. In this study, the food liking questionnaire was translated and adapted to the food culture and Turkish language using the Brislin method [30]. The translated forms were compared with the original form by an expert panel. After deciding on necessary adjustments consisting in a change of one item (bacon was replaced by beef because of culturally influenced eating habits), the last version of the Turkish food liking questionnaire was formed.

Tab. 1. Characteristics of study participants.

	Food neophobia groups									*p*	Total (n = 51)		
	Neophilic (n = 16)			Neutral (n = 17)			Neophobic (n = 18)						
	n	Proportion [%]		*n*	Proportion [%]		*n*	Proportion [%]			*n*	Proportion [%]	
Gender													
Male	8	50.0		7	41.2		5	33.3		0.407 *	20	39.2	
Female	8	50.0		10	58.8		13	66.7			31	60.8	
	$X \pm SEM$	Median	*IQR*	$X \pm SEM$	Median	*IQR*	$X \pm SEM$	Median	*IQR*		$X \pm SEM$	Median	*IQR*
Age (19–43 years)	28.50 ± 2.07	27.00	21.25–37.00	27.64 ± 1.63	27.00	22.00–33.50	30.66 ± 1.84	33.50	22.50–37.50	0.547 **	28.98 ± 1.06	27.00	22.00–36.00
Weight [kg]	69.42 ± 2.00	67.60	64.85–73.82	69.08 ± 1.82	70.00	64.05–73.15	73.24 ± 2.28	72.15	68.30–80.57	0.340 **	70.65 ± 1.19	70.30	64.80–74.00
BMI [$kg \cdot m^{-2}$]	23.63 ± 0.53	23.97	21.62–24.73	24.30 ± 0.47	24.31	23.39–24.71	25.49 ± 0.36	25.61 [ab]	25.05–26.23	0.004 **	24.51 ± 0.28	24.49	23.66–25.86
FNS	30.62 ± 1.69	31.50	28.25–36.50	41.52 ± 0.67	41.00 [a]	39.00–44.00	50.77 ± 1.00	49.50 [b]	48.00–53.25	< 0.01 **	41.37 ± 1.33	42.00	37.00–48.00

n – number of samples, *X* – arithmetic mean, *SEM* – standard error of the mean, *IQR* – interquartile range, *BMI* – body mass index, *FNS* – food neophobia score, *p* – statistical significance (* – chi-square test, ** – statistical comparisons were made by Kruskal-Wallis test, a – median was significantly different from that for the neophilics group, b – median was significantly different from that for the neutrals group, $p < 0.05$).

Anthropometric assessment

The body weight of the participants was measured using the Body Composition Analyzer TBF-300A (Tanita, Tokyo, Japan). Height (to the nearest 0.1 cm) was measured using a portable stadiometer SECA213 (SECA, Hamburg, Germany). *BMI* was calculated by dividing the individual's weight (in kilograms) by the square of the individual's height (in square metres).

Statistical analysis

Statistical analysis was performed using IBM SPSS statistical software version 22 (SPSS, Chicago, Illinois, USA). All graphs were created using GraphPad Prism 9 (GraphPad, San Diego, California, USA). Visual and analytical methods were used to analyse normality of the data. The descriptive results of the individuals were mean (X) with standard error (*SEM*) and median with interquartile range (*IQR*). The chi-square test was used to examine gender differences between food neophobia groups. One-way analysis of variance (ANOVA) was used to compare the mean taste thresholds and food liking scores, according to food neophobia groups, and Tukey's test was used for post hoc analysis. Kruskal-Wallis test was used to compare the mean *BMI* and food neophobia score according to neophobia groups and Mann-Whitney U test was used for post hoc analysis. Bivariate relationships between food neophobia scores, taste thresholds, food liking scores and *BMI* were estimated using Pearson and Spearman correlation coefficient. After adjusting for *BMI*, partial correlation was used to compare the degree of association between food neophobia scores, individual taste thresholds and each food liking score. The significance level was set at $p < 0.05$.

RESULTS

This study involved 31 women (60.8 %) and 20 men (39.2 %). The characteristics of them are presented in Tab. 1. The mean food neophobia score was 41.37 ± 1.33. Among the participants, the frequency of neophilics, neutrals and neophobics were 31.4 %, 33.3 % and 35.3 %, respectively. The neophilic group consisted of participants aged between 19 and 43 (mean age 28.50 ± 2.07 years) and a *BMI* range from 19.35 $kg \cdot m^{-2}$ to 27.50 $kg \cdot m^{-2}$ (mean *BMI* 23.63 ± 0.53 $kg \cdot m^{-2}$). The neutral group consisted of participants aged between 19 and 41 years (mean age, 27.64 ± 1.63 years) and *BMI* range from 19.39 $kg \cdot m^{-2}$ to 28.04 $kg \cdot m^{-2}$(mean *BMI* 28.46 ± 0.55 $kg \cdot m^{-2}$). The neophobic group consisted of participants aged between 20 and 41 years (mean age, 30.66 ± 1.84 years) and *BMI* range from 20.58 $kg \cdot m^{-2}$ to 27.80 $kg \cdot m^{-2}$ (mean *BMI* 25.49 ± 0.36 $kg \cdot m^{-2}$). There was a significant difference between food neophobia scores according to food neophobia groups ($p < 0.05$). Also, the neophobic group had a significantly higher *BMI* compared to the neutral and neophilic groups ($p < 0.05$).

Fig. 1 shows the comparison of taste thresholds of the neophilic, neutral and neophobic individuals. The neophobic participants had significantly higher taste thresholds in comparison to neophilic participants and neutral participants for sweet [(4.83 ± 0.38) vs (3.18 ± 0.40), (3.29 ± 0.29)], and fat [(8.27 ± 0.51) vs (6.37 ± 0.60), (6.29 ± 0.39)] tastes (for sweet $p = 0.01$; for fat $p = 0.01$). The mean salty taste threshold of the neophilic, neutral and neophobic individuals was 3.68 ± 0.47 $mmol \cdot l^{-1}$, 3.28 ± 0.40 $mmol \cdot l^{-1}$ and 4.44 ± 0.36 $mmol \cdot l^{-1}$, respectively. The bitter taste threshold of the neophilics was 3.25 ± 0.39 $mmol \cdot l^{-1}$; the bitter taste threshold of the neutrals was 3.64 ± 0.39 $mmol \cdot l^{-1}$ and the bitter taste threshold of the neophobic participants was 3.77 ± 0.34 $mmol \cdot l^{-1}$. The mean sour taste threshold of the neophilic, neutral and neophobic individuals was 3.75 ± 0.37 $mmol \cdot l^{-1}$, 3.76 ± 0.40 $mmol \cdot l^{-1}$ and 3.83 ± 0.45 $mmol \cdot l^{-1}$, respectively. There was no significant difference in salty, bitter and sour taste threshold levels among the neophilics, neutrals and neophobics (for salty $p = 0.13$, for bitter $p = 0.59$, for sour $p = 0.98$).

The scores for liking foods based on individual tastes are given in Tab. 2. According to food neophobia groups, no significant differences were found among subjects' food liking scores ($p > 0.05$). In addition, when each food in the food liking questionnaire was examined according to food neophobia groups (Tab. 3), the coffee liking scores of the neophobic adults were higher than the others ($p = 0.01$). Also, neophilics had higher cream liking scores than neutral subjects ($p = 0.02$).

There was no correlation between food liking scores and food neophobia scores or between food liking scores and taste thresholds (sweet, salty, bitter, sour, fat). However, food neophobia scores positively correlated with sweet and fat taste thresholds (Tab. 4). When the data were adjusted for *BMI*, there was a positive correlation only between food neophobia and sweet taste threshold ($r = 0.33$, $p = 0.01$).

Furthermore, when the relationship between sweet threshold and sweet foods in the food liking questionnaire was examined, there was a positive relationship between sweet and cola liking scores

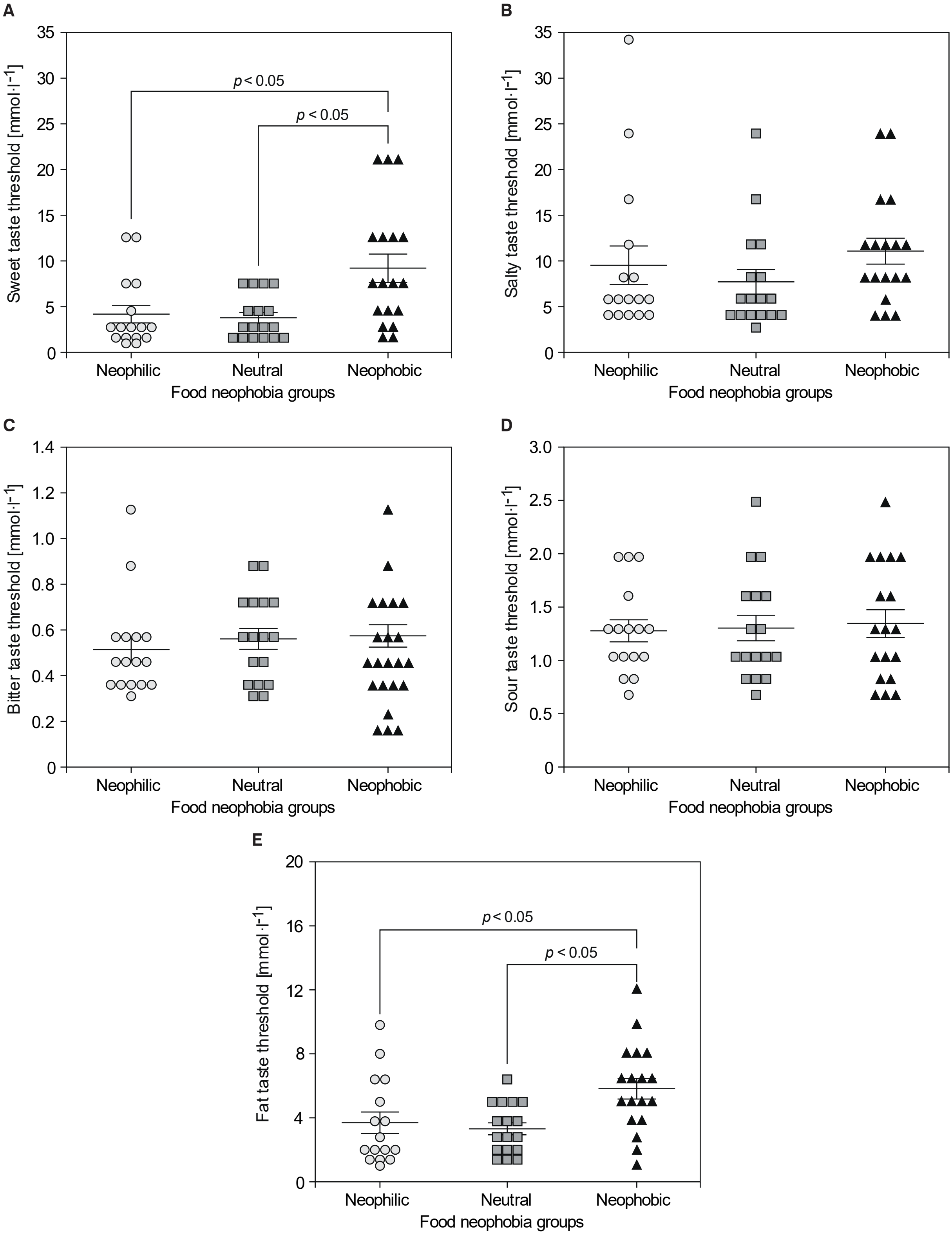

Fig 1. Distribution of taste thresholds according to food neophobia groups.

A – distribution of the sweet taste threshold, B – distribution of the salty taste threshold, C – distribution of the bitter taste threshold, D – distribution of the sour taste threshold, E – distribution of the fat taste threshold.

Scatter plots show mean ± standard error of the mean. Individual taste thresholds of neophilics (little circles), neutrals (little squares), and neophobics (little triangles) subjects are plotted.

One-way ANOVA followed by Tukey's post hoc test. Statistical significance ($p < 0.05$) is indicated.

Tab. 2. Distribution of food liking scores according to food neophobia groups.

	Food liking score			p
	Neophilic group	Neutral group	Neophobic group	
Sweet food liking	6.61 ± 0.43	6.28 ± 0.40	6.10 ± 0.30	0.63
Salty food liking	6.68 ± 0.35	6.76 ± 0.36	6.30 ± 0.35	0.62
Bitter food liking	3.82 ± 0.27	3.96 ± 0.44	3.47 ± 0.26	0.56
Sour food liking	4.46 ± 0.26	5.67 ± 0.55	4.92 ± 0.24	0.09
Fatty food liking	5.80 ± 0.36	5.78 ± 0.33	5.49 ± 0.30	0.75

Food liking score is expressed as arithmetic mean ± standard error of the mean, p – statistical significance (value was calculated by One-way ANOVA).

($r = 0.30$, $p = 0.03$). Likewise, when the relationship between fat taste threshold and fatty foods in the food liking questionnaire was examined, there was a positive correlation between the fat threshold and the liking score of beef, margarine, hot dogs, chicken with skin and turkey with skin ($r = 0.43$, $p = 0.02$; $r = 0.47$, $p = 0.08$; $r = 0.31$, $p = 0.02$; $r = 0.31$, $p = 0.02$ and $r = 0.28$, $p = 0.04$, respectively). Moreover, when the correlation between food neophobia scores and each food in the food liking questionnaire was examined, there was a negative correlation between coffee and food neophobia scores ($r = –0.35$, $p = 0.01$) and a positive correlation between cola and food neophobia scores ($r = 0.29$, $p = 0.03$).

DISCUSSION

The associations between taste thresholds, food neophobia, and food liking were investigated with 51 adult participants. To our knowledge, this is the first study to examine the relationship between taste thresholds and food neophobia with a food liking questionnaire based on taste classification. We compared taste thresholds and food liking scores according to the food neophobia groups. Based on our data, only the sweet and fat taste threshold were associated with a food neophobia score. As individuals' sweet and fat taste thresholds increased, they became less open to trying new types of food (i.e. adopted a neophobic attitude). This was contrary to our hypothesis. Also, there was an association between the sweet taste threshold and food neophobia score after adjusting for *BMI*. Additionally, consistent with many previous findings [10, 21, 22] and our hypothesis, we observed that taste thresholds were not associated with food liking scores based on taste classification.

Contemporary evidence regarding the connection between taste sensitivity and food neophobia is contradictory [2, 13–15]. In a study by Frank and van der Klaauw [15], adults tested for sensitivity to phenylthiocarbamide or quinine hemisulfate showed that they did not differ depending on their attitude. Similarly, another study reported that high, medium and low neophobic subjects did not differ in chemosensory responsiveness [2]. Other studies showed that neophilics had better taste acuity, or that there was a link between salty taste sensitivity, bitter taste sensitivity, and food neophobia [13, 14]. Sweet threshold and fat threshold of neophobics were higher than those of neophilics and neutral participants as well as the sweet and fat taste thresholds were positively correlated with food neophobia.

Neophobic people are more sensitive to tastes. This is explained by the fact that food neophobia is an adaptive evolutionary response that prevents the ingestion of toxic substances, which are often bitter, acidic or astringent [26]. Moreover, neophobics are more sensitive to sensory perception and can detect even minimal changes in food properties [31]. However, In our study, neophobic individuals were found to have higher thresholds (lower taste sensitivity), especially for sweet and fat tastes. Studies on this topic suggest that there may be a relationship between taste sensitivity [13, 14] and the acceptance or rejection of new foods (food neophobia), which can affect variety of diet [27]. However, larger samples and more extensive studies are needed to determine which tastes are more likely to be associated with food neophobia.

The relationship between food neophobia and nutritional status is unclear [14]. On the one hand, food neophobia might limit the variety of the diet, thus reducing energy intake. On the other hand, neophobics might prefer to consume traditional foods with higher energy density than foods with lower energy density, resulting in a higher *BMI* [32]. Also, food neophobia seems to play a mar-

Tab. 3. Food liking score of foods in the food liking questionnaire according to food neophobia groups.

	Statistical test	Food liking score									p
		Neophilic group (n = 16)			Neutral group (n = 17)			Neophobic group (n = 18)			
		X ± SEM	Median	*IQR*	*X ± SEM*	Median	*IQR*	*X ± SEM*	Median	*IQR*	
Sweet foods											
Candy bars	AN	6.00 ± 0.73	6.00	3.50–8.75	5.35 ± 0.59	5.00	3.00–7.00	4.83 ± 0.50	5.00	3.00–6.25	0.41
Jams	AN	6.43 ± 0.57	7.00	4.25–8.00	5.35 ± 0.37	5.00	4.50–6.50	5.83 ± 0.52	6.00	4.75–8.00	0.32
Chocolates	KW	8.37 ± 0.39	9.00	7.00–10.00	8.70 ± 0.49	10.00	7.50–10.00	8.11 ± 0.41	8.50	7.00–9.25	0.28
Cola	AN	4.68 ± 0.74	4.50	2.25–7.00	5.35 ± 0.63	5.00	3.50–8.00	6.11 ± 0.65	7.00	3.00–8.25	0.33
Other SCB	AN	4.93 ± 0.78	5.00	1.50–7.75	5.47 ± 0.51	5.00	4.00–7.00	5.16 ± 0.60	5.00	3.00–8.00	0.84
Doughnuts	KW	4.87 ± 0.83	4.00	2.00–8.25	5.58 ± 0.57	5.00	4.00–8.00	4.41 ± 0.74	3.00	2.00–7.50	0.43
Sweet rolls	AN	6.00 ± 0.63	6.00	4.00–8.00	6.17 ± 0.37	6.00	5.00–7.00	9.61 ± 2.64	7.00	5.75–8.25	0.22
Hawaiian punch	KW	5.20 ± 0.88	6.50	1.00–8.00	6.41 ± 0.72	7.00	5.00–9.00	6.44 ± 0.63	7.00	5.50–8.00	0.67
Pies	KW	8.00 ± 0.91	8.00	5.00–9.00	6.52 ± 0.66	7.00	4.00–9.00	7.00 ± 0.65	8.00	4.00–9.00	0.66
Brownies	KW	8.12 ± 0.47	8.50	7.00–10.00	7.35 ± 0.57	8.00	5.50–9.50	6.66 ± 0.70	8.00	3.75–9.00	0.35
Cookies	KW	7.31 ± 0.60	7.50	5.25–9.75	7.35 ± 0.49	8.00	6.00–9.00	7.11 ± 0.57	7.50	6.50–9.00	0.97
Cakes	KW	7.50 ± 0.67	8.50	5.25–10.00	6.82 ± 0.47	7.00	5.50–8.00	6.66 ± 0.56	7.00	6.25–8.00	0.38
Ice-Cream	KW	7.68 ± 0.62	8.50	5.50–10.00	7.05 ± 0.58	7.00	6.00–9.00	8.50 ± 0.39	9.00	8.00–10.00	0.12
Salty foods											
Potato chips	AN	7.00 ± 0.55	7.00	5.25–8.75	6.58 ± 0.64	7.00	5.00–8.50	6.72 ± 0.65	7.50	4.75–9.00	0.89
Maize chips	AN	6.68 ± 0.59	7.00	6.00–8.75	6.76 ± 0.68	8.00	4.50–9.00	6.61 ± 0.63	7.00	4.75–8.50	0.98
Salt	AN	6.31 ± 0.62	6.00	4.25–8.75	5.70 ± 0.68	5.00	3.00–8.50	5.88 ± 0.49	6.00	4.75–7.00	0.77
French fries	AN	8.56 ± 0.92	8.50	6.50–9.75	7.94 ± 0.46	8.00	6.50–10.00	7.94 ± 0.42	8.00	6.75–9.25	0.72
Popcorn	AN	6.18 ± 0.54	6.50	5.00–7.75	6.29 ± 0.62	7.00	5.50–8.00	6.44 ± 0.45	6.50	5.00–8.00	0.94
Processed meats	AN	6.00 ± 0.68	6.50	4.00–7.75	6.23 ± 0.63	6.00	4.50–8.50	6.44 ± 0.62	7.00	4.75–8.00	0.89
Crackers	AN	7.06 ± 0.45	7.00	6.00–8.75	6.29 ± 0.56	6.00	5.00–8.00	9.05 ± 2.76	7.00	4.75–8.25	0.50
Nuts	AN	7.68 ± 0.50	7.50	6.00–10.00	7.47 ± 0.47	8.00	6.00–9.00	8.05 ± 0.46	8.50	7.00–10.00	0.67
Tomato juice	AN	6.06 ± 0.62	6.00	4.00–8.75	4.88 ± 0.74	4.00	2.00–8.00	5.44 ± 0.60	5.00	3.75–8.00	0.46
Hot dogs	AN	4.37 ± 0.84	3.00	1.00–7.75	4.23 ± 0.56	5.00	2.50–6.00	5.11 ± 0.69	6.00	2.50–8.00	0.63
Bitter foods											
Grapefruit juice	KW	2.25 ± 0.46	1.50	1.00–3.00	3.82 ± 0.63	3.00	1.50–6.00	3.38 ± 0.57	2.50	1.00–5.25	0.16
Mustard greens	KW	2.37 ± 0.46	1.50	1.00–3.00	2.11 ± 0.48	1.00	1.00–2.50	1.72 ± 0.34	1.00	1.00–2.00	0.47
Coffee	KW	8.00 ± 0.63	8.50	7.25–10.00	7.05 ± 0.62	7.00	5.00–9.50	5.22 ± 0.60	5.50	3.00–7.25 †	0.01 *
Grapefruits	KW	3.43 ± 0.63	3.00	1.00–5.00	3.64 ± 0.60	2.00	1.50–6.00	3.16 ± 0.54	2.50	1.75–4.25	0.90
Kale greens	KW	4.12 ± 1.96	1.50	1.00–3.75	2.52 ± 0.47	2.00	1.00–3.00	2.94 ± 0.56	2.50	1.00–3.50	0.85
Chard greens	KW	6.56 ± 1.86	5.00	3.00–6.75	3.70 ± 0.44	3.00	2.50–5.00	5.83 ± 1.70	4.50	2.00–6.25	0.31
Lemonades	AN	7.12 ± 0.49	7.00	5.25–8.00	6.76 ± 0.53	7.00	5.00–8.50	6.83 ± 0.48	7.00	5.00–8.25	0.87
Brussels sprouts	KW	5.18 ± 0.65	5.00	3.25–6.75	3.47 ± 0.58	3.00	1.00–6.50	3.33 ± 0.53	3.00	1.00–5.00	0.09

Tab. 3. *continued*

	Statistical test	Food liking score									p
		Neophilic group (n = 16)			Neutral group (n = 17)			Neophobic group (n = 18)			
		$X \pm SEM$	Median	*IQR*	$X \pm SEM$	Median	*IQR*	$X \pm SEM$	Median	*IQR*	
Mustard	KW	3.18 ± 0.52	3.00	1.00–5.00	2.05 ± 0.35	2.00	1.00–2.50	3.00 ± 0.45	2.00	1.75–5.00	0.17
Liquor	KW	3.12 ± 0.70	1.50	1.00–6.25	1.35 ± 0.14	1.00	1.00–2.00	3.22 ± 0.72	1.50	1.00–6.25	0.14
Beer	KW	3.06 ± 0.69	1.00	1.00–6.00	1.29 ± 0.23	1.00	1.00–1.00	2.27 ± 0.44	1.00	1.00–3.25	0.08
Red wine	KW	3.37 ± 0.74	1.00	1.00–6.00	1.58 ± 0.21	1.00	1.00–2.50	3.22 ± 0.67	1.50	1.00–6.00	0.26
Sour foods											
Grapefruit juice	KW	2.25 ± 0.46	1.50	1.00–3.00	3.82 ± 0.63	3.00	1.50–6.00	3.38 ± 0.57	2.50	1.00–5.25	0.16
Lemonade	KW	7.12 ± 0.49	7.00	5.25–8.00	6.76 ± 0.53	7.00	5.00–8.50	6.83 ± 0.48	7.00	5.00–8.25	0.87
Mustard	KW	3.18 ± 0.50	3.00	1.00–5.00	2.05 ± 0.35	2.00	1.00–2.50	3.00 ± 0.45	2.00	1.75–5.00	0.17
Red wine	KW	3.37 ± 0.74	1.00	1.00–6.00	1.58 ± 0.21	1.00	1.00–2.50	3.22 ± 0.67	1.50	1.00–6.00	0.26
Sour cream	KW	3.18 ± 0.59	2.50	1.25–4.00	3.11 ± 0.51	3.00	2.00–3.50	3.44 ± 0.53	3.00	1.00–5.00	0.89
Dressing with oil and vinegar	KW	5.93 ± 0.77	6.00	4.00–8.75	9.70 ± 5.61	3.00	2.50–6.50	5.05 ± 0.69	4.00	2.75–8.00	0.33
Yogurt	AN	7.81 ± 0.48	8.00	6.00–10.00	7.88 ± 0.40	8.00	6.50–10.00	7.61 ± 0.41	7.00	6.00–9.25	0.90
Oranges	KW	10.62 ± 3.02	8.00	6.25–10.00	7.76 ± 0.47	8.00	6.00–9.50	7.66 ± 0.37	7.50	7.00–8.50	0.78
Orange juice	KW	7.00 ± 0.70	7.50	6.00–9.00	7.47 ± 0.61	8.00	6.00–9.50	7.38 ± 0.93	8.00	5.00–9.25	0.84
Cider	KW	2.87 ± 0.60	1.50	1.00–4.75	1.94 ± 0.40	1.00	1.00–2.00	3.00 ± 0.64	1.00	1.00–5.00	0.25
White wine	KW	3.06 ± 0.71	1.00	1.00–5.00	1.76 ± 0.34	1.00	1.00–2.50	3.22 ± 0.64	1.50	1.00–5.50	0.58
Grapefruit	KW	3.43 ± 0.63	3.00	1.00–5.00	3.64 ± 0.60	2.00	1.50–6.00	3.16 ± 0.54	2.50	1.75–4.25	0.90
Fatty foods											
Doughnuts	KW	4.87 ± 0.83	4.00	2.00–8.25	5.58 ± 0.57	5.00	4.00–8.00	4.41 ± 0.74	3.00	2.00–7.50	0.43
Processed meats	AN	6.00 ± 0.68	6.50	4.00–7.75	6.23 ± 0.63	6.00	4.50–8.50	6.44 ± 0.62	7.00	4.75–8.00	0.89
Potato chips	KW	7.00 ± 0.55	7.00	5.25–8.75	6.58 ± 0.64	7.00	5.00–8.50	6.72 ± 0.65	7.50	4.75–9.00	0.89
French fries	KW	8.56 ± 0.92	8.50	6.50–9.75	7.94 ± 0.46	8.00	6.50–10.00	7.94 ± 0.42	8.00	6.75–9.25	0.72
Butter	AN	6.68 ± 0.65	8.00	4.00–8.75	5.64 ± 0.58	6.00	4.00–7.00	6.22 ± 0.58	6.00	4.75–8.00	0.49
Margarine	AN	3.50 ± 0.56	3.00	2.00–5.00	3.70 ± 0.45	4.00	2.00–5.00	4.50 ± 0.60	5.00	2.00–6.00	0.39
Cream	AN	6.31 ± 0.71 ^{a}	6.00	4.00–9.00	3.82 ± 0.50 ^{b}	3.00	2.00–6.00	5.44 ± 0.61 ^{ab}	6.00	3.50–7.25	0.02 *
Turkey with skin	KW	3.37 ± 0.57	3.00	1.00–5.00	3.76 ± 0.61	4.00	1.00–5.00	4.05 ± 0.58	4.00	1.00–6.00	0.73
Chicken with skin	KW	3.93 ± 0.72	3.00	1.25–6.00	4.11 ± 0.60	4.00	1.50–6.50	4.66 ± 0.70	4.50	1.00–7.00	0.79
Hot dogs	KW	4.37 ± 0.84	3.00	1.00–7.75	4.23 ± 0.56	5.00	2.50–6.00	5.11 ± 0.69	6.00	2.50–8.00	0.63
Mayonnaise	AN	5.62 ± 0.61	6.00	4.00–7.00	4.17 ± 0.58	5.00	1.50–6.00	5.27 ± 0.57	5.50	3.75–7.00	0.20
Hamburger	KW	7.93 ± 0.54	8.50	7.00–10.00	6.35 ± 0.64	7.00	4.50–8.50	6.27 ± 0.63	7.00	3.00–8.00	0.09
Beef	KW	7.62 ± 0.56	8.00	6.25–9.75	7.82 ± 0.33	8.00	7.00–9.00	8.88 ± 0.31	9.50	8.00–10.00	0.06

n – number of samples, X – arithmetic mean, *SEM* – standard error of the mean, *IQR* – interquartile range, p – statistical siginificance (* – $p < 0.05$).
Statistical tests: AN – One-way ANOVA test, KW – Kruskal-Wallis test. Means with the same letter in superscript indicate no significant difference (Tukey's post hoc test).
† – median was significantly different from that for the neophilic and neutrals groups (Mann–Whitney's U post hoc test).

ginal role in discriminating subjects according to *BMI* and taste sensitivity, so openness to new food experiences is not related to weight gain [13]. This study determined that *BMI* of neophobic individuals was higher than that of neophilic or neutral individuals.

There was no significant difference between sweet, bitter, salty, sour and fatty food liking scores between food neophobia groups. In the study by Appleton et al. [33], individuals aged 12–19 were found to have a higher liking score for bitter vegetables associated with a lower food neophobia. In another study, high levels of food neophobia in young adults were associated with low pleasantness of food and reduced use of vegetables [34]. Some authors suggested that eating behaviour is due to personality traits [35], while others report perceptual [36] or even genetic reasons [34].

The present study also focused on taste thresholds to provide further insights into eating behaviour and food liking. In a study conducted in New Zealand, there was no correlation between the liking of 16 sweet beverages and sweet taste thresholds (glucose detection and recognition thresholds) [10]. Also, liking fatty foods may not be associated with fat taste sensitivity [21, 22]. Taste sensitivity affects food consumption rather than food liking [7].

In our study, no relationship was found between taste sensitivity and food liking, which was probably related to the fact that the typical taste of food is generally above the detection threshold [37] while less typical, low-intensity tastes would only be perceived [18]. Pangborn and Pecore [38] showed that taste acuity is different from the hedonic response and indicated that taste sensitivity might not be directly related to food liking.

Some of the results obtained in this study were surprising and/or difficult to explain. When examining the relationship between sweet foods in the food liking questionnaire and sweet taste threshold, a relationship was found between sweet taste threshold and cola liking score. Similarly, when the relationship between fatty foods, the food liking questionnaire and fat taste threshold was examined, there was a relationship between fat taste threshold and beef, margarine, hot dog, chicken with skin and turkey with skin liking score. No other studies dealing with this aspect have been published yet, so we cannot compare the current results. Therefore, more large-scale studies are needed. The objective of this study was to investigate the relationship between taste threshold, food neophobia and food liking. Of the five taste

Tab. 4. Correlation between food neophobia score, taste thresholds and food liking score.

		Pearson and Spearman correlation						Partial correlation (*BMI* adjusted)					
		Sweet taste threshold	Salty taste threshold	Bitter taste threshold	Sour taste threshold	Fat taste threshold	*FNS*	Sweet taste threshold	Salty taste threshold	Bitter taste threshold	Sour taste threshold	Fat taste threshold	*FNS*
FNS	*r*	0.36	0.22	0.14	0.01	0.38	1.00	0.33	0.10	0.10	0.01	0.20	1.00
	p	0.01 *	0.10	0.30	0.92	0.01 *		0.01*	0.47	0.47	0.90	0.14	
Sweet food liking	*r*	0.04	−0.09	0.18	−0.13	0.01	−0.10	0.05	−0.05	0.19	−0.13	−0.01	−0.09
	p	0.76	0.51	0.19	0.35	0.95	0.48	0.72	0.71	0.17	0.33	0.90	0.55
Salty food liking	*r*	−0.00	−0.19	−0.13	−0.17	0.02	−0.11	−0.01	−0.22	−0.11	−0.19	0.02	−0.12
	p	0.98	0.16	0.34	0.22	0.86	0.41	0.90	0.11	0.421	0.18	0.89	0.40
Bitter food liking	*r*	−0.04	0.01	0.03	0.07	−0.13	−0.05	0.03	0.16	0.13	0.07	0.01	0.05
	p	0.75	0.91	0.80	0.58	0.33	0.70	0.81	0.25	0.33	0.61	0.99	0.74
Sour food liking	*r*	0.05	−0.09	0.05	−0.01	−0.01	0.11	0.07	0.01	0.06	−0.02	0.01	0.13
	p	0.70	0.52	0.70	0.96	0.93	0.41	0.60	0.93	0.65	0.84	0.97	0.36
Fatty food liking	*r*	0.12	−0.08	−0.12	−0.17	0.02	−0.11	0.13	−0.10	−0.17	−0.16	−0.05	−0.15
	p	0.36	0.55	0.39	0.21	0.86	0.41	0.37	0.45	0.23	0.25	0.69	0.29

FNS – food neophobia score, *BMI* – body mass index, *r* – correlation coefficient; *p* – statistical significance (* – $p < 0.05$).

thresholds examined, only sweet and fatty taste thresholds were associated with food neophobia. There was no correlation between food liking and taste thresholds.

Although previous studies examined the relationship between taste thresholds and eating behaviour, the results of this study are relevant and valuable as it is the first study to analyse five taste thresholds and examine their link with food neophobia and food liking in adults. Despite the strengths of this study and its contribution to knowledge, some limitations of it were acknowledged. It should be noted that the study was limited by the cross-sectional design and a comparatively small sample size. We used only one method and only one prototypical compound per taste quality in the determination of taste sensitivity. Generalizing the results would be beneficial to assess taste sensitivity using further or different methods and greater number of participants.. In addition, in our study, taste sensitivity was measured using water solutions, but food liking was measured by a stated liking (without tasting) in a given questionnaire. Because participants had been exposed to each food since childhood, this could affect their liking for each food.

CONCLUSIONS

Results of this study suggest that food neophobia may be related to some tastes. They also suggest that food liking may depend on other factors more than on taste, such as habits, food environment or factors related to the food choice of the individuals. We think there is still a gap in knowledge about how individuals differ in taste preferences and how food fear or food liking occur. Future studies are needed to investigate the relationship between food liking, neophobia and taste thresholds in greater detail to determine how these factors affect food choice.

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