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Comportement alimentaire

Relation between fat and bitter detection thresholds and weight status

Relation entre les seuils de détection du gras et amer et statut pondéral

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Abstract ***Introduction.*** It is generally accepted that humans have the ability to detect five basic tastes (sweet, salty, bitter, sour, and umami). However, there is common agreement for a sixth fat flavor. Many studies suggest that bitter taste and fat taste could interfere with each other. ***Objective.*** This study aimed to investigate the link between bitter taste threshold, fat perception and its association with weight status in Algerian adults. ***Material and methods***. Through a public advertisement, 130 young individuals (33 males/97 females), between 20 and 35 years old, were recruited. Weight, height and body mass index (BMI) were measured. The determination of detection thresholds for oleic acid (OA) and 6-n-propylthiouracil (PROP) was performed. Statistical analysis was performed with SPSS. ***Results.*** According to PROP sensitivity, 33% of adults were non tasters, 6% were medium tasters and 60% were super tasters. Taster participants had less BMI compared with non-tasters (P=0.005). Detection thresholds for OA increased with BMI (Rho=0.203, *p*=0.021). A significant correlation was identified between the detection thresholds for OA and detection thresholds for PROP (Rho= 0.349, *p*<0.0001). PROP tasters gave higher taste intensity ratings for OA compared with PROP non-tasters (*p*=0.012). ***Conclusion.*** Our findings confirm the hypothesis that fat and bitter detection thresholds may interact with each other. Future behavioural and genetic investigations will be required to confirm this association in various populations.

Key words: *Taste, Oleic acid, 6-n-propylthiouracil, Sensitivity, Body mass index*

Résumé ***Introduction.*** Il est généralement admis que les humains ont la capacité de détecter cinq saveurs de base (sucré, salé, amer, acide et umami). Cependant, il est généralement admis qu'il existe une sixième saveur de graisse. De nombreuses études de masse corporelle (IMC) ont été mesurés. La détermination des seuils de détection

pour l'acide oléique (OA) et le 6-n-propylthiouracile (PROP) a été réalisée. L'analyse statistique a été réalisée avec SPSS. ***Résultats***. Selon la sensibilité du PROP, 33% des adultes n'étaient pas des dégustateurs, 6% étaient des dégustateurs moyens et 60% étaient des super goûteurs. Les participants dégustateurs avaient un IMC faible comparés aux non-dégustateurs (*P*=0,005). Les seuils de détection de l'AO augmentaient avec l'IMC (Rho=0,203; *p*=0,021). Une corrélation significative a été identifiée entre les seuils de détection de l'OA et les seuils de détection du PROP (Rho=0,349; *p*<0,0001). Les dégustateurs PROP ont donné des notes d'intensité gustative plus élevées pour l'AO que les non-dégustateurs PROP (*p*=0,012). ***Conclusion***. Nos résultats confirment l'hypothèse selon laquelle les seuils de détection du gras et de l'amer peuvent interagir les uns avec les autres. De futures investigations comportementales et génétiques sont nécessaires pour confirmer cette association dans diverses populations.

Mots clés: *Goût, acide oléique, 6-n-propylthiouracile, Sensibilité, Indice de masse corporelle*

Introduction

Human individuals can perceive five basic taste modalities: sweet, salty, bitter, sour and umami. These flavors allow us to distinguish between food and toxic; however, the work carried in both humans and rodents support the idea that there is a sixth taste modality dedicated to the perception of certain dietary lipids (long chain fatty acids) [1,2]. Bitter taste seems to be the most complex quality in humans, based both on the wide variety of chemical structures that cause bitterness, and on the apparently large number of genes coding for the receptors of this modality (about 25 receptors) [3-5]. In humans, the family of TAS2R receptors has been demonstrated to be implicated in the perception of bitter taste [6]. The bitter taste has evolved to allow organisms to detect and avoid environmental toxins. In 1931, Fox discovered taste blindness, reporting that some individuals find phenyl-thiocarbamide (PTC) very bitter, when others cannot distinguish PTC from pure water. Family studies discovered this trend, and has been confirmed for a number of substances that contained N-C=C chemical structures including 6-n-propylthiouracil (PROP) [7,8]. Fisher was the first who suggest the use of PROP instead of PTC, not only that PROP is odorless (PTC has a sulfurous smell) but also it is less toxic [9,10]. Many psychophysical methods are used to classify individuals by PROP taste status, [11,10] but the most of these procedures cannot distinguish medium-tasters from super-tasters, limiting its utility in numerous research application [3].

For a long time, it was considered that only texture and smell of lipids were responsible for their orosensoryperception. In experiments on rats, mice and then on humans, a new parameter involved in the detection of lipids: CD36 lingual, a lipido-receptor was discovered; it acts as a factor in covering the body energy needs by selecting and promoting the absorption of lipid nutrients [2]. Other long chain fatty acid (LCFA) receptors belong to the G protein coupled receptor (GPCR) family, GPR120 and GPR140 have recently recognized in some taste receptor cells (I and II) of the tongue taste buds [12,13], in mice and humans [14] or they have a role in the detection of dietary lipids.

Many studies suggested that bitter taste and fat taste could interfere with each other. Indeed, Duffy *et al*.,[8] estimated that PROP super tasters may avoid high-fat food due to their extreme sensation. Tepper and Nurse [15] reported that PROP tasters could distinguish fat content for Italian salad dressing. Nasser *et al.,* [16] have shown that PROP tasters could discriminate fatty acids in high-fat food; however, Drewnowski *et al*., [17] reported that PROP sensi-tivity was not related with the presence of low dietary lipids.

The aim of this study was to investigate the link between fat and bitter taste thresholds and weight status in Algerian adults.

Material and Methods

Participants

This study was carried out during the period from January to December 2019. A total of 130 young adults (33 males and 97 females) were recruited through public advertisements (*via* posters and on online platforms: Facebook). The exclusion criteria for choosing subjects were: individuals with any history of a chronic pathology, such as cardiovascular diseases, diabetes, or digestive diseases, under medi-

cation treatment that could modify taste perception, pregnant or breastfeeding and smokers. Subjects must be weight-stable in the last six months.

All the participants provided informed consent and completed the study. The present study was performed according to the principles established by the Declaration of Helsinki and institutional guidelines. The study protocol has been approved by the council of the University of Constantine 1(N:01/2018).

Anthropometric measurements

Height and weight were measured according to WHO recommendation [18]. Body weight (kg) was measured in light clothing to the nearest 0.1 kg using regularly calibrated electronic scales (Seca, Germany). Height was measured in a standing position without shoes to the nearest 0.1 cm using a stadiometer (Seca, Germany). BMI was calculated as weight (kg) divided by height squared (m^2). Subjects were classified into two groups based on cut-off values: Overweight (OW) BMI ≥ 25 (OW group included both over weight=31 and obese=14 subjects), and Normal weight (NW) BMI <25; (a total of 85 subjects).

Determination of OA detection thresholds

In the first session, subjects determined the detection thresholds for OA (C18: 1); Food grade OA (C18: 1) was obtained from Sigma-Aldrich, MO, USA). The solutions were prepared according to protocol of Chale-Rush *et al*., [19]; an aqueous solution of Gum Arabic (Sigma) at 5% (w/v) was prepared with distilled water. The stock solution at 12 mM/L was obtained by dissolving 90µl of OA in 24 mL of Gum Arabic and 24.09 mg of EDTA to avoid oxidation.

The dilutions 6, 3, 1.5, 0.75, 0.37, 0.18, 0.018 mM/L were then prepared from the stock solution (12mM/L) and homogenized (UltraTurrax, IKA T18 digital, Allemande) at rotor speed of 12 to 20 rpm x 1000 for 5-6 min. The control samples were prepared in the same way, but without added OA (only Gum Arabic 5 w/v). Samples were stored in opaque flasks and used for testing within 48h of preparation. Detection thresholds for OA were determined using ascending series the three-alternative forced choice procedure (3-AFC) detailed in our recent study [20].

Sensitivity classification

On the basis of orosensory detection of OA and the cumulative distribution of minimum detection thresholds for OA which showed that more than half of the participants (52.2%) detected the OA at concentration of 0.75mM, the subjects were divided into two groups as hypersensitive or hyposensitive to OA. Hypersensitive individuals were able to correctly identify OA at C18:1≤ 0.75 mM, while hyposensitive subjects required higher concentrations > 0.75 mM.

Determination of bitter taste sensitivity

In the second session, a bitter detection threshold was determined using a method modified from Drewnowski *et al*., [11]. 10 PROP solutions (Sigma-Aldrich) ranged in concentration from 0.001 mM to 1 mM. The lower concentrated solutions (0.001, 0.002, 0.0032, 0.01, 0.1 mM) were prepared by diluting the four stock solutions (0.2, 0.32, 0.6, 1 mM). The PROP was dissolved in distilled water, with continuous stirring of 5 rpm at approximately 35°C on a magnetic stirrer until completely dissolved. The solutions were prepared at least one day before testing and stored at 4°C. The bitter thresholds test was carried out according to the three-alternative forced choice procedure, where the control solution was a sample of distilled water.

PROP taster status

PROP taster status was determined using the three-solution test method of Beverly JT *et al.,*[3] consisted of Three PROP (Aldrich Chemical, Milwaukee, WI) solutions (0.032, 0.32 and 3.2 mmol/L) and three NaCl (Fischer Scientific, Fair) solutions (0.01, 0.1 and 1.0 mol/L), thus, Sodium chloride was used as a standard because taste intensity to sodium chloride does not change by PROP taster status [3]. Subjects tasted and rated the three PROP and three NaCl solutions for intensity using the labelled magnitude scale (LMS). Non-tasters (33%) gave higher intensity ratings to NaCl than PROP. Medium tasters (6%) gave similar intensity ratings to NaCl and PROP Super tasters (60%) gave higher intensity ratings to PROP than NaCl. In our study, medium tasters were only 6% of participants, thus, we continued our analysis only with the two groups of super-tasters and non-tasters.

Rating scale

The general labelled magnitude scale (LMS) is quasi-logarithmic scale with label descriptors that is equivalent to magnitude estimation; the gLMS consisted of a vertical line 230 mm high. Considering the scale to be 100 units, the labels were placed at barely detectable, 1.4; weak, 6; moderate, 17; strong, 34.7; very strong, 52.5; strongest imaginable sensation of any kind, 100 [3,10,22]. Instructions for using the scale were given according to Green *et al.,* [22].

The participants were instructed to taste the solutions and rated them on the scale by comparing with the oral sensations of daily life [23]. Taster status was

determined primarily by the subjects psychophysical function of NaCl *versus* PROP solutions; if subjects perceived the NaCl solutions as much stronger than the PROP solutions, they were classified as non-tasters. If they rated both sets of solutions the same, they were classified as medium-tasters and those who rated PROP more intense than NaCl were super-tasters.

Statistical analysis

Statistical analysis was performed using SPSS version 25 (SPSS, Inc., Chicago, IL, USA). Data were presented as mean and standard deviation (SD). Spearman's rank correlation test was performed between two quantitative variables. Comparison between two averages was done by means of the reduced deviation ($Z_{0.05}$) and that of several averages by one way analysis of variance (ANOVA). When ANOVA showed a sig overall differences comparisons between pairs of groups were made by Tukey post hoc test. *P*-Value < 0.05 was considered statistically significant.

Results

Subject characteristics

Subjects characteristics are summarized in **Table 1**. The mean age of the population was 22.11±3.33 years. Ninety-seven participants were women and thirty-three were men.

Table 1. Baseline characteristics of participants

	Men n=33	Women n=97	Total n=130	*P*
Age year	21.93±2.90	22.39±3.45	22.11±3.33	0.25
Height m	1.74±0.05	1.62±0.06	1.65±0.07	0.001
Weight kg	69.53±9.59	64.62±14.50	65.87±13.56	0.95
BMI kg/m^2	22.93±2.80	24.40±5.40	24.01±4.88	<0.0001

*BMI: body mass index. Data are presented as means with standard deviation (Mean±SD). *Statistical difference between men and women by means of the reduced deviation ($Z_{0.05}$) P<0.05.*

PROP taster status

The division of PROP tasters into groups was based on supra-thresholds of PROP. Subjects were classified as PROP non tasters (33%, n=43), medium tasters (6%, n=8) or super tasters (60%, n=79). A significant interaction was observed between taster group, solution type and concentration on the intensity ratings (*p*<0.001) (**Fig. 1**). Non-tasters gave lower intensity rating to the two highest concentration of PROP (0.32 and 3.2mmol/L) as compared to the two highest concentrations of NaCl (0.1 and 1.0 mol/L), respectively (*p*<0.0001). Medium tasters gave similar ratings of PROP and NaCl at all concentrations. Super tasters gave higher ratings to 0.32 and 3.2 mmol/L) PROP as compared to the highest concentrations of NaCl, respectively (*p*<0.0001).

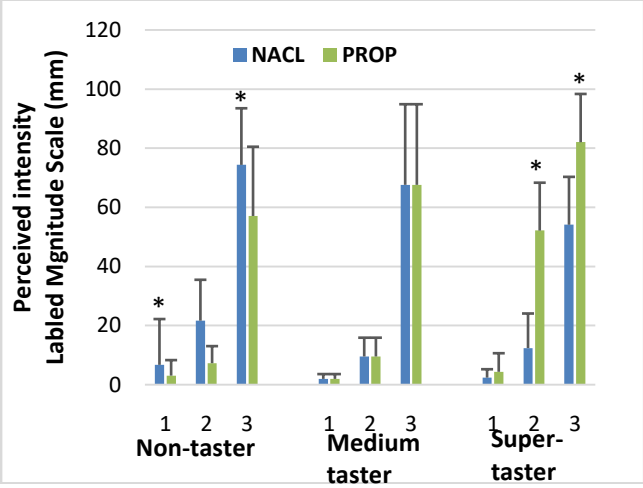

Fig. 1. Relationship between perceived taste intensity and stimulus concentration in PROP taster groups

*The numbers 1, 2 and 3 on the x-axis correspond to three NaCl and PROP solutions (NaCl: 0.01, 0.1, 1mol /L) and (PROP: 0.032, 0.32 and 3.2 mmol/L). Statistical differences were identified using ANOVA (Tukey post hoc test). Data are presented as Mean±SD. *Significant difference between PROP and corresponding sodium chloride concentration (p<0.0001).*

In our study, only 8 medium tasters were found among 130 participants that is why we continued our analysis only with super-tasters and non-tasters.

OA detection thresholds and BMI

The relation between the detection thresholds for OA and BMI was examined. A statistically significant association was observed (*p*=0.021, rho=0.203) (**Fig. 2**).

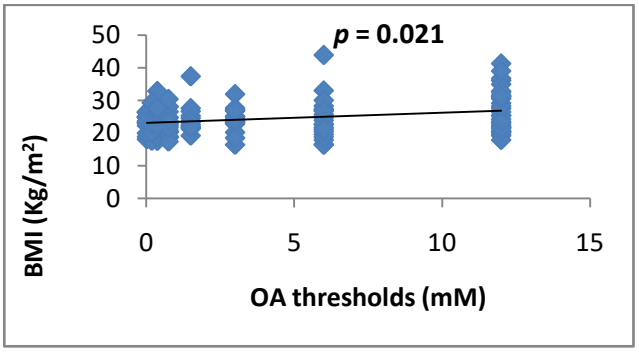

Fig.2. Association between oleic acid thresholds and body mass index

**Statistical difference was identified using Spearman rank correlation.*

Bitter detection thresholds and BMI

The relation between BMI and PROP detection thresholds was also examined. Even if it was not significant, we observed statistically significant differrence in BMI between PROP taster groups; taster participants had less BMI compared with non-tasters (23.4 *vs* 25.6 kg/m^2, *p*= 0.005).

OA detection thresholds and bitter perception

To assess the effect of the PROP status on the detection thresholds for OA, the link between the detection thresholds for OA and PROP was first examined **(Fig. 3).** A high statistically significant asso-ciation was identified (*p*<0.0001, r=0.349). Besides, PROP tasters gave higher taste intensity ratings for OA compared with PROP non-tasters (*p*=0.012); thus, the most of bitter taster subjects (65%) were hypersensitive to fat taste.

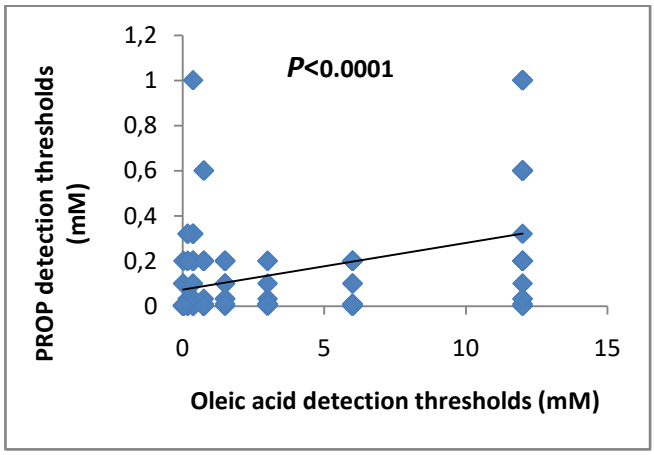

Fig. 3. Association between OA and PROP thresholds
**Statistical difference was identified using Spearman's rank correlation.*

Discussion

The aim of our study was to evaluate the link between fat and bitter taste thresholds and weight status in Algerian young adults. It was important to note that no study has been carried out among the Algerian adults population concerning the PROP taster status and its relationship with fat taste. Taste sensitivity is an important contributor to food liking and consumption; it may influence eating behaviour and health [24,25]. Our results supported the hypothesis that fatty acids can be sensed in the oral cavity over a range of concentrations; about 42% of participants were able to detect OA at highest concentrations (3 to 12 mM), 48% of participants were able to detect OA at middle concentrations (0.18 to 1.5 Mm), and only 10% of participants were able to detect OA at lowest concentration (0.018Mm).

In the present study, we clearly reported that the detection thresholds for OA was associated with BMI; the observation that overweight subjects were less sensitive to OA supported the notion that fat consumption played a role in the regulation of body weight. The relation between the perception of fat taste and the obesity in humans was still debatable. Many studies were consistent with our findings and reported a positive correlation between fat detection thresholds and BMI [1,21,26,42], while others had no recurrent correlation between these parameters [27, 28]. These differences could be within individuals generally related to genetic variety and biological or cultural factors. Furthermore, the BMI is an imperfect representative for subject adiposity and the discrimination of oral sensitivity to fatty acids may be confounded by olfaction and other oro-sensory modalities, such as textural attributes and viscosity which can influence taste [29].

The ability to taste the bitter compounds 6-n-propylthiouracil (PROP) is inherited attribute shared by many people over the world, and its genetic basis was identified over 80 years ago [7,30]. In the present study, 60% of the subjects were able to discriminate PROP solutions "supertasters", the remaining 30% of them perceived PROP feeble or tasteless and called non tasters. This distribution was also homogeneous with that reported in the literature indicating that the frequency of non-tasters depended on race and ethnicity, about 30% of the Caucasian population own this characteristic [3,7].

The difference in BMI values between the various groups of tasters was assessed. When compared to super tasters, non-tasters had higher BMI levels. This result was similar to those of Beverly *et al.,* [31], Goldestein *et al.,* [32], and Karmous *et al.,* [38]. The relation between PROP taster status and BMI has often been investigated but with contradictory results [8,32]. These discrepancies in the findings can be related to the frequency of non-tasters, which varies considerably among populations in different parts of the world and is depends on race and ethnicity [33], some studies have reliably announced that people who contrast in their reaction to PROP are additionally anatomically unique [34]. Besides many other factors include the chemical composition of saliva, its physical properties, number, size and morphology of taste papillae [34-36]. Also, the measurement errors are one of the major issues influ-encing the relation between PROP sensitivity and BMI; it is reported that psychophysical approaches include thresholds measures and supra-thresholds

methods showed high intra-subjects' variability to measurement errors [37].

Fat and bitter have been the most extensively studied tastes modalities. According to many authors [15,16, 38], we observed that PROP tasters gave higher taste intensity ratings for OA compared with PROP non-tasters and most of bitter non-taster subjects were also hyposensitive to fat taste. To understand these interactions, some studies suggest that TAS2R38 bitter receptor plays a role in the textural perception of dietary fat *via* its relation with the PROP taster status [39]. Although recent studies suggested that bitter and fat taste sensitivity might be related to the density of taste papillae and taste bud cells [36,40], the subjects with high density of taste papillae might be more sensitive to orosensory detection of bitter and fatty acids. Furthermore, a recent study by Barbarossa *et al*., [41] has demonstrated that olfactory stimulation appeared to play a crucial role in the perception of bitter taste of fatty acids. The authors reported that about half of subjects' perceived bitterness in milkshakes contained very dilutes concentrations of oleic acid. More studies in this area of research are needed to better understand this interaction. It will need more behavioral and genetic research to validate this link across other groups.

Some limitations should be considered when evaluating the results of this study. First, the number of eligible participants was limited to 130 due to the selection criteria and missing information of some individuals. Moreover, results were analyzed according to orosensory methods. Genetic polymorphism of CD36/GPR120 and TAS2R receptors size, and morphology of taste papillae are needed to affirm this relationship.

Conclusion

Taste perception plays a key role in determining individual food preferences and dietary habits. In our study, we shed light on the interaction of bitter, fat and corpulence in Algerian adults. Our findings confirm the relation between oro-sensory detection of fatty acids and PROP taster status. Furthermore, oral fat sensitivity inversely correlates with BMI, while a significant difference performs between PROP taster and corpulence. In summary, these data report that fat perception can be associated to genetic and anato -mical differences intra-individuals, and that PROP taster status may be a marker for these differences.

Conflict of interests

The authors declare no conflict of interests.

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