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Chemical Senses

**DETERMINANTS OF OBESITY IN ITALIAN ADULTS:
THE ROLE OF TASTE SENSITIVITY, FOOD LIKING AND FOOD
NEOPHOBIA**

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Complete List of Authors:	Proserpio, Cristina; University of Milan , DeFENS (Dept. of Food, Environmental & Nutritional Science) Laureati, Monica; University of Milan, DeFENS (Dept. of Food, Environmental & Nutritional Science) Bertoli, Simona; University of Milan, International Center for the Assessment of Nutritional Status, Department of Food, Environmental and Nutritional Sciences Battezzati, Alberto; University of Milan, International Center for the Assessment of Nutritional Status, Department of Food, Environmental and Nutritional Sciences Pagliarini, Ella; University of Milan, DeFENS (Dept. of Food, Environmental & Nutritional Science)
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3 27 Keyword: overweight, taste threshold, fungiform papillae, BMI, food preferences
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7 **Introduction**

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9
10 30 The complications and associated mortality of obesity are major public health issues world-wide
11
12 31 (WHO, 2000). The pathology of obesity is considered as a disease with a multifactorial etiology
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14 32 that has a genetic basis but requires lifestyle influences to manifest (Qi L and Cho YA 2008). Diet
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16 33 certainly constitutes an important part of such environmental influences. Although it has been
17
18 34 established that taste plays a pivotal role in food choice, acceptability (Drewnowsky 1997,
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20 35 Mennella JA et al. 2005) and, thus, energy intake, the extent of specific taste perception in
21
22 36 relation to weight status is not well understood. Past studies (Malcolm R et al. 1980, Frijters JE
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24 37 and Rasmussen-Conrad EL 1982) have failed to show any relationship between sweet thresholds
25
26 38 and nutritional status, whereas more recent studies (Simchen et al. 2006; Monneuse et al. 2008;
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28 39 Bertoli et al. 2014) described a difference between overweight and normal-weight subjects; in
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30 40 particular, a lower taste perception ability with an increase in weight has been found. It can be
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32 41 assumed that overweight and obese subjects might have a reduced or distorted sensory sensitivity
33
34 42 that could increase the desire for and ingestion of food, thus leading to excessive energy intake
35
36 43 and weight gain (Donaldson 2009). Instead, some reviews (De Graaf, 2005; Mela and Rogers,
37
38 44 1998) have concluded that obese subjects exhibit “normal” chemosensory function and liking for
39
40 45 specific tastes or aromas. These results show that the relationship between sensory perception
41
42 46 and nutritional status remains unclear.

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44
45 47 In addition to the study of the perception of basic tastes, attention has been recently focused on
46
47 48 the perception of “fat,” which could be directly linked to obesity. First, is it possible to consider
48
49 49 fat a taste? Observations from some studies suggest that “fatty” might actually be a quality of
50
51 50 taste (Mattes 2001; Nasser et al. 2001; Cooper et al. 2002; Kamphuis et al. 2003), even though
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53 51 preliminary human data (Nasser et al. 2001; Kamphuis et al. 2003) were not satisfactory because
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55 52 of the difficulty in isolating a taste component. In fact, many physical and chemical attributes can
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3 53 provide a signal incorrectly interpreted as a “fatty” taste, such as oral irritation (Verhagen et al.
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5 54 2003), viscosity (Mela and Rogers, 1998) and lubricity (Rolls et al. 1999). The perception of fat in
6
7 55 relation to nutritional status has been investigated in some recent studies (Stewart et al. 2010;
8
9 56 Stewart et al. 2011; Stewart and Keast 2012) in which an inverse association between Body Mass
10
11 57 Index (BMI) and both fatty acid taste sensitivity and fat intake was found. Accordingly, a strong
12
13 58 liking for highly fatty foods in subjects with higher BMI has been recently evidenced (Deaglaire et
14
15 59 al. 2015). These findings suggest that decreased sensitivity to fats may be a factor that contributes
16
17 60 to the pathogenesis of obesity, although it is important to recognize that causality cannot be
18
19 61 inferred from association studies. However, other studies reported non-significant associations
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21 62 between fat sensitivity and weight status (Alexy et al. 2011; Salbe et al. 2004; Simchen et al. 2006),
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23 63 thus underlining inconsistencies in literature data.
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26
27 64 Food neophobia, defined as the reluctance to taste a new food (Raudenbush et al. 2003), is
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29 65 another factor that has been suspected to be involved in the development of obesity. Food
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31 66 neophobics have less variety in their diet than do food neophilics (Falciglia et al. 2000), which
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33 67 could clearly affect their energy intake and nutritional status. Literature data suggest that food
34
35 68 neophobia is related to sensory sensitivity in adults (Carter et al., 2000; Ullrich et al., 2004), with
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37 69 people having a higher sensitivity to taste stimuli being less open to food experience (i.e.,
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39 70 neophobic attitude). If apparently taste sensitivity seems to be negatively related to BMI and
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41 71 positively related to food neophobia, then a relationship between food neophobia and nutritional
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43 72 status might be envisaged.
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47 73 In this perspective, the first goal of the present research was to compare taste sensitivity in
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49 74 normal weight and obese subjects by evaluating taste thresholds for the 4 basic tastes (sweet,
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51 75 salty, sour and bitter) and the fat stimulus. The density of the fungiform papillae in relation to
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53 76 nutritional status was also evaluated as additional measurement of taste acuity. We hypothesize
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55 77 that obese subjects could be less sensitive than normal weight subjects and maybe one factor that
56
57 78 lead to this different perception might be related with the morphology of the tongue (e.g. FP).
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3 79 A second research goal was to evaluate food liking and food neophobia according to subjects'
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5 80 BMI in order to study the relationship between these variables and taste sensitivity. We expect
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7 81 that any difference in taste sensitivity in relation to the nutritional status could be reflected in a
8
9 82 different attitude towards foods (e.g. prefer high energy foods and not have a varied diet).
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14 84 **Materials and Methods**

17 85 **Participants**

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20 86 One hundred three adults gave informed consent and completed the study. Fifty-one (N= 28
21
22 87 female; N= 23 male) obese (OB) patients admitted to the International Center for the
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24 88 Assessment of Nutritional Status (Università degli Studi di Milano, Italy) and fifty-two healthy
25
26 89 volunteers of normal-weight (NW) (N= 27 female; N= 25 male) were recruited. The exclusion
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28 90 criteria were individuals aged > 65 years, individuals ageusia or subjects undergoing medical
29
30 91 treatment that could modify taste perception. All subjects were invited to the sensory laboratory
31
32 92 that was designed according to ISO guidelines (ISO 8589, 2007), before lunch from 12.00 to
33
34 93 13.00, and were assessed for their taste sensitivity (taste thresholds and fungiform papillae
35
36 94 density) in pre-prandial condition. Subsequently, they were asked to complete a questionnaire
37
38 95 concerning food neophobia and food liking. The entire session took approximately 1 hour. Data
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40 96 were collected using the Fizz v2.31 software program (Biosystemes, Couteron, France).
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44 97 Every subject was asked for informed consent before the assessments were made. The present
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46 98 study was performed according to the principles established by the Declaration of Helsinki, after
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48 99 the protocol was approved by the Institutional Ethics Committee of the University of Milan
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50 100 (protocol number 91/14).
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55 102 **Anthropometric assessment**

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3 103 Anthropometric evaluations were made by collecting body weight (to the nearest 0.1 kg) and
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5 104 standing height (to the nearest 0.1 cm) using the same calibrated scale on a telescopic vertical
6
7 105 steel stadiometer (SECA 220; Germany), with the subjects dressed only in underwear. BMI was
8
9 106 derived accordingly [weight (kg)/height (m²)]. Waist circumference was also measured (to the
10
11 107 nearest 0.5 cm) at the midpoint between the iliac crest and the last rib (Lohman TG et al 1988).
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15 16 109 **Taste sensitivity assessment**

17 18 110 *Stimuli for taste threshold evaluation*

19
20 111 Sucrose, caffeine, sodium chloride, citric acid and oleic acid were used to elicit sweet, bitter, salty,
21
22 112 sour and fat sensation tastes, respectively. Seven concentrations of each compound were
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24 113 prepared in mineral water (Levissima, Spa, Italy). The concentration range for each taste stimulus
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26 114 was chosen based on the threshold values reported in the literature (Mojet et al. 2001; Bertoli et
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28 115 al. 2014). Concentration ranges were established such that the lowest concentration was clearly
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30 116 below and the highest concentration was clearly above the level at which subjects could detect or
31
32 117 recognize the stimulus. Preliminary tests were carried out to adjust the concentration ranges
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34 118 because the subjects occasionally recognized the lowest concentration or did not recognize the
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36 119 highest concentration of the stimuli in some cases. The final concentration ranges (expressed in
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38 120 g/L) and dilution factors used to elicit the sensations are shown in **Table I**.
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INSERT TABLE I

123 Sucrose, sodium chloride, citric acid and caffeine were dissolved in water, prepared on the same
124 day as the session and tested at room temperature. Initially, to study the sensitivity to fat, an
125 emulsion of 5% w/v (1.8×10^{-1} M) oleic acid (OA, Sigma-Aldrich, Spa, Milano) in deionized
126 water with 12% gum arabic (Sigma-Aldrich, Spa, Milano), 0.01% xanthan gum (Sigma-Aldrich,
127 Spa, Milano), and 0.01% ethylenediaminetetraacetic acid (Sigma-Aldrich, Spa, Milano) was
128 prepared (Tucker et al. 2014). Subsequently, the OA concentration was reduced to 3% because

1
2
3 129 we realized that it was an identifiable concentration during the initial tests. Oleic acid emulsion
4
5 130 was prepared in 200 mL batches by homogenization (IKA T18 Basic Ultra Turrax) for 20 min at
6
7 131 15500 rpm and then diluted by 0.4 log steps to create a range of 7 stimulus concentrations.
8
9 132 Samples were made less than 24 h before testing, stored under nitrogen in glass containers, and
10
11 133 served at room temperature.
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15 16 135 ***Procedure for taste threshold assessment***

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18 136 Taste thresholds were evaluated using the 3-AFC (Three Alternative Forced Choice) method
19
20 137 reported in ASTM E-679-04. This standard describes a reliable procedure to determine a sensory
21
22 138 threshold for any compound dissolved in any liquid. For each stimulus, participants were
23
24 139 presented with 7 triads of samples marked with three-digit numbers. Each triad consisted of one
25
26 140 cup containing the stimulus and two cups containing an equal volume of a blank solution
27
28 141 (mineral water). The 7 triads proceeded from a weaker to a progressively stronger concentration,
29
30 142 and the position of the cup containing the stimulus was randomized over trials and assessors. For
31
32 143 each triad, participants were instructed to indicate which sample was different from the other two
33
34 144 (ASTM E 679-04). If the assessors were uncertain, they were instructed to guess (forced choice
35
36 145 procedure). At the beginning of each session, and before each triad, the assessors were instructed
37
38 146 to rinse their mouth with mineral water. To mask the visual and olfactory component
39
40 147 (particularly regarding the samples containing emulsions of oleic acid in water), the entire
41
42 148 evaluation was carried out under red light and with a nose clip. The individual threshold for each
43
44 149 sensory stimulus was calculated as the geometric mean of the concentration at which the last miss
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46 150 occurred and the next higher concentration that was correctly recognized (ASTM E 679-04).
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48 151 Participants were asked not to smoke, eat or drink anything except water before the test.
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54 55 153 ***Fungiform papillae assessment***

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3 154 The fungiform papillae density was measured according to Nachtsheim and Schlich (2013). The
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5 155 subjects' tongues were stained with a blue food dye (F.lli Rebecchi, Color Dolci, Spa, Milano,
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7 156 Italy). A circle of filter paper (6 mm diameter) was placed on the center of the tongue
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9 157 approximately 1–2 cm from the tip. Several photos of the tongue were taken using a 12-
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11 158 megapixel digital camera (FUJIFILM USA, Inc., Hollywood, CA, USA) in a brightly light room
12
13 159 using the camera's macro mode with no flash. The best photograph was selected to measure the
14
15 160 papillae density, and Adobe Photoshop was used to mark the area in which papillae were to be
16
17 161 counted according to Bakke and Vickers (2011). To do this, three circles were drawn in the front
18
19 162 of the anterior tongue using the filter paper as a template (**Figure I**). The FP were counted inside
20
21 163 the marked circles. Only FP that were at least 50% inside a circle were counted. The FP were
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23 164 counted independently by three researchers. There was no significant difference ($F=2.07$;
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25 165 $p=0.13$) between the researchers' counts, so the mean of the counts was calculated.
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29 166 INSERT FIGURE I
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32 33 168 *Food neophobia assessment*

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35 169 The Food Neophobia Scale (FNS), which was developed by Pliner and Hobden (1992) was
36
37 170 translated into Italian (see **Table II**). In the first stage of the study, the original version was
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39 171 carefully examined to establish whether the items, vocabulary and response format would be
40
41 172 appropriate for Italian adults. The wording for some items had to be changed slightly to retain
42
43 173 the same meaning as the original items. Some of the items in other studies on food neophobia
44
45 174 were also slightly changed such that they were meaningful to the study participants (Siegrist et al.
46
47 175 2013; Flight et al 2003; Henriques et al. 2009; Laureati, Bergamaschi et al. 2015). The FNS
48
49 176 consists of ten statements, such as "I don't like new foods," each offering seven graded response
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51 177 alternatives, from "strongly disagree" (1) to "strongly agree"(7). Half of the statements are
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53 178 worded in reverse relative to food neophobia, so responses to these statements were reversed
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3 179 when calculating the score. The FNS score was calculated as a sum of the responses, yielding a
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5 180 range of 10–70. The items indicated with R in **Table II** were reversed.
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7 181 INSERT TABLE II
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11 183 ***Food liking assessment***

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14 184 Each subject completed a 26-item food liking questionnaire. The subjects were asked to indicate
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16 185 their liking on a linear scale anchored at the extremes “I don’t like it at all” (rated 0) to “I like it a
17
18 186 lot” (rated 10) for the following food categories: vegetables (e.g., carrots, broccoli and tomatoes);
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20 187 fruits (e.g., banana, cherry and apple); carbohydrates (e.g., pasta, bread and rice); seasonings (e.g.,
21
22 188 butter and olive oil); meat and fish (e.g., white meat, red meat and fish); dairy products (e.g., milk,
23
24 189 cheese); and sweets (e.g., chocolate, snacks). The products were chosen based on their energy
25
26 190 content: “low energy dense” (<100 kcal/100 g) and “high energy dense” (> 100 kcal/100 g).
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30
31 192 ***Statistical analysis***

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33 193 The matrix of the correct and incorrect answers produced separately by each judge was used to
34
35 194 calculate the individual taste threshold. The geometric mean of the value to the last wrong answer
36
37 195 and the first correct answer was chosen to represent the best estimate of the threshold for each
38
39 196 subject (ASTM E 679-04). After verifying that taste sensitivity, food liking and food neophobia
40
41 197 data were normally distributed, independent t-tests were performed to compare normal weight
42
43 198 and obese subjects. Statistical analysis was performed using STATGRAPHICS PLUS v.16
44
45 199 software (Manugest KS Inc., Rockville, USA). To further interpret the relationship between
46
47 200 sensitivity and food neophobia, the subjects were divided according to their level of taste acuity
48
49 201 for each sensation and FP into 2 groups: “highly sensitive” (adults with a taste threshold less than
50
51 202 the median taste threshold group and FP density above or equal than the median FP density
52
53 203 group; sweet: 1.61 g/L, salt: 0.35 g/L, bitter: 0.03 g/L, fat: 0.14 g/L; 0.61 g/L and FP: 13); “less
54
55 204 sensitive” (adults with taste threshold above or equal to the median taste threshold group and FP
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205 density less the median FP density group; sweet: 1.61 g/L, salt: 0.35 g/L, bitter: 0.03 g/L, fat:
206 0.14 g/L; 0.61 g/L and FP: 13).

207

208 **Results**

209 **Characterization of participants**

210 The characteristics of the population investigated are presented in **Table III**. Normal weight and
211 obese subjects were balanced according to gender ($\chi^2= 1.58$; $p= 0.21$) and age ($t= 1.72$; $p= 0.09$).

212 INSERT TABLE III

213

214 **Taste sensitivity assessment**

215 The mean taste threshold values and the mean of fungiform papillae density in NW and OB
216 subjects are shown in **Figure II**. Significant differences between NW and OB subjects were
217 found for all taste stimuli (sweet taste: $df= 101$, $t = 3.48$, $p = 0.0002$; salty taste: $df= 101$, $t =$
218 2.98 , $p = 0.003$); bitter taste: $df=101$, $t = 3.00$, $p = 0.003$; fat sensation: $df=101$, $t = 4,42$, $p=$
219 0.00002 , sour taste: $df= 101$, $t = 2.15$, $p = 0.03$) and for FP density ($df=101$, $t= 4,04$, $p= 0.0001$).
220 OB subjects showed higher threshold values and a reduced number of FP compared with NW
221 controls.

222 INSERT FIGURE II

223

224 **Food neophobia assessment**

225 Internal consistency was satisfactory (Cronbach's $\alpha=0.83$; $n=10$). No significant differences
226 were detected in the food neophobia scores among subjects according to nutritional status
227 (NW= 28.21 ± 9.80 ; OB= 28.59 ± 9.82). To investigate the relationship between taste sensitivity and
228 BMI, the subjects were divided into 2 groups according to their level of taste acuity for each taste
229 and for FP density: "high sensitivity" and "low sensitivity." As observed in **Table IV**, the only
230 significant difference in food neophobia scores ($t= 2.85$; $p= 0.005$) between the two groups was

1
2
3 231 found for the salty taste, with high sensitive subjects being more neophobic than the low
4
5 232 sensitive.

6
7 233 INSERT TABLE IV

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10 11 235 **Food liking assessment**

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13 236 Mean hedonic ratings for the different product categories for NW and OB subjects are reported
14
15 237 in **Table V**. Subjects differed in their liking for carbohydrates, seasoning, and animal derivatives.
16
17 238 OB had significantly higher scores than did NW for these product categories.

18
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20 239 INSERT TABLE V

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23
24 241 The foods investigated in the liking questionnaire were also categorized according to energy
25
26 242 density: “low energy dense” (<100 kcal/100 g) and “high energy dense” (>100 kcal/100 g). The
27
28 243 mean liking data for OB and NW subjects are reported in **Figure III**. As can be seen, NW and
29
30 244 OB subjects appeared to be comparable for “low energy dense” products (df= 101; t= -1.05; P-
31
32 245 value= 0,29), whereas OB subjects showed a significantly higher liking for “high energy dense”
33
34 246 products (df= 101; t = -2,51; P-value = 0,01) than did NW subjects.

35
36
37 247 INSERT FIGURE III

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40 41 42 249 **Discussion**

43
44 250 The sensory properties of food are important determinants of food choice. Taste sensitivity
45
46 251 varies among individuals, and even when several studies have described differences between
47
48 252 obese and non-obese subjects concerning taste perception, the data are contradictory and
49
50 253 insufficient.

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52
53 254 The first purpose of this study was to compare the taste sensitivity (taste thresholds and
54
55 255 fungiform papillae density) in obese and non-obese adults. The hypothesis that obese and non-
56
57 256 obese adults differ in their taste sensitivity was confirmed in the present investigation, with obese

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3 257 subjects showing a significantly lower sensitivity than normal weight controls for all tastes and for
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5 258 the fat sensation. Recent evidence has suggested that overweight and obese individuals are less
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7 259 sensitive to fatty acids; hence, this reduced taste acuity might lead to the consumption of excess
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9 260 dietary energy and weight gain (Stewart et al 2010; Stewart et al 2011). However, some studies
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11 261 have reported no significant association between fat sensitivity and weight status (Alexy et al.
12
13 262 2011; Salbe AD et al. 2004). Mattes (2009) suggested that the sense of taste and the
14
15 263 somatosensory system in the oral cavity are considered to be the main pathways involved in fat
16
17 264 perception. Both sensory systems have a common anatomical unit: the fungiform papilla. Taste
18
19 265 buds in the FP contain fatty acid receptors (Galindo et al., 2012) and mechanoreceptors
20
21 266 (Whitehead et al., 1985). Thus, a higher amount of FP may increase the perception of fat via
22
23 267 enhanced tactile and chemosensory perception. Currently, there is little information about the
24
25 268 effect of the number of FP on fat perception. Only Hayes and Duffy (2007) investigated the
26
27 269 relationship between the number of FP on the tongue tip and the perception of the fat-related
28
29 270 attribute creaminess, showing that subjects with a higher FP count gave higher creaminess ratings
30
31 271 to milk–cream mixtures. Moreover, the FP density seems to be correlated not only with the
32
33 272 perception of fat but also with taste acuity in general. In fact, a growing body of evidence
34
35 273 suggests that lingual tactile perception and taste sensitivities covary and reflect individual
36
37 274 differences in the density and diameter of fungiform papillae (Essick et al. 2003). This hypothesis
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39 275 seems to be supported by our results, showing that the density of FP is higher in lean subjects,
40
41 276 who are also more sensitive than obese subjects to basic tastes and fat sensation.

42
43 277 Our findings agree with most of literature data indicating that obese subjects are less sensitive to
44
45 278 both the sweet (Bartoshuk et al. 2006, Overberg et al. 2012, Simchen et al. 2006) and bitter
46
47 279 (Goldstein GL et al. 2005; Tepper BJ and Ullrich NV 2002) tastes than are normal weight
48
49 280 subjects. However, in other studies, no association between sweet (Alexy et al. 2011, Salbe AD et
50
51 281 al. 2004) and bitter (Drewnowski A et al. 2007; Kaminski LC et al. 2000; Yackinous CA and
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53 282 Guinard JX 2002) tastes acuity and weight status was found, and one study even reported a
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1
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3 283 positive relationship (Paquet et al. 2010). Little is known about the sensitivity to salt and sour
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5 284 tastes in relation to the body weight. Evidence for reduced thresholds in obese subjects for salty
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7 285 (Overberg et al. 2012, Simchen et al. 2006) and sour (Simchen et al. 2006, Bertoli et al. 2014)
8
9 286 tastes are found in the literature, but again, the results are often contradictory, with studies
10
11 287 reporting either no relationship between BMI and sensitivity (Alexy et al. 2011; Overberg et al.
12
13 288 2012) or a positive relationship (Paquet et al. 2010).

14
15
16 289 The relationship between sweet, salty, sour or bitter tastes and weight status is still unclear (Cox
17
18 290 et al. 2015). The discrepancy between studies may be attributable to differences in the techniques
19
20 291 used to measure taste perception. In particular, the differences could be due to the different
21
22 292 stimuli used to elicit the tastes.

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24
25 293 In addition to the different abilities to perceive taste stimuli in relation to BMI we also found that
26
27 294 obese subjects seem to prefer energy dense food more than normal weight subjects. The
28
29 295 hypothesis that overweight and obese people have a greater liking for certain types of taste
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31 296 stimuli that contributes to an excess energy intake has been explored previously (Mela and Rogers
32
33 297 1998), and, in agreement with our results, such studies have generally reported a positive
34
35 298 relationship between liking and both fat-sweet content and high-calorie products (Cox et al.
36
37 299 2015). In particular, fat preference may have a greater influence on body mass compared with
38
39 300 sweet preference. In this context, literature data indicate that obese women may prefer foods that
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41 301 are less sweet but higher in fat compared with normal-weight women (Drewnowski A et al.
42
43 302 1985). This difference could be due to genetic and behavioral factors, but this relationship is still
44
45 303 under discussion.

46
47
48 304 Obviously, not only factors related to taste perception could lead to weight gain. Evidence
49
50 305 suggests that body weight could be related to personality traits such as food neophobia
51
52 306 (Raudenbush T al. 2003). Food neophobia might manifest itself as a limited variety of food in the
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54 307 diet, thus leading to a reduced overall food intake and, in turn, to a reduced energy intake; in
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56 308 contrast, food neophobics could prefer to consume traditional food with a higher energy density
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3 309 compared with healthier food, which results in a higher BMI (Laureati, Bertoli et al. 2015).

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5 310 However, the results of the present study did not find any relationship between BMI and food

6
7 311 neophobia, a finding that was already observed in children (Laureati, Bertoli et al. 2015) and

8
9 312 young adults (Knaapila et al. 2011).

10
11 313 Regarding the relationship between food neophobia and taste acuity, it seems from our work that

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13 314 people who are sensitive to salty taste are significantly more neophobic than less sensitive

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15 315 individuals, which suggests that higher taste sensitivity might lead to neophobic reactions. Our

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17 316 results are in agreement with literature data reporting that taste sensitivity for bitterness is

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19 317 positively related to food neophobia (Carter et al. 2000).

20
21 318 In conclusion, we evaluated, in a sample of reasonable dimension, several determinants that

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23 319 could be involved in weight gain. From our results obese subjects differed in terms of taste

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25 320 sensitivity from normal weight controls and that these differences might lead to a different

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27 321 pattern of food preferences. More specifically, obese people that seem to be less sensitive to taste

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29 322 stimuli and have a reduced number of FP may have an increased need for food to compensate

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31 323 for their chemosensory deficit. Food neophobia seems to play a marginal role in discriminating

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33 324 subjects according to BMI and taste sensitivity. Thus, being more open to new food experiences

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35 325 seems to have no relationship with weight gain.

36
37 326 Several limitations should be considered when evaluating the results of this study. First, the two

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39 327 groups of individual haven't been matched on other possible factors that may affect their

40
41 328 performance as attitudes towards foods, restraint eating, taste and health attitudes and also

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43 329 cognitive factors affecting their attention. Second, we evaluated taste thresholds and not olfactory

44
45 330 thresholds, which could be useful to investigate in a more exhaustive way subjects' perception.

46
47 331 Third, taste sensitivity measured by taste detection threshold values in water are not

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49 332 representative of real foods, thus future researches are needed to study the different perceptions

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51 333 in models foods and considering all the sensory modalities. Fourth, we used a single stimulus for

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53 334 each sensation; it might be interesting to examine whether different stimuli affect the results.

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3 335 Fifth, the assessment of food liking was made without actually administering the product. These
4
5 336 aspects should be considered in future investigations of the perceptive and behavioral
6
7 337 determinants of obesity.
8

9 338

11 339 **Acknowledgments**

12
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16
17 342 Italy), who provided help in recruiting obese subjects and the students Chiara Rota, Camilla
18
19 343 Perego and Andrea Borsa for the help in the experimental phase.
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22 344

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Table I. Compounds used to elicit the stimuli with relevant dilution step and concentration range.

Compounds	Concentration range (g/L)		Log Steps
	lowest	highest	
Sucrose	0.16	40	0.4
Sodium chloride	0.06	4	0.4
Caffeine	0.003	2	0.4
Citric acid	0.33	50	0.5
Oleic acid	0.02	30	0.5

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Table II. Original English items of the food neophobia scale, and Italian translation of the items

<i>English items</i>	<i>Italian items</i>
1. I am constantly sampling new and different foods (R)	1. Mangio costantemente cibi nuovi e diversi dal solito (R)
2. I do not trust new foods	2. Non mi fido di nuovi alimenti
3. If I do not know what is in a food, I won't try it	3. Se non conosco un alimento, non lo provo
4. I like foods from different countries (R)	4. Mi piacciono i cibi provenienti da diversi paesi (R)
5. Ethnic food looks too weird to eat	5. Il cibo etnico mi sembra strano
6. At dinner parties, I will try a new food (R)	6. Ai pranzi e cene con gli amici mi piace assaggiare cibi che non conosco (R)
7. I am afraid to eat things I have never had before	7. Ho paura a mangiare qualcosa che non ho mai assaggiato prima
8. I am very particular about the foods I will eat	8. Sono molto schizzinoso quando si tratta di mangiare
9. I will eat almost anything (R)	9. Mangerei quasi tutto (R)
10. I like to try new ethnic restaurants (R)	10. Mi piace provare ristoranti etnici (R)

(R) Reversed items

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Table III. Characteristics of study participants (data are reported as mean values \pm sd or counts)

	ALL (n=103)	NORMALWEIGHT (n=52)	OBESE (n= 51)
Sex (F:M)	55:48	27:25	28:23
Age (years)	40.17 \pm 10.79	38.38 \pm 11.65	42.00 \pm 9.61
Height (m)	1.69 \pm 0.11	1.72 \pm 0.10	1.66 \pm 0.11
Weight (Kg)	79.44 \pm 19.60	64.25 \pm 10.19	94.92 \pm 13.92
BMI (Kg m ⁻²)	27.76 \pm 7.10	21.57 \pm 1.95	34.08 \pm 4.29

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Table IV. Neophobia index (mean value \pm sd) in relation with taste sensitivity: “low sensitive” and (“high sensitive). Values in bold show the significant differences.

Taste thresholds	Food neophobia score		t	p
	Low sensitive	High sensitive		
Sweet	28.60 \pm 10.06	28.23 \pm 9.64	0.19	0.848
Salty	25.6 \pm 9.43	30.82 \pm 9.47	2.85	0.005
Sour	28.64 \pm 10.47	28.29 \pm 9.57	0.16	0.870
Bitter	29.4 \pm 9.06	27.49 \pm 10.34	1.01	0.315
Fat	29.27 \pm 9.92	27.54 \pm 9.63	0.91	0.364
FP	28.34 \pm 10.18	25.93 \pm 10.60	1.78	0.077

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Table V. Mean hedonic ratings \pm sd in normal weight and obese subjects. Values in bold show the significant differences.

Food category	Normal weight (n=52)	Obese (n= 51)	t	p
Carbohydrates	7.01 \pm 2.67	7.91 \pm 1.47	2.11	0.04
Seasoning	5.07 \pm 2.28	6.03 \pm 2.24	2.17	0.03
Sweets	5.43 \pm 1.96	6.14 \pm 2.10	1.78	0.08
Fruits	6.58 \pm 2.03	7.02 \pm 2.17	1.04	0.30
Dairy products	6.22 \pm 2.67	6.59 \pm 2.60	0.70	0.50
Animal derivatives	6.29 \pm 2.33	7.42 \pm 2.00	2.63	0.01
Vegetables	5.83 \pm 1.84	6.23 \pm 1.94	1.05	0.30

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Figure I. Example of image taken for fungiform papillae (FP) count showing the placement of the template (6 mm diameter) and the three counted areas.

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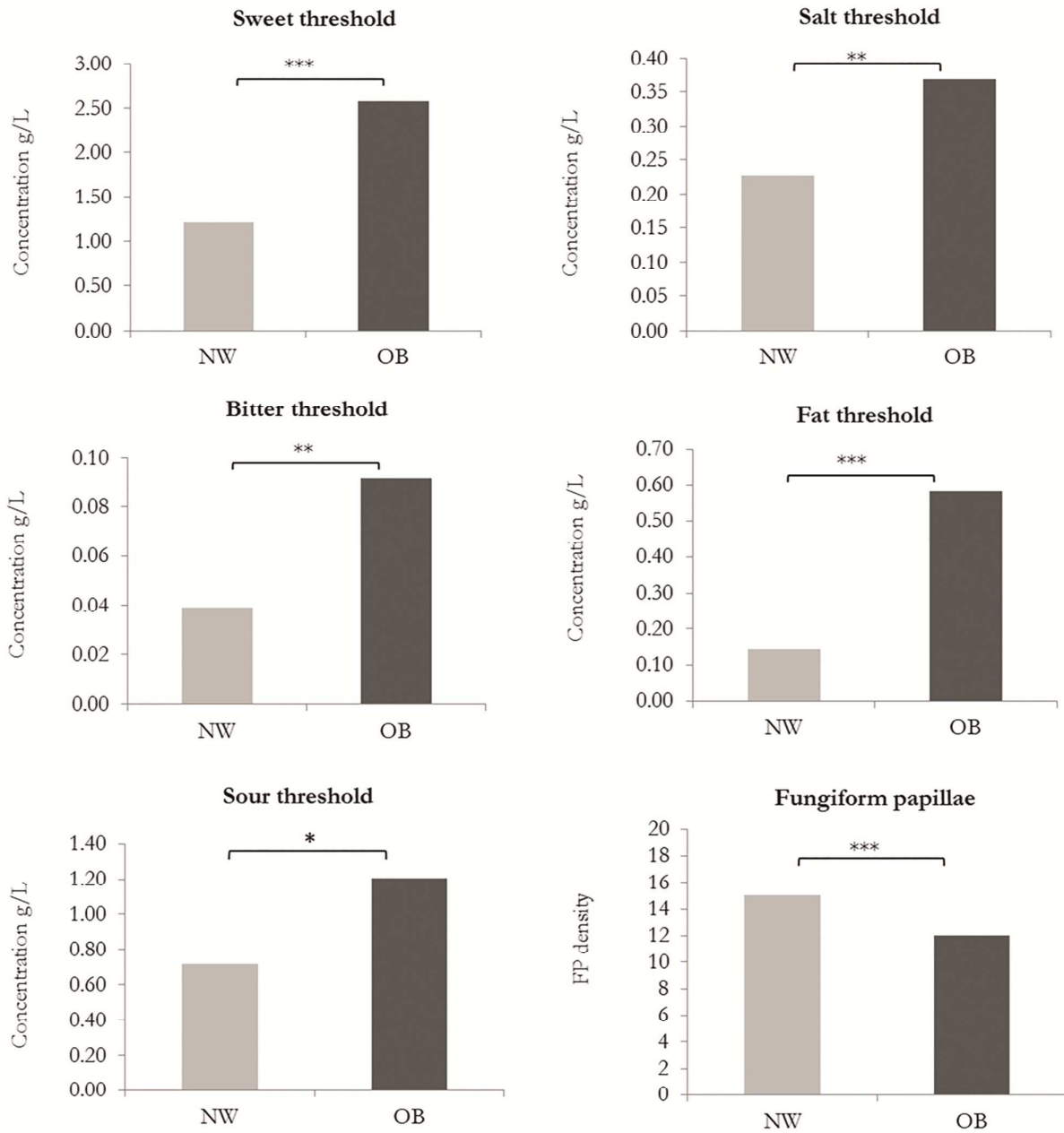


Figure II. Mean taste thresholds (g/L) and mean FP density in relation with nutritional status. Means that differ at significant levels of $p < 0.05$, $p < 0.01$, $p < 0.001$ are indicated by *, **, *** respectively.

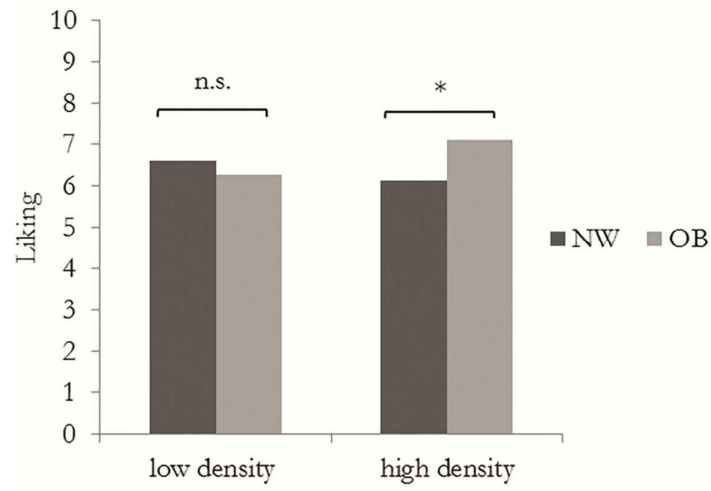


Figure III. Mean hedonic ratings for “low energy dense” and “high energy dense” products in relation to subjects’ nutritional status. Means that differ at significant levels of $p < 0.05$ are indicated by *.

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