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Original Article

Perceived Intensity and Palatability of Fatty Culinary Preparations is Associated with Individual Fatty Acid Detection Threshold and the Fatty Acid Profile of Oils Used as Ingredients

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Abstract

The term oleogustus was recently proposed to describe a sixth basic taste that could guide preference for fatty foods and dishes to an extent. However, experimental data on food preference based on fatty acid (FA) content is scarce. Our aim was to examine the role of FA profile of oils and preparations as well as FA sensory thresholds on the palatability of salty and sweet culinary preparations representative of traditional Spanish Mediterranean cooking. In this study, we used three oils with similar texture and odor profile but different in their FA composition (saturated, monounsaturated, and polyunsaturated) and compared subjects in regard to their FA detection threshold and perceived pleasantness and intensity. Our results indicate that whereas saturated FAs cannot be detected at physiological concentrations, individuals can be categorized as tasters and nontasters, according to their sensory threshold to linoleic acid, which is negatively associated with perceived intensity ($r = -0.393$, $P < 0.001$) but positively with palatability ($r = 0.246$, $P = 0.018$). These differences may be due to a possible response to a fat taste. This sixth taste, or oleogustus. would allow establishing differences in taste intensity/palatability considering the FA profile of the culinary preparations. Given that tasters can detect linoleic and oleic acid at lower concentrations than nontasters, a greater amount of unsaturated FAs in culinary preparations could provoke an unpleasant experience. This finding could be relevant in the context of the culinary sector and to further our understanding of food preference and eating behavior.

Key words: fatty acids, food preference, oleogustus, sensory response

Introduction

Like most mammals, humans are naturally attracted to dietary fats (Nesse et al. 1997). This trait is evolutionarily significant, given that fat provides the most energy per gram, compared with other nutrients and some fatty acids (FAs) such as linoleic and linolenic acids are essential. The motivational processes driving the preference for this macronutrient facilitate the association between fat and the beneficial consequences of its consumption, thus reinforcing its seeking and intake (Salamone et al. 2002). In addition, foods containing fats also provoke a positive hedonic response (reward), adding to the acquisition and strengthening of preferential consumption. However, the increased availability of highly palatable and energy-dense foods rich in fat and sugar, and the profound changes in the western lifestyle, especially in regard to eating habits, have been consistently associated with the risk for developing obesity and obesity-related diseases (Erlanson-Albertsson 2005; Temple 2016). Some authors have pointed out that physicochemical features of fats could be a relevant factor for food preference (Gaillard et al. 2008; Mennella et al. 2010; Corwin et al. 2011).

Among the various orosensory properties of food, only texture (Mindell et al. 1990) and/or olfaction have been traditionally related with fat intake. However, the term oleogustus was recently introduced by Running et al. (2015) to describe the taste sensation elicited by FAs, different from the usually reported "fattiness" (Kinney and Antill 1996). Thus, it has been shown that specific receptors present in the sensory cells of taste buds such as GPR40 (Laugerette 2005; Cartoni et al. 2010), GPR120 (Cartoni et al. 2010; Yasumatsu et al., 2019), and CD36 (Gaillard et al. 2008; Sundaresan et al. 2015) can detect free FAs. Furthermore, these receptors seem to be involved in complex physiological circuities that could be the basis for this sixth taste (Running et al. 2015; Besnard et al. 2016).

Yoneda et al. (2007) reported that the oral detection of FAs depends on the length of the carbon chain, the unsaturated state and the carboxyl groups. Several candidates have been proposed to be involved in FA perception. Concretely, it has been proposed that the CD36 protein partakes in the detection of long-chain FAs (LCFAs; Laugerette et al. 2007; Pioltine et al. 2016). Also, GPR40 and GPR120 have been shown to specifically bind unsaturated LCFAs, among which linoleic and linolenic acids display the highest affinity (Hirasawa et al. 2005; Yoneda et al. 2007).

Importantly, most studies on FAs taste have used either pure free FAs or products also containing triglycerides (TGs; Stewart et al. 2010; Keller et al. 2012; Garneau et al. 2017; Tucker et al. 2017). Considering this, it is surprising that while there is substantial experimental support to chemical perception of FAs (Kawai et al. 2003; Pittman et al. 2007), evidence suggesting that the capacity to recognize TGs in the oral cavity is remarkably limited (Keller et al. 2012). Nonetheless, some studies reported the role of lingual lipase activity in the orosensory detection of fat in humans (Kulkarni et al. 2014; Voigt et al. 2014). Unveiling the mechanisms behind (fat) taste perception could be relevant to better understanding the influence of taste in food choice and the modulation of eating behavior (Fushiki 2014; Andersen et al. 2020). Fat taste could be a key component of the palatability, relevant in culinary context for obvious reasons. The goal of this study was to examine the role of oils with different FA profile as well as FA sensory thresholds on palatability of salty and sweet culinary preparations representative of traditional Spanish Mediterranean cooking.

Material and methods

Sensory panel (participants)

Participants were volunteer students ($N = 20$; 14 women and 6 men, 18–19 years old) from the Food Sciences and Technology Degree (Campus Torribera, University of Barcelona). A previous history of food intolerances and/or allergies, eating disorder, metabolic disorder, and current or recent gastrointestinal disorder was used as exclusion criteria. All participants were informed of the nature and conditions of the study before participation and voluntarily agreed to join the study. The experiments carried out in this work comply with the Declaration of Helsinki for Medical Research involving Human Subjects.

Materials

Lauric (W261416), oleic (364525) and linoleic (W800075) acids, acacia gum (30888), and EDTA were purchased from Sigma-Aldrich (Sigma-Aldrich Quimica, Spain). Refined coconut oil (Aukso), refined high-oleic sunflower, and refined sunflower oils (Eroski, S. Coop., Spain) were used for culinary preparations and served as source of saturated FAs (SFAs), monosaturated FAs (MUFAs), and polyunsaturated FAs (PUFAs), respectively.

Determination of the FA profile of oils

The FA composition of the three refined oils (coconut, high-oleic sunflower, and sunflower) was determined using gas chromatography following previously published protocols (Tres et al. 2009). The FA methyl esters were prepared following previous procedures available in the literature (Guardiola et al. 1994). The methanolic solution of sodium methoxide was added in boiling water until homogenization. After this, 3 mL of a boron trifluoride was added. The resulting FA methyl ester was cooled to 30–40 °C and extracted by the addition of 1 mL of hexane and 4 mL of NaCl saturated solution. Finally, the organic phase was injected in gas chromatograph (HP6890, Agilent Technologies, Waldbronn, Germany) and FA methyl esters were identified and quantified.

Culinary preparation

Two popular culinary preparations were selected for the study, béarnaise sauce (salty, like Mayonnaise sauce 80% fat, wt/wt, usually from butter), and crema catalana, a Catalan version of a crème brulée (sweet, 30% fat, wt/wt, usually from cream). For the béarnaise sauce, two large eggs yolks, salt, ground black pepper, one tablespoon of fresh lemon juice, and a tablespoon of fresh tarragon was used. For the crema catalana, four large egg yolks, a cup of sugar, cinnamon, and a peel of lemon was used. Both recipes were prepared according to the traditional recipe with common house-hold methods and utensils. Refined coconut, high-oleic sunflower, and sunflower oils were used in substitution of butter and whole milk in the béarnaise sauce and the crema catalana, respectively. Therefore, three different versions of the same preparation resulted from this design, with similar organoleptic properties (i.e., texture and smell) but different FA profile. Batches of the three versions of each recipe were produced immediately before the tasting.

Procedure and study design

Figure 1 describes the experimental protocol used in this study. Briefly, the study consisted of 2 sessions in which the participants had to perform a taste test of the culinary preparations (session 1) and establish a discrimination sensory threshold for characteristics FAs of oils used in the culinary preparations (session 2). Experiments were conducted Monday to Friday in the sensory evaluation room at the Campus of Food Sciences Torribera, from 11 a.m. to 1 p.m. Participants were instructed not to consume any food or drinks and not to smoke 2 hours before the beginning of the sessions. Upon arrival to the session 1, volunteers occupied an individual booth and conducted a taste test of the three oils and the three versions of the two culinary preparations. Participants wore a nose clip to limit olfactory inputs. All oils and culinary preparations were served at 30 °C under soft white light. At these conditions, the viscosity of oils was similar (coconut oil: 27.6 cP; high-oleic sunflower oil:

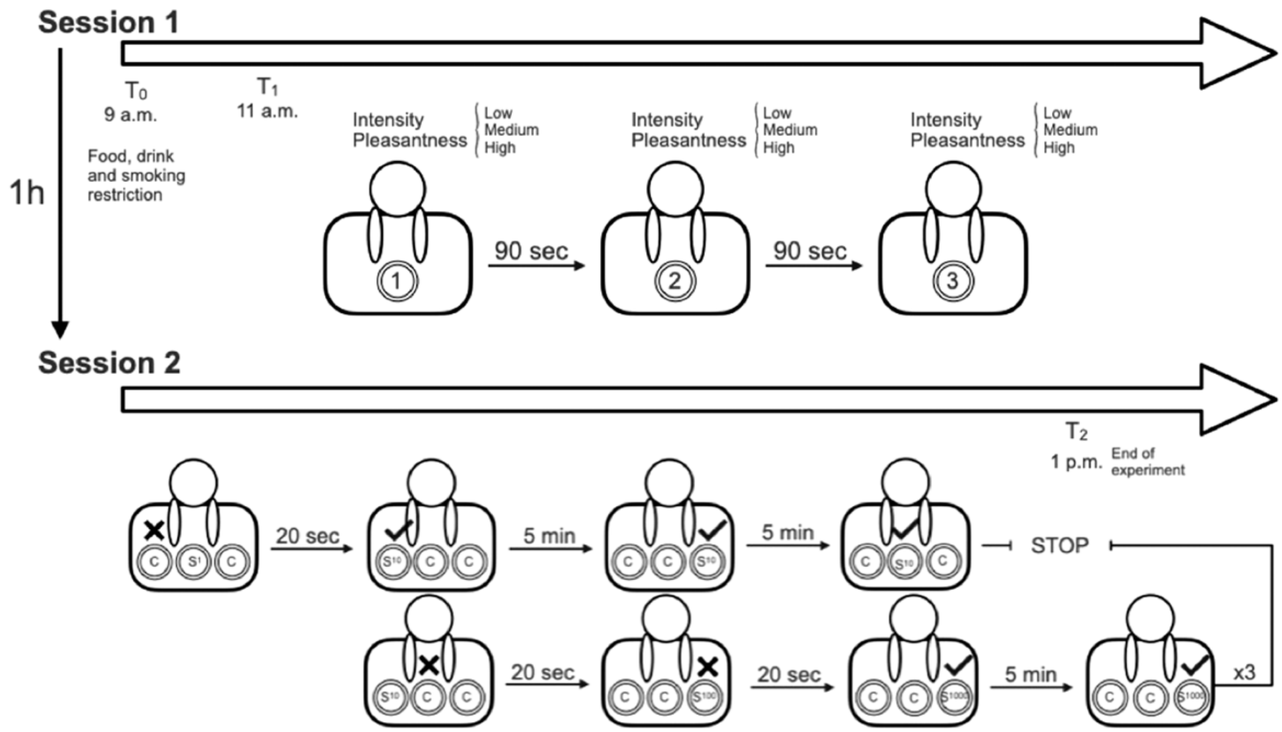

Figure 1. Experimental procedure. In session 1, participants ranked the perceived intensity and pleasantness of the culinary preparations accord. In session 2, the detection threshold for lauric, oleic, and linoleic acids was established.

30.7 cP; sunflower oil: 33.5 cP, measured by Rotational viscosimeter Fungilab u21001, Barcelona, Spain) and culinary preparations presented similar texture assayed by Texturometer TA-XT2 (Stable Micro Systems, Godalming, UK). Portions of 1 g of each sample were presented in transparent spoons, labelled with random letter blinding codes. This was repeated three times, with 1- to 2-min pauses between the presentation of the samples. Participants rated the intensity and pleasantness of each sample as "low," "medium," and "high." Mineral water was provided to the participants in between tests for washout. Sensory threshold for FAs was registered in session 2. This was carried out under the same conditions (i.e., individual booth, soft, white light), 1 h after finishing the first session. All samples were prepared the day of the session and stored at 4 °C in propylene light-protected tubes sealed under nitrogen until use. Lauric, oleic, and linoleic emulsions were prepared in a solution of 5% acacia gum and 0.01% EDTA diluted in reverse osmosis water. Samples were mixed by using a stirrer T18 Ultra Turrax for 5 min at 12 000 rpm. Acacia gum was added to limit viscosity and lubricity differences between control and samples. EDTA was added to prevent the oxidation of FAs. Sensory thresholds were determined by using the 3-alternative forced-choice procedure (3-AFC, ISO 13301:2018). This method was selected because of its long-demonstrated validity in the mid-1980s and its popular implementation in psychophysical experiments (Shelton et al. 1984). Participants were provided with successive sets of three samples. Each set contained two control samples and one stimuli sample. Within each set, participants had to indicate which sample was different from the other samples. Sets were presented in ascending concentrations from 2 µM to 2000 mM of lauric, oleic, or linoleic acids. Participants held 1 mL of sample at 30 °C in their mouth for 5–10 s, discarded the solution, washed out with reverse osmotic water, and waited for 20 s before tasting the next sample. In addition, participants wore a nose clip to limit olfactory inputs. When the subjects could not identify the stimuli sample, the FA concentration was increased for the following set. When the subject identified the stimuli sample, the procedure was repeated 5 min later. The assay stopped when the participant correctly identified the stimuli sample at a given concentration three consecutive times. The concentration at which the procedure stopped was considered the FA detection-threshold.

Statistical analysis

Kendall tau correlation was calculated for the associations between sensory threshold and orosensory properties of oils and culinary preparations. A chi-square (χ^2) test was performed to establish differences on the reported frequency measures of sensory threshold and orosensory response to FAs. A general linear model (GLM) with repeated measures was performed to analyse group differences in perceived intensity and pleasantness of the culinary preparations with lauric, oleic, and linoleic oils. For this, a qualitative rating (low, medium, and high) was assigned a quantitative value of 1, 2, or 3. A confidence interval of 95% (α = 0.05) was assumed for all the tests. Data values are shown as mean ± SEM, except indicated otherwise. All the statistical procedures were conducted using the Statistical Software Package SPSS (version 25; IBM SPSS, Chicago, IL).

Results

Lipid profile

The FA profile of the three oils analyzed is depicted in Table 1. Briefly, coconut oil presented an 89.9% of SFAs, with lauric (39.5%) and myristic (20.5%) acids as its major components. High-oleic sunflower oil was mainly composed of MUFAs (80.9%), with oleic acid as its main contributor (79.8%). Finally, the largest amount of

Table 1. Fatty acids composition of coconut, high oleic sunflower, and sunflower oils

Fatty acid	Proportion (%) respect total FA		
	Coconut	High-oleic sunflower	Standard sunflower
Caproic (C6:0)	0.63 ± 0.02	ND	ND
Caprilic (C8:0)	8.94 ± 0.05	ND	ND
Capric (C10:0)	7.17 ± 0.04	ND	ND
Lauric (C12:0)	39.58 ± 2.34	ND	ND
Myristic (C14:0)	20.47 ± 1.38	0.04 ± 0.01	0.08 ± 0.01
Palmitic (C16:0)	9.98 ± 0.05	3.88 ± 0.03	6.44 ± 0.04
Estearic (C18:0)	2.93 ± 0.02	3.17 ± 0.02	3.42 ± 0.03
Arachidic (C20:0)	0.09 ± 0.01	0.29 ± 0.01	0.26 ± 0.01
Behenic (C22:0)	0.03 ± 0.01	0.99 ± 0.02	0.30 ± 0.01
Lignoceric (C24:0)	0.04 ± 0.01	0.35 ± 0.01	0.30 ± 0.01
Total SFA	**89.86 ± 3.93**	**8.72 ± 0.1**	**10.80 ± 0.11**
Palmitoleic (C16:1)	0.05 ± 0.01	0.11 ± 0.01	0.12 ± 0.01
Oleic (C18:1, n-9)	7.71 ± 0.04	79.79 ± 3.67	30.57 ± 1.65
Veccenic (C18:1, n-7)	0.13 ± 0.01	0.68 ± 0.02	0.75 ± 0.01
Eicosanoic (C20:1, n-9)	0.05 ± 0.01	0.27 ± 0.01	0.17 ± 0.01
Total MFA	**7.94 ± 0.07**	**80.85 ± 3.71**	**31.61 ± 1.68**
Linoleic (C18:2, n-6)	2.07 ± 0.03	10.19 ± 0.04	60.73 ± 3.24
A-Linolenic (C18:3, n-3)	0.02 ± 0.01	0.10 ± 0.01	0.18 ± 0.01
Total PUFA	**2.09 ± 0.04**	**10.29 ± 0.05**	**60.91 ± 3.25**

Values correspond to mean ± SEM of three determinations. ND, nondetected.

PUFAs was found in standard sunflower oil (60.9%), with linoleic acid as its main component (60.7%).

Sensory threshold

Panelists' sensory threshold varied depending on the FA tested. None of the participants were able to detect lauric acid under 20 mM, but they perceived the presence of oleic and linoleic acids in the oral cavity (Figure 2). Oleic and linoleic acid detection thresholds were 278.727 ± 629.84 and 172.837 ± 484.684 µM (mean ± SEM), respectively, and varied between 2000 to 0.002 mM. These thresholds are like those previously reported by Smutzer et al. (2020). Participants were categorized as FA tasters or FA nontasters according to their linoleic acid threshold. A 1 mM linoleic acid threshold cut-off was considered. This cut-off value is similar to the linoleic acid threshold reported in humans by Running et al. (2015) and corresponds to the mean ± 2 SD from linoleic acid thresholds of the panelist population of our study. This value yielded 10 FA nontasters (subjects 2, 7, 8, 9, 11, 14, 15, 16, 17, and 19) and 10 FA tasters (subjects 1, 3, 4, 5, 6, 10, 12, 13, 18, and 20).

The GLM test yielded a significant difference between tasters and nontasters ($F = 59.143$, $P < 0.01$) and between FAs ($F = 35.527$, $P < 0.001$). Also, an interaction between group and FA was significant ($F = 15{,}785$, $P < 0.001$). Post hoc analysis revealed that tasters and nontasters differed significantly in their threshold for oleic ($t = 6{,}576$, $P < 0.001$) and linoleic ($t = 6{,}888$, $P < 0.001$) acids. Additionally, the tasters showed a significant difference between lauric and oleic acids ($t = 9.120$, $P < 0.001$) and lauric and linoleic acid ($t = 7.920$, $P < 0.001$; Figure 2).

We also performed a correlation analysis between the detection threshold of the different FAs. Only oleic and linoleic acids correlated significantly when data were analyzed together ($r = 0.901$, $P < 0.001$). However, when we analyzed by group, our data indicated a correlation between the detection threshold of lauric and oleic acids ($r = 0.539$, $P = 0.046$), between lauric and linoleic acids ($r = 0.576$, $P = 0.030$), and between oleic and linoleic acids ($r = 0.854$. $P = 0.001$) in FA nontasters. In FA tasters, only the detection threshold of oleic and linoleic acids correlated significantly ($r = 0.685$, $P = .001$; Figure 3).

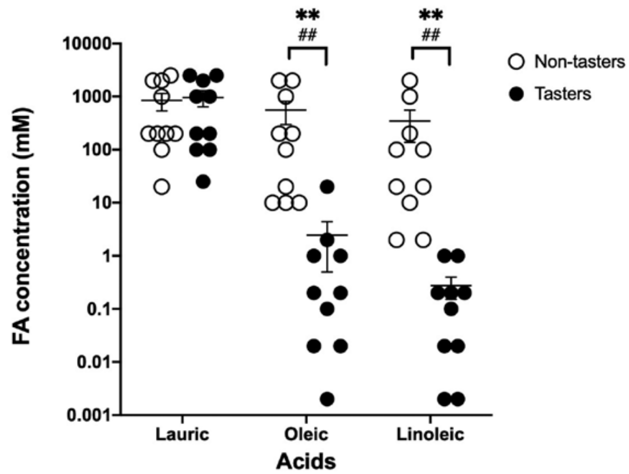

Figure 2. Detection thresholds and sensory groups. Panelists' detection threshold of fatty-acid concentration (in mM) for lauric, oleic, and linoleic acids is shown (mean group ± SEM). White circles represent FA nontasters; black circles represent FA tasters. ** significant at $P < 0.001$ with respect to the other group; ## significant at $P < 0.001$ with respect lauric acid.

Orosensory response and FAs

A chi-square analysis showed a significant effect on perceived intensity of the culinary preparations when different oils were used. The perceived intensity was significantly higher when high-oleic sunflower oil [$\chi^2(1, N = 20) = 7.2$, $P = 0.007$] and standard sunflower oil [$\chi^2(1, N = 20) = 5$, $P = 0.025$] were used. For the béarnaise sauce, the perceived intensity was significantly different when coconut oil [$\chi^2(2, N = 20) = 9.10$, $P = 0.011$], high-oleic sunflower oil [$\chi^2(2, N = 20) = 6.7$, $P = 0.035$], and standard sunflower oil [$\chi^2(2, N = 20) = 6.4$, $P = 0.041$] were used (Figure 4A). This indicates that participants rated the sauce as most intense when prepared with sunflower oil (PUFA rich oil). Finally, the perceived intensity of the crema catalana was not affected, regardless of the oil used in the preparation.

With respect to perceived pleasantness, oils, béarnaise sauce, or crema catalana differed significantly when coconut oil was used in the making. The use of high-oleic sunflower oil affected the perceived pleasantness of the oils [$\chi^2(2, N = 20) = 9.7$, $P = 0.008$] and the béarnaise sauce [$\chi^2(2, N = 20) = 9.1$, $P = 0.011$]. Finally, standard sunflower oil had an impact on the perceived pleasantness of the béarnaise sauce [$\chi^2(2, N = 20) = 7.3$, $P = 0.026$] and the crema catalana [$\chi^2(2, N = 20) = 12.4$, $P = 0.002$] (Figure 4B).

We performed a GLM analysis to explore whether FA tasters and nontasters differ on the perceived intensity and pleasantness of the culinary preparations depending on the oils used in the making. Our results show that both groups rate the coconut oil as the least intense in comparison to high-oleic sunflower oil ($t = 7.8$, $P < 0.001$) and sunflower oil ($t = 12$, $P < 0.001$), which was also rated more intense than the high-oleic sunflower oil ($t = 3.9$, $P = 0.004$). With respect to pleasantness, FA tasters rated the coconut oil as the most pleasant in comparison to high-oleic sunflower oil ($t = 4{,}4$, $P < 0.001$) and sunflower oil ($t = 6.4$, $P < 0.001$). Conversely, FA nontasters rated the sunflower oil as significantly more pleasant than the coconut oil ($t = 5.6$, $P < 0.001$; Figure 5A and B).

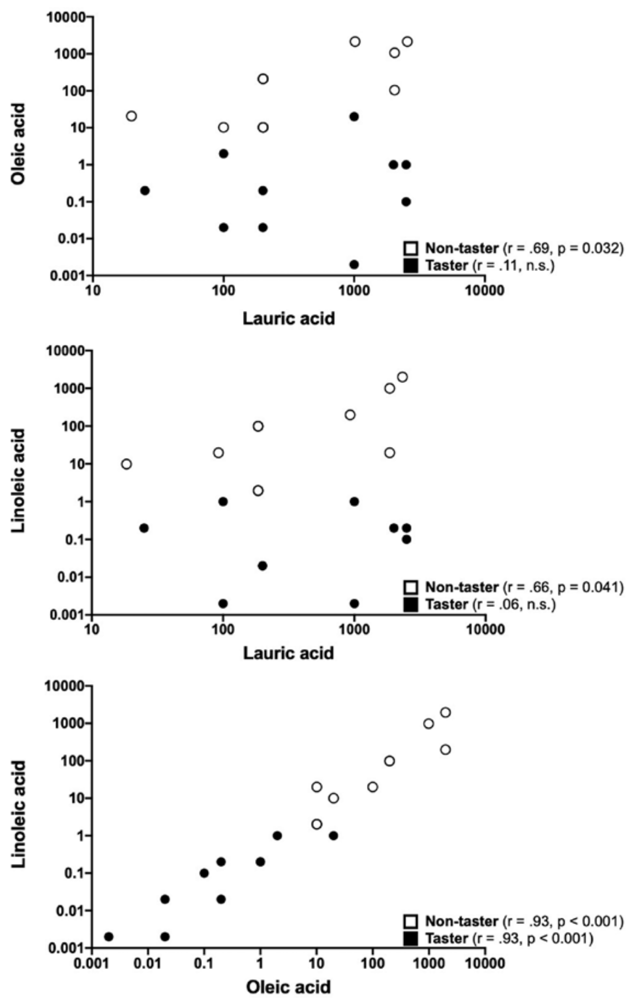

Figure 3. FA threshold correlations. Plots show the correlation between the detection threshold of the different FAs in both tasters and nontasters.

The perceived intensity of the béarnaise sauce was also greater when sunflower oil was used in the making, in comparison to coconut oil ($t = 3.5$, $P = 0.017$), but not with high-oleic sunflower oil, and only in FA nontasters (Figure 5C). The perceived pleasantness of this preparation was not different within nor between groups, regardless of the oil used in the making.

Both FA tasters and nontasters rated the crema catalana similarly in terms of intensity, and no differences were found between coconut, high-oleic sunflower, and sunflower oils preparations (Figure 5D). With respect to perceived pleasantness, the preparation with coconut oil was rated as the more pleasant by nontasters, in comparison to high-oleic sunflower oil ($t = 3.5$, $P = 0.015$) and sunflower oil ($t = 4.9$, $P < 0.001$). FA tasters also rated the crema catalana prepared with coconut oil as the most pleasant, but only in comparison to sunflower oil ($t = 4.2$, $P = 0.002$). No difference was found in this group between high-oleic sunflower and sunflower oils (Figure 5E and F).

Association between sensory threshold and orosensory properties of oils and culinary preparations

The correlation between the linoleic detection threshold, and perceived intensity and pleasantness of the three versions of the two culinary preparations revealed a positive association between detection threshold and pleasantness ($r = 0.246$, $P = 0.018$), but negative with perceived intensity ($r = -0.393$, $P < 0.001$). The correlation between perceived intensity and perceived pleasantness was found nonsignificant.

A significant and positive correlation was found in perceived intensity between FA unsaturation content in oils ($r = 0.721$, $P < 0.001$) and béarnaise sauces ($r = 0.420$, $P < 0.001$). When analyzed by group, a correlation was found between FA unsaturation in oils ($r = 0.711$, $P < 0.001$) among tasters. The same correlation pattern was found in nontasters; FA unsaturation correlated positively in oils ($r = 0.731$, $P < 0.001$) and béarnaise sauces ($r = 0.557$, $P < 0.001$).

With respect to perceived pleasantness, a negative, significant correlation was found between the FA unsaturation and the crema catalana ($r = -0.597$, $P < 0.001$). When analyzed by group, the FA unsaturation correlated negatively and significantly with the oils ($r = -0.710$, $P < 0.001$) and crema catalana ($r = -0.627$, $P < 0.001$) among the tasters. In nontasters, the FA unsaturation correlated positively with the oils ($r = 0.653$, $P < 0.001$) and negatively with crema catalana ($r = -0.560$, $P = 0.001$).

Discussion

Oleogustus has been recently proposed as the sixth basic taste supported by diverse basic studies on FA detection (Laugerette et al., 2005; Cartoni et al., 2010) and FA perception by animals (Yoneda et al., 2007 and 2009) and humans (Mattes 2009; Running et al. 2014; Garneau et al., 2017). In this study, our goal was to explore the ability to detect changes in FA composition of dishes and analyze the relationship between FA composition in culinary preparations and taste intensity and palatability. To these purposes, we used two traditional recipes of Spanish cuisine, one sweet and one salty, varying in their total fat content, and prepared with three oils containing different FA composition: coconut oil (SFA profile), high-oleic sunflower oil (MUFA profile), and refined sunflower oil (PUFA profile).

Several elements could be involved in FA detection/perception. Thus, CD36 variants are associated with changes in linoleic threshold in obese individuals (Pepino et al. 2012; Plesník et al. 2018). Further, a single amino acid mutation in CD36 seems to modify the perception of fat taste (Chamoun et al., 2018; Bajit et al., 2020), an event that is related to changes in the pattern of food intake and a greater risk of obesity. Moreover, GPR120 seems to mediate FA taste quality information signaling in mice (Yasumatsu et al. 2019). Recent studies suggested GPR120-mediated detection of PUFAs as a modulator of fat, sweet and umami perception, rather than being directly involved in fat taste detection (Gaillard et al. 2019; Yasumatsu et al. 2019).

This information above could partially explain the linoleic acid threshold heterogeneity of our population. Analyzing the findings, we divided the participants in an FA taster group capable of detecting linoleic acid at concentrations below 1 mM, and an FA nontaster group, whose detection threshold for linoleic acid was above 1 mM. The detection threshold of nontasters was significantly higher than oral FA concentrations usually reached by the action of oral lipases after fatty food intake (Kulkarni et al. 2014). Our finding shows that FA tasters require only a small concentration of oleic and linoleic acids in the oral cavity to detect fat. Furthermore, these findings are consistent with previous studies on linoleic acid detection in humans (Kamphuis et al. 2003; Mattes 2009; Running et al. 2014, 2015; Garneau et al. 2017). However, we found a lower

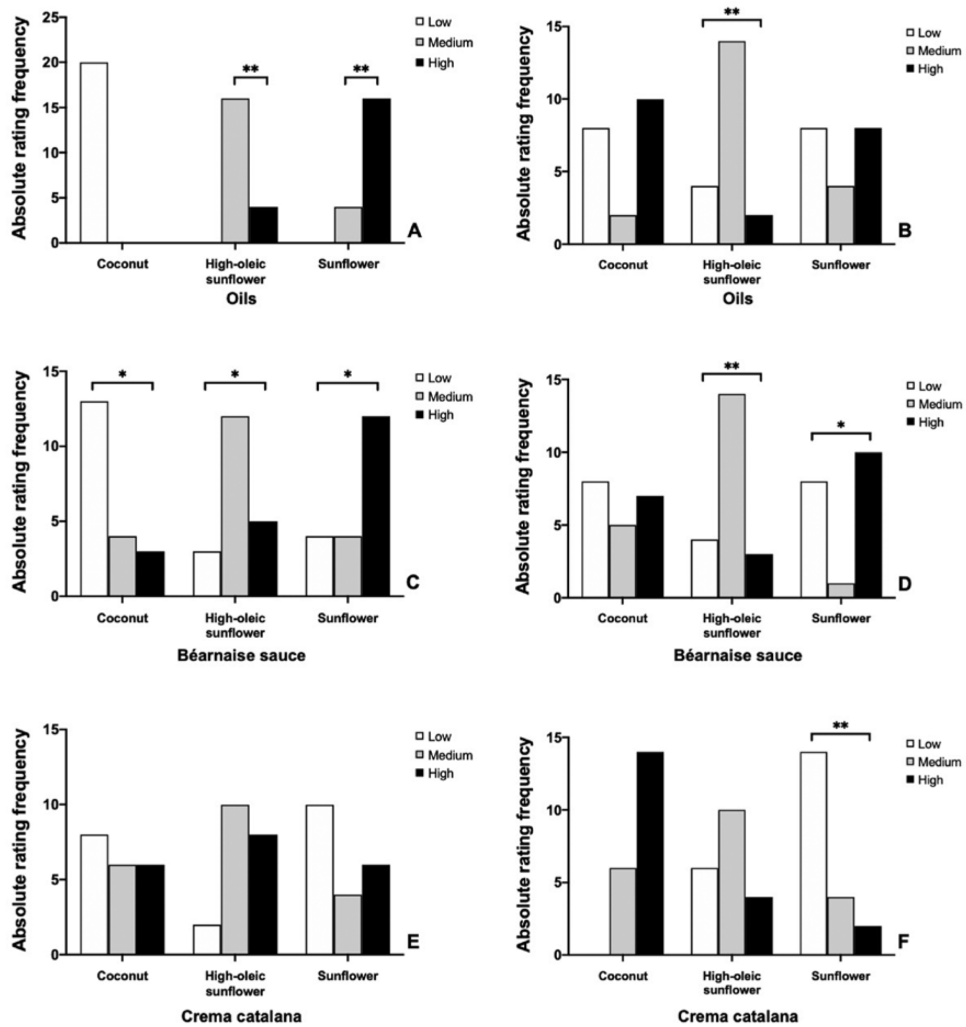

Figure 4. Subjective orosensory response to oils and dishes. Frequency of ratings (low, medium, and high) of the perceived intensity and pleasantness, respectively, of the oils (A,B), béarnaise sauce (C,D) and crema catalana (E,F) using coconut, high-oleic sunflower or sunflower oils in the making of the dishes. * Significant at $P < 0.05$; ** significant at $P < 0.001$.

linoleic acid detection threshold than the previously reported by Chevrot et al. (2014). A reason for this discrepancy is that our study enrolled mainly young women, whereas Chevrot and colleagues involved adult men, primarily. Another difference from other studies is that our taster panel was not overweight nor obese (data not shown), which could have influenced orosensory detection (Kaufman et al. 2020).

Interestingly, when forced to make a classification based on perceived taste intensity, all the participants were all able to categorize the three oils from less to more intense, regardless of the FA composition of the oils. Participants rated as more intense the taste induced by standard sunflower oil, rich in linoleic acid. This finding is consistent with experimental studies in rodents that demonstrate higher sensibility to PUFAs, such as linoleic acid (Saitou et al. 2009; Yoneda et al. 2009; Peterschmitt et al. 2018). We also found that perceived taste intensity varies depending on the type of oil used in the culinary preparations. That is, it varies according to the preparation's FA profile. Both linoleic acid tasters and nontasters rated the recipe prepared with higher unsaturated FA oils as more intense, compared with the other recipes.

With respect to perceived pleasantness, FA tasters considered coconut oil and the dishes prepared with coconut oil (without linoleic acid) more pleasant, while FA nontasters preferred the variants with sunflower oil, rich in linoleic acid. This finding is consistent with a recent study reporting that increased craving for foods high in fat (but not high in sugar, or a combination of fat and sugar), was associated with higher oral linoleic acid detection threshold (Plesník et al. 2018). According to our results, individual sensitivity to linoleic acid and FA profiles influence perceived pleasantness of the oils and dishes.

Yoneda et al. (2009) suggested that the recognition of FAs depends on complex factors, including carbon chain length and the unsaturated state of the FAs; therefore, we cannot exclude that changes in the composition of saliva, oral microbiota, and oral inflammation status may also influence PUFA threshold (Rawson et al. 2009; Besnard et al. 2018; Kaufman et al. 2018; Cataneo et al. 2019). Given that FA tasters can detect unsaturated FAs at lower concentrations, a higher concentration in the preparation could provoke an aversive response. Contrarily, FA nontasters would need higher fat concentrations to elicit a gustatory response.

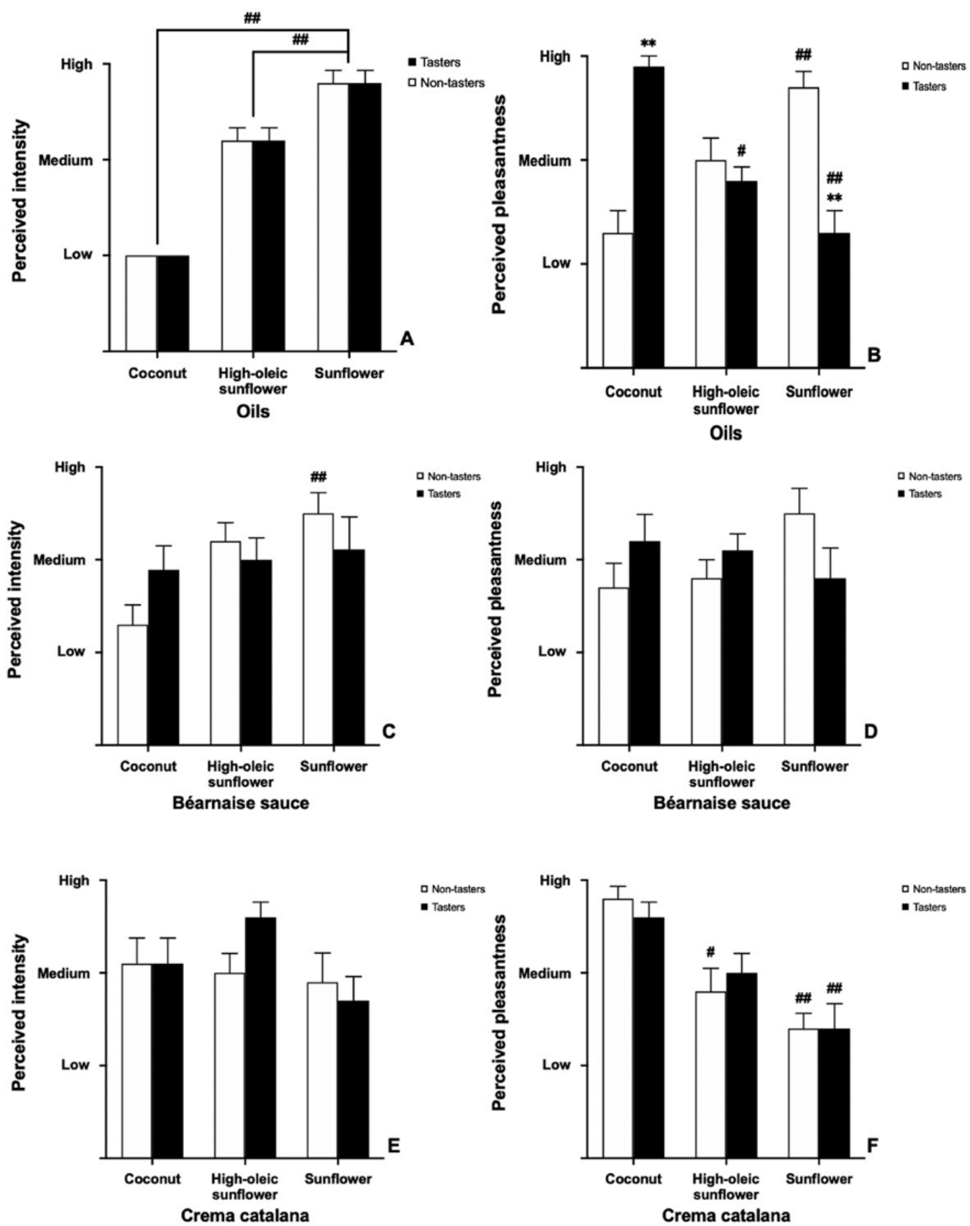

Figure 5. Fatty acid influence on orosensory response of oils and dishes. Differences between FA tasters and nontasters with respect to the perceived intensity and pleasantness of oil (A,B), béarnaise sauce (C,D) and crema catalana (E,F) using coconut, high-oleic sunflower or sunflower oils in the making of the dishes (mean ± SEM). * Significant at $P < 0.05$ with respect to the other group; ** significant at $P < 0.001$ with respect to the other group; # significant at $P < 0.05$ with respect to the different oils; ## significant at $P < 0.001$ with respect to the different oils.

Our data also show that SFAs such as lauric acid are perceived as less intense but more pleasant in the sweet preparations. Both FA tasters and FA nontasters responded similarly, reporting a greater preference for the crema catalana prepared with coconut oil (i.e., SFAs). This suggests that the absence of PUFA may impact the perceived preference of crema catalana (sweet), but not béarnaise sauce (salty) preparations. This result aligns with another recent, interesting study demonstrating that FA unsaturation influences rejection of chocolate with added linoleic acid (PUFAs), but not with added SFAs (Running et al. 2017). Therefore, it is reasonable to think that, for some individuals, the relationship between intensity and pleasantness is mediated by the oleogustus response (McCrickerd et al. 2016). Considering that the standard sunflower oil has 30% oleic acid, this overlap in MUFA with high-oleic sunflower oil represents a limitation worth mentioning. Variations in fat concentration between crema catalana and bearnaise sauce preparations could explain the disparity of these results. Interestingly, the panelists in our study did not report changes in sweet/salty intensity regardless of the FA composition of crema catalana or bearnaise sauce.

This dichotomy would agree with a recent finding showing that higher sensitivities to salt, sweet, or umami taste are associated with reduced preference for these tastes (Chamoum et al. 2019). According to our data, 30% of fat in the preparation would not be enough to trigger differences in food preference, since no difference was observed between tasters and nontasters in perceived pleasantness of crema catalana. The results in our study suggest that sweet components dampen the perceived intensity of preparations also containing fat, and that MUFAs (i.e., high-oleic sunflower oil) would be the best option to implement in recipes if the goal is to stimulate a mild taste (oleogustus).We must address various limitations of our study. Although acceptable for a pilot study, a larger sample size would be desirable to draw more robust conclusions. We are also aware that the threshold detection test should have been done twice for each participant to improve response reliability. Finally, we cannot rule out the influence of individual preference for certain types of foods (salty vs sweet).

This is, to our knowledge, the first study exploring the oleogustus response in elaborated culinary preparations. Also, no previous studies have observed the impact of using different oils, with various levels of saturation, in the sensory assessment of meal taste intensity and palatability. It is still unclear whether humans can perceive and identify fat taste as clearly as other taste qualities. The findings presented here, albeit limited, represent an interesting path to further explore the importance of oleogustus in expressing, and perhaps acquiring and developing, food preferences; and would be worth considering not only in a culinary context but also given dietary habits.

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Author contributions

J.J.M. designed research; P.C.C.V. and P.G.O. performed the research and J.J.M. and E.T. analyzed the data and wrote the manuscript. All authors read and approved the final version of the manuscript.

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