Liking for fat is associated with sociodemographic, psychological, lifestyle and health characteristics

Aurélie Lampuré[1]*, Amélie Deglaire[2,3], Pascal Schlich[2], Katia Castetbon[1,4], Sandrine Péneau[1], Serge Hercberg[1,4,5] and Caroline Méjean[1]

[1]*Université Paris 13, Sorbonne Paris Cité, Equipe de Recherche en Epidémiologie Nutritionnelle (EREN), Centre d'Epidémiologie et Biostatistiques Paris Nord, Inserm (U1153), Inra (U1125), Cnam, Université Paris 5, Université Paris 7, UREN, SMBH Paris 13, 74 rue Marcel Cachin, F-93017 Bobigny Cedex, France*
[2]*Centre des Sciences du Goût et de l'Alimentation, UMR6265 CNRS/UMR1324 INRA/Université de Bourgogne, Dijon, France*
[3]*Agrocampus Ouest – UMR1253 Inra Science et Technologie du Lait et de l'Œuf, Rennes, France*
[4]*Université Paris 13, Sorbonne Paris Cité, Unité de Surveillance et d'Epidémiologie Nutritionnelle (USEN), Institut de Veille Sanitaire (InVS), Département Maladies Chroniques et Traumatisme, Bobigny, France*
[5]*Department of Public Health, Hôpital Avicenne, Bobigny, France*

Abstract

Sensory liking influences dietary behaviour, but little is known about specifically associated individual profiles. The aim of the present study was to investigate the associations between liking for fat-and-salt and fat-and-sweet sensations and sociodemographic, economic, psychological, lifestyle and health characteristics in a large sample. Individual characteristics and liking scores were collected by a questionnaire among 37 181 French adults. Liking scores were constructed using a validated preference questionnaire. Multinomial logistic regression models were used to assess the associations between liking levels and individual characteristics. In both sexes, subjects belonging to low-level occupational categories (OR 1·39, 95 % CI 1·16, 1·67 in men; OR 1·28, 95 % CI 1·16, 1·41 in women), highly uncontrolled eaters (men: OR 2·90, 95 % CI 2·60, 3·23; women: OR 2·73, 95 % CI 2·27, 3·30) and obese subjects (men: OR 1·45, 95 % CI 1·14, 1·84; women: OR 1·47, 95 % CI 1·29, 1·68) were more likely to have a strong liking for the fat-and-sweet sensation, whereas older individuals (men: OR 0·13, 95 % CI 0·10, 0·16; women: OR 0·11, 95 % CI 0·09, 0·14) and highly cognitive restrainers (men: OR 0·52, 95 % CI 0·44, 0·63; women: OR 0·60, 95 % CI 0·55, 0·66) were less likely to have a strong liking. Regarding liking for the fat-and-salt sensation, the same associations were found and specific relationships were also highlighted: current smokers and heavy drinkers were more likely to strongly prefer the fat-and-salt sensation compared with non-smokers and abstainers or irregular alcohol consumers. The relationship between individual characteristics and a liking for fat sensation provides new and original information that may be useful for a better understanding of the associations between sensory liking and individual behaviour.
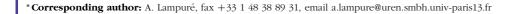
Key words: Dietary determinants: Liking: Fat: Sociodemographic factors: Psychological factors

Overconsumption of fatty foods has been identified as a risk factor in major chronic diseases, including CVD, diabetes and obesity[1]. Moreover, fat contributes to eating pleasure through its sensory properties, and influences food choices and dietary intake[2–4]. Taste ranks first among the reasons for individual food and beverage choices, ahead of price, health or convenience[5]; individual sensory liking thus appears to be an important determinant of dietary intake[6–10]. According to Mela[11], liking is defined as a qualitative hedonic evaluation of a food: the degree of pleasure or displeasure experienced. In the present study, we examined overall liking for sensory sensations measured via an original questionnaire.

In order to better understand the framework in which taste sensitivity, sensory liking, dietary intake and other characteristics interact with one another, it is useful to identify individual factors associated with liking for fat. Indeed, few previous studies[8,12–15] explored the relationship between liking for fat and specific individual characteristics.

Available studies have shown that a strong liking for fat was associated with weaker cognitive restraint in an obese population[14] and highly uncontrolled eating among dieters[15]. Moreover, positive associations have been shown between liking for fat and cardiovascular risk factors such as BMI and blood pressure[8,12,13]. No significant association has been found between liking for fat and sex or age[2,16].

Major limitations of previous studies included a small sample size and the absence of demographic heterogeneity in the study population (children, females and dieters), which restricts

* **Corresponding author:** A. Lampuré, fax +33 1 48 38 89 31, email a.lampure@uren.smbh.univ-paris13.fr

variability in terms of liking and individual factors. Moreover, associations between liking for fat and lifestyle, socio-economic characteristics and health status have not been previously studied, even though these factors are strongly associated with taste sensitivity or dietary intake[17,18]. Finally, no study has separately considered liking for fat-and-salt and fat-and-sweet sensations, and yet we assume that specific associations might exist, such as uncontrolled eating associated with fatty-salted food consumption, and emotional eating associated with fatty-sweetened food[19].

The aim of the present study was to investigate the associations between liking for fat-and-salt and fat-and-sweet sensations and sociodemographic, economic, psychological, lifestyle and health characteristics in a large sample of French adults.

Subjects and methods

Study population

We used data from the NutriNet-Santé Study, a large Web-based observational cohort launched in France in May 2009 with a scheduled follow-up period of 10 years. It was implemented in a general population and targeted Internet-using adult volunteers aged 18 years or older. The study was designed to investigate the relationship between nutrition and health (incidence of IHD, cancer and all-cause mortality), as well as the determinants of dietary behaviour and nutritional status. The design, methods and rationale have been described elsewhere[20]. Briefly, in order to be included in the cohort, participants had to fill out an initial set of questionnaires assessing dietary intake, physical activity, anthropometry, lifestyle, socio-economic conditions and health status. As part of their follow-up, the participants complete the same set of questionnaires every year. Moreover, each month, they were invited to fill out complementary questionnaires related to the determinants of food behaviour, nutritional and health status. The present study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures were approved by the Institutional Review Board of the French Institute for Health and Medical Research (IRB Inserm no. 0000388FWA00005831) and the 'Commission Nationale Informatique et Libertés' (CNIL no. 908450 and 909216). Electronic informed consent was obtained from all subjects (EudraCT no. 2013-000929-31).

Data collection

Assessment of liking for fat-and-salt and fat-and-sweet sensations. Liking for fat-and-salt and fat-and-sweet sensations was assessed using the PrefQuest, an original Web-based questionnaire which was internally validated using factor analyses[21]. This questionnaire also permitted the evaluation of liking for salt and sweet sensations. In May 2010, 65 683 participants were invited to complete this questionnaire on the 'NutriNet-Santé' website (https://www.etude-nutrinet-sante.fr/) available online for 6 months. The development and validation of the questionnaire has been described elsewhere[21]. Briefly, eighty-three relevant items were divided into liking for salt (eleven items), sweet (twenty-one items), fat-and-salt (thirty-one items) and fat-and-sweet (twenty items) sensations. The questionnaire included four types of items: (1) liking for sweets, fatty-sweet and fatty-salty foods, rated on a 9-point hedonic scale; (2) preferred level of salt, sweet, fat-and-salt or fat-and-sweet seasoning, measured on a 5- or 6-point scale; (3) preferred drinks (sweet/sweetened or unsweetened) on a restaurant menu; and (4) eating behaviour regarding sweet, salty and fatty food, measured on a 5- or 9-point scale. For most items, subjects also had the option of checking a non-applicable answer, such as 'I have never tasted (this food)' or 'I do not like (this food)'.

Assessment of sociodemographic, economic, psychological, lifestyle, anthropometric and health data. Sociodemographic, economic, lifestyle, anthropometric and self-reported health data were collected at baseline with the initial set of questionnaires. Psychological data were collected 14 months after inclusion using the Three-Factor Eating Questionnaire, which is a self-assessment instrument of eating behaviour[22] (its completion was optional). The revised version was selected (Three-Factor Eating Questionnaire-R21) and covers three eating behaviour domains: the cognitive restraint scale (six items); the emotional eating scale (six items); the uncontrolled eating scale (nine items)[23].

Statistical analysis

The present analysis focused on subjects living in metropolitan France and included in the NutriNet-Santé cohort who had completed the initial set of questionnaires, the PrefQuest and the Three-Factor Eating Questionnaire. All analyses were performed separately for men and women because most interactions between sex and individual characteristics were significant ($P < 0.05$).

The calculation of liking scores for the fat-and-salt and fat-and-sweet sensations has been detailed previously[21]. Factor analyses demonstrated that the fat-and-salt and fat-and-sweet sensations were multidimensional and presented a hierarchical factorial structure. The fat-and-salt sensation was composed of two compounding factors, 'added fat-and-salt' and 'fatty-salty foods' (based on 'meats', 'cheese products' and 'savoury snacks'); the fat-and-sweet sensation was composed of two compounding factors, 'added fat-and-sweet' and 'fatty-sweet foods' (based on 'pastries and desserts', 'chocolate spread' and 'chocolate desserts'). Since we used different hedonic scales in the questionnaire (from 5 to 9 points), all data were linearly transformed into values ranging from 0 to 10 so as to standardise the ratings. First, for each participant, liking scores of each factor composing a sensation were calculated by summing the ratings of the items belonging to the factor and dividing by the number of items of this factor. Next, overall liking scores of a sensation were computed by averaging the liking scores of the compounding factors. If a responder had more than 25% of non-applicable answers, i.e. 'I have never tasted (this food)' or 'I do not like (this food)' for a given sensation, the corresponding liking score was not computed and was excluded from the analysis. If a responder had 25% of non-applicable answers or less, an imputation was performed for these missing values.

Non-applicable answers were estimated within each sensation by adding the mean of all ratings of the subject to the mean of all ratings of the given item in the sample, and then subtracting by the mean of all ratings of the sensation in the sample[21]. Quartiles of the score for fat-and-sweet and fat-and-salt sensations were computed and defined from quartile 1 'low liking' to quartile 4 'high liking'.

We categorised sociodemographic and economic variables as follows: sex (men, women); age by quartiles (male: <40, 40–54, 54–63, >63 years; female: <32, 32–44, 44–56, >56 years); matrimonial status (single, couple, married, divorced/widowed); having at least one child (yes, no); living area (rural, urban <20 000 inhabitants, urban ≥20 000 inhabitants, urban ≥100 000 inhabitants, Paris); educational level (elementary school, secondary school, college graduate, advanced degree, other); occupational category (never worked, farmers/self-employed, manual workers/employees, intermediate profession, managerial staff); income per consumption unit (<900, 900–1800, 1800–2700, >2700€, refused to answer). Regarding cognitive restraint and uncontrolled eating, according to tertiles, categories were created: low; medium; high. As the emotional eating variable was not normally distributed, we categorised it into three classes using the median: no emotional eating; low emotional eating; high emotional eating.

According to French recommendations[24], male drinkers were categorised as abstainers and irregular consumers (≤4 g alcohol/d), moderate (>4 and ≤30 g alcohol/d) or heavy drinkers (>30 g alcohol/d), and females as abstainers and irregular consumers (≤3 g alcohol/d), moderate (>3 and ≤20 g alcohol/d) or heavy drinkers (>20 g alcohol/d). Smoking status was classified into three categories: never smoker; former smoker; current smoker. We also assessed current dieting (yes, no) and past dieting (yes, no). Normal weight, overweight and obesity were defined according to the WHO classification for BMI, as BMI <25 kg/m² (normal weight), $25 \leq BMI < 30$ kg/m² (overweight) and BMI ≥30 kg/m² (obese)[25], and self-reported health problems listed were type 1 and type 2 diabetes, hypertension, hypertriacylglycerolaemia and hypercholesterolaemia. Menopause (yes, no, no answer) and pregnancy status (yes, no) were also recorded.

Comparisons between included and excluded participants and sex comparisons were performed using Student's t test and the χ^2 test. First, in order to use ordinal logistic regression, we tested the hypothesis of proportionality of OR, but the latter was not valid. Therefore, associations of liking for fat-and-sweet and fat-and-salt sensations with all individual characteristics were assessed by multinomial logistic regression analysis (common reference: quartile 1 'low liking') stratified by sex. Univariate logistic regressions were performed by calculating OR and 95 % CI to determine the strength of the associations between liking and each explanatory variable. According to the literature and our hypotheses, interaction effects between age and cognitive restraint[19,26], age and smoking status and age and alcohol consumption[27] were also examined. Only explanatory variables and interaction terms associated with liking at the 0·1 significance level were retained for inclusion in the initial multivariate model. Subsequently, using stepwise backward elimination, multivariate logistic regression models were constructed. Variables were removed from the model one by one using a P value >0·05 for exclusion. Variables whose exclusion from the model caused large fluctuations in OR (>10 %), as well as variables whose exclusion gave rise to significant likelihood ratio tests ($P<0·05$) were re-entered into the model. Data management and statistical analyses were performed using SAS software (version 9.3; SAS Institute, Inc.). A P value <0·05 was considered statistically significant.
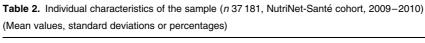
Results

Among the 65 683 participants in the NutriNet-Santé Study in May 2010, 49 066 had responded to the PrefQuest, i.e. a 75 % participation rate. Among the responders, 24 % were excluded (n 11 885) because they were non-responders to the Three-Factor Eating Questionnaire (n 10 481), had non-applicable data for a sensation (n 822) or had missing data for BMI, living area or alcohol consumption (n 582), leaving 37 181 subjects available for analysis (28 504 women and 8677 men). Compared with excluded subjects, included subjects were older (46 $v.$ 41 years, $P<0·0001$), the proportion of men was higher (23 $v.$ 21 %, $P<0·0001$), the proportion of subjects with high incomes was higher (26 $v.$ 21 %, $P<0·0001$) and the proportion of smokers was lower (15 $v.$ 20 %, $P<0·0001$) (data not shown).

For women and men, fat-and-salt-liking scores ranged from 0 to 9·48 with a mean of 3·9 (SD 1·4) and from 0 to 9·82 with a mean of 4·2 (SD 1·4), respectively, while fat-and-sweet-liking scores ranged from 0 to 9·92 with a mean of 3·8 (SD 1·8) and from 0 to 10 with a mean of 3·7 (SD 1·8), respectively. All results mentioned below were statistically significant. Men had a significantly higher liking score for the fat-and-salt sensation than women, while the opposite was observed for the fat-and-sweet sensation (Table 1). Regarding individual characteristics, women were younger and had higher psychological scores, while men had higher BMI (Table 2). The proportions of married men, those who had at least one

Table 1. Quartiles of liking scores for the fat-and-salt and fat-and-sweet sensations

(Mean values and standard deviations)

Liking scores	Sex	Mean	SD	Quartile 1 (low liking)	Quartile 2	Quartile 3	Quartile 4 (high liking)
Fat-and-salt sensation	Women	3·9	1·4	0·00, 2·88	2·88, 3·85	3·85, 4·83	4·83, 9·48
	Men	4·2	1·4	0·00, 3·20	3·20, 4·17	4·17, 5·11	5·11, 9·82
Fat-and-sweet sensation	Women	3·8	1·8	0·00, 2·48	2·48, 3·52	3·52, 4·84	4·84, 9·92
	Men	3·7	1·8	0·00, 2·41	2·41, 3·44	3·44, 4·80	4·80, 10·00

Table 2. Individual characteristics of the sample (n 37 181, NutriNet-Santé cohort, 2009–2010)

(Mean values, standard deviations or percentages)

Variables	Men (n 8677)	Women (n 28 504)	P
Age (years)			<0·0001
Mean	51·9	44·4	
SD	14·5	13·9	
Matrimonial status (%)			<0·0001
Single	12·7	17·0	
Couple	17·0	23·1	
Married	62·7	49·5	
Divorced/widowed	7·6	10·4	
Having at least one child (%)	74·1	65·7	<0·0001
Living area (%)			0·04
Rural	21·4	21·7	
Urban <20 000 inhabitants	15·8	14·7	
Urban ≥20 000 inhabitants	12·5	12·0	
Urban ≥100 000 inhabitants	32·0	33·1	
Paris	18·3	18·5	
Educational level (%)			<0·0001
Elementary school	4·0	2·9	
Secondary school	36·3	33·6	
College graduate	22·9	32·1	
Advanced degree	36·1	30·7	
Missing data	0·7	0·7	
Occupational category (%)			<0·0001
Never worked	2·4	5·0	
Farmer/self-employed/entrepreneur	5·2	2·8	
Manual worker/employee	17·2	34·7	
Intermediate profession	23·8	28·2	
Managerial staff	51·4	29·3	
Income (€) (%)			<0·0001
<900	6·2	10·8	
900–1800	30·3	33·6	
1800–2700	26·3	24·9	
>2700	33·6	23·7	
Missing data	3·6	7·0	
Cognitive restraint			<0·0001
Mean	38·7	44·3	
SD	20·0	30·3	
Uncontrolled eating			<0·0001
Mean	27·6	30·3	
SD	17·8	18·2	
Emotional eating			<0·0001
Mean	26·6	43·5	
SD	23·7	27·2	
Alcohol consumption (%)			<0·0001
Abstainer and irregular consumer	30·3	55·4	
Moderate drinker (women: ≤20 g/d; men: ≤30 g/d)	55·4	38·0	
Heavy drinker (women: >20 g/d; men: >30 g/d)	14·3	6·6	
Smoking status (%)			<0·0001
Never smoker	40·6	52·1	
Former smoker	45·7	32·5	
Current smoker	13·7	15·4	
BMI (kg/m^2)			<0·0001
Mean	25·2	23·5	
SD	3·9	4·6	
Current dieter (%)	35·1	47·7	<0·0001
Former dieter (%)	25·6	53·6	<0·0001
Menopause (%)			-
No	–	60·8	
Yes	–	35·0	
Missing data	–	4·2	
Pregnancy (%)	–	2·0	–
Hypertension (%)	18·0	8·5	<0·0001
Type 1 diabetes (%)	1·0	0·4	<0·0001
Type 2 diabetes (%)	3·9	1·1	<0·0001
Hypercholesterolaemia (%)	16·2	7·9	<0·0001
Hypertriacylglycerolaemia (%)	3·8	1·1	<0·0001

child and those who belonged to a high-level occupational category were higher than in women (Table 2).

Individual characteristics associated with liking for the fat-and-salt sensation

For greater clarity of results, only multivariate results from the 'high liking' level (fourth quartile) were reported here, and we defined this as the 'high risk' group. In men, age was negatively associated with a strong liking for the fat-and-salt sensation (Table 3). Women who had at least one child were more likely to have a strong liking for the fat-and-salt sensation (Table 4). Men and women with low income and women belonging to a low-level occupational category were more likely to have a high liking for the fat-and-salt sensation compared with those with higher income or a managerial position (Tables 3 and 4). In addition, current smokers and heavy drinkers were more likely to have a stronger liking for this sensation than never smokers, abstainers or irregular alcohol consumers.

Regarding psychological characteristics, men and women with highly uncontrolled eating were more likely to strongly prefer the fat-and-salt sensation than less uncontrolled eaters (Tables 3 and 4). Moreover, men with high cognitive restraint were less likely to have a strong liking for the fat-and-salt sensation than low cognitive restrainers. In women, a significant interaction between age and cognitive restraint was found. In stratified models by age, women with high cognitive

Table 3. Multivariate multinomial logistic analysis of the associations between sociodemographic, economic, psychological, lifestyle, anthropometric and health characteristics and levels of liking for the fat-and-salt sensation in men (n 8677, NutriNet-Santé cohort, 2009–2010)

(Odds ratios and 95 % confidence intervals)

Variables	Men (n 8677)						
	Quartile 2		Quartile 3		Quartile 4 (high liking)		
	OR	95 % CI	OR	95 % CI	OR	95 % CI	P*
Age (years)							<0·0001
<40	1		1		1		
40–54	0·70	0·57, 0·86	0·50	0·41, 0·62	0·41	0·34, 0·50	
54–63	0·46	0·37, 0·56	0·28	0·22, 0·34	0·21	0·17, 0·26	
>63	0·47	0·38, 0·58	0·32	0·26, 0·40	0·19	0·16, 0·24	
Living area							0·002
Paris	1		1		1		
Urban ≥100 000 inhabitants	0·94	0·78, 1·13	0·77	0·64, 0·93	0·81	0·67, 0·98	
Urban ≥20 000 inhabitants	0·90	0·72, 1·13	0·88	0·70, 1·11	0·83	0·65, 1·06	
Urban <20 000 inhabitants	0·78	0·63, 0·96	0·87	0·71, 1·08	0·74	0·59, 0·92	
Rural	1·10	0·89, 1·34	1·10	0·89, 1·34	0·98	0·79, 1·21	
Income (€)							0·003
>2700	1		1		1		
1800–2700	0·99	0·85, 1·16	1·03	0·88, 1·21	1·03	0·87, 1·22	
900–1800	1·16	0·99, 1·36	1·16	0·99, 1·37	1·37	1·16, 1·62	
<900	0·86	0·64, 1·16	1·01	0·75, 1·35	1·38	1·04, 1·84	
Missing data	0·87	0·62, 1·20	0·92	0·66, 1·28	0·81	0·57, 1·17	
Cognitive restraint							<0·0001
Low	1		1		1		
Medium	0·85	0·71, 1·00	0·71	0·60, 0·84	0·54	0·45, 0·64	
High	0·59	0·50, 0·70	0·49	0·41, 0·58	0·29	0·24, 0·35	
Uncontrolled eating							<0·0001
Low	1		1		1		
Medium	1·27	1·08, 1·48	1·50	1·28, 1·77	1·81	1·52, 2·15	
High	1·72	1·44, 2·06	2·48	2·07, 2·97	3·50	2·90, 4·23	
Emotional eating							0·003
No	1		1		1		
Low	0·84	0·71, 0·99	1·03	0·87, 1·22	0·86	0·72, 1·03	
High	1·05	0·87, 1·26	0·96	0·80, 1·17	0·95	0·78, 1·16	
Alcohol consumption							<0·0001
Abstainer and irregular consumer	1		1		1		
Moderate drinker (women: ≤20 g/d; men: ≤30 g/d)	1·38	1·21, 1·59	1·59	1·38, 1·83	1·71	1·47, 1·97	
Heavy drinker (women: >20 g/d; men: >30 g/d)	1·90	1·54, 2·35	2·30	1·86, 2·85	2·88	2·31, 3·58	
Smoking status							<0·0001
Never smoker	1		1		1		
Former smoker	1·16	1·01, 1·34	1·10	0·96, 1·27	1·04	0·90, 1·21	
Current smoker	1·25	1·00, 1·55	1·56	1·26, 1·94	1·83	1·48, 2·27	
BMI (kg/m^2)							<0·0001
<25 (normal)	1		1		1		
≥25 and <30 (overweight)	1·26	1·10, 1·45	1·35	1·17, 1·55	1·63	1·41, 1·89	
≥30 (obese)	1·40	1·11, 1·77	1·85	1·47, 2·33	2·30	1·82, 2·90	

* Multinomial logistic regression analysis was performed using the common reference (quartile 1 'low liking').

Table 4. Multivariate multinomial logistic analysis of the associations between sociodemographic, economic, psychological, lifestyle, anthropometric and health characteristics and levels of liking for the fat-and-salt sensation in women (*n* 28 504, NutriNet-Santé cohort, 2009–2010)

(Odds ratios and 95 % confidence intervals)

	Women (*n* 28 504)						
	Quartile 2		Quartile 3		Quartile 4 (high liking)		
Variables	OR	95 % CI	OR	95 % CI	OR	95 % CI	*P**
Matrimonial status							0·04
Single	1		1		1		
Couple	0·99	0·87, 1·13	0·93	0·82, 1·05	1·06	0·94, 1·20	
Married	1, 00	0·88, 1·14	0·98	0·86, 1·12	0·95	0·83, 1·09	
Divorced/widowed	0·93	0·80, 1·08	0·92	0·78, 1·08	0·88	0·75, 1·04	
Having at least one child (yes *v.* no)	1·29	1·16, 1·44	1·29	1·15, 1·44	1·45	1·29, 1·63	<0·0001
Occupational category							0·002
Managerial staff	1		1		1		
Intermediate profession	1·17	1·07, 1·28	1·12	1·02, 1·22	1·14	1·04, 1·26	
Manual worker/employee	1·16	1·05, 1·27	1·11	1·01, 1·22	1·20	1·09, 1·33	
Farmer/self-employed/entrepreneur	0·87	0·71, 1·07	0·96	0·78, 1·19	1·00	0·80, 1·25	
Never worked	1·05	0·86, 1·29	1·07	0·88, 1·31	1·27	1·05, 1·55	
Income (€)							0·004
>2700	1		1		1		
1800–2700	0·97	0·88, 1·06	1·01	0·91, 1·12	1·11	1·00, 1·23	
900–1800	0·93	0·84, 1·14	1·07	0·97, 1·19	1·16	1·04, 1·30	
<900	0·89	0·77, 1·03	0·98	0·85, 1·14	1·12	0·96, 1·30	
Missing data	0·87	0·76, 1·01	0·90	0·77, 1·04	0·94	0·81, 1·11	
Uncontrolled eating							<0·0001
Low	1		1		1		
Medium	1·35	1·24, 1·47	1·57	1·44, 1·72	2·01	1·82, 2·23	
High	1·78	1·61, 1·97	2·45	2·20, 2·72	4·18	3·74, 4·68	
Emotional eating							<0·0001
No	1		1		1		
Low	1·05	0·94, 1·18	1·13	1·00, 1·28	0·92	0·81, 1·04	
High	1·14	1·00, 1·29	1·16	1·01, 1·33	0·96	0·83, 1·11	
Alcohol consumption							<0·0001
Abstainer and irregular consumer	1		1		1		
Moderate drinker (women: ≤20 g/d; men: ≤30 g/d)	1·41	1·31, 1·51	1·56	1·45, 1·68	1·71	1·58, 1·85	
Heavy drinker (women: >20 g/d; men: >30 g/d)	1·63	1·40, 1·89	2·11	1·81, 2·46	2·70	2·31, 3·14	
Smoking status							<0·0001
Never smoker	1		1		1		
Former smoker	0·95	0·88, 1·02	0·94	0·87, 1·01	0·97	0·89, 1·05	
Current smoker	1·14	1·02, 1·27	1·20	1·07, 1·33	1·44	1·29, 1·60	
Current dieter (yes *v.* no)	1·13	1·05, 1·22	1·22	1·12, 1·31	1·28	1·18, 1·39	<0·0001
Former dieter (yes *v.* no)	0·89	0·82, 0·96	0·85	0·78, 0·92	0·78	0·72, 0·85	<0·0001
BMI (kg/m²)							<0·0001
<25 (normal)	1		1		1		
≥25 and <30 (overweight)	1·40	1·27, 1·54	1·52	1·37, 1·67	1·59	1·43, 1·76	
≥30 (obese)	1·67	1·45, 1·92	1·86	1·62, 2·15	2·30	1·99, 2·65	
Menopause							<0·0001
No	1		1		1		
Yes	1·22	0·92, 1·61	1·43	1·09, 1·87	1·42	1·09, 1·86	
Missing data	0·85	0·76, 0·96	0·76	0·67, 0·86	0·70	0·61, 0·80	
Pregnancy (yes *v.* no)	1·49	1·00, 2·21	1·56	1·07, 2·29	1·75	1·20, 2·57	0·04
Hypertension (yes *v.* no)	1·08	0·96, 1·22	1·20	1·06, 1·36	1·12	0·98, 1·29	0·046
Age × cognitive restraint							<0·0001

* Multinomial logistic regression analysis was performed using the common reference (quartile 1 'low liking').

restraint were less likely to have a strong liking than those with low cognitive restraint, and this relationship was stronger in young women (data not shown).

Compared with non-dieters, women who were currently dieting were more likely to have a strong liking for the fat-and-salt sensation, while women who had already dieted at least once (former dieters) were less likely to have a strong liking. In both sexes, obese and overweight individuals were more likely to strongly prefer the fat-and-salt sensation than those with normal corpulence. Pregnant and postmenopausal women were also more likely to have a strong liking for the fat-and-salt sensation (Table 4).

Individual characteristics associated with liking for the fat-and-sweet sensation

In both sexes, age was negatively associated with a strong liking for the fat-and-sweet sensation (Tables 5 and 6).

Table 5. Multivariate multinomial logistic analysis of the associations between sociodemographic, economic, psychological, lifestyle, anthropometric and health characteristics and levels of liking for the fat-and-sweet sensation in men (n 8677, NutriNet-Santé cohort, 2009–2010)
(Odds ratios and 95 % confidence intervals)

	Men (n 8677)						
	Quartile 2		Quartile 3		Quartile 4 (high liking)		
Variables	OR	95 % CI	OR	95 % CI	OR	95 % CI	P*
Age (years)							<0·0001
<40	1		1		1		
40–54	0·56	0·44, 0·71	0·42	0·34, 0·53	0·37	0·29, 0·46	
54–63	0·34	0·27, 0·43	0·24	0·19, 0·30	0·16	0·13, 0·21	
>63	0·27	0·22, 0·35	0·18	0·14, 0·23	0·13	0·10, 0·16	
Having at least one child (yes v. no)	1·23	1·03, 1·47	1·08	0·91, 1·29	1·00	0·84, 1·19	0·04
Occupational category							<0·0001
Managerial staff	1		1		1		
Intermediate profession	0·97	0·83, 1·12	1·10	0·94, 1·28	1·21	1·03, 1·42	
Manual worker/employee	0·86	0·72, 1·04	1·16	0·97, 1·39	1·39	1·16, 1·67	
Farmer/self-employed/entrepreneur	0·93	0·71, 1·21	1·02	0·78, 1·34	1·03	0·77, 1·38	
Never worked	2·05	0·89, 4·76	3·04	1·36, 6·80	3·32	1·50, 7·36	
Cognitive restraint							<0·0001
Low	1		1		1		
Medium	1·03	0·88, 1·22	0·87	0·74, 1·03	0·75	0·63, 0·89	
High	0·89	0·75, 1·06	0·70	0·59, 0·84	0·52	0·44, 0·63	
Uncontrolled eating							<0·0001
Low	1		1		1		
Medium	1·20	1·03, 1·40	1·38	1·18, 1·63	1·60	1·34, 1·91	
High	1·41	1·18, 1·68	1·74	1·45, 2·08	2·73	2·27, 3·30	
Emotional eating							0·008
No	1		1		1		
Low	1·15	0·98, 1·35	1·22	1·03, 1·44	0·98	0·82, 1·17	
High	1·21	1·00, 1·45	1·39	1·15, 1·68	1·20	0·99, 1·46	
Alcohol consumption							0·02
Abstainer and irregular consumer	1		1		1		
Moderate drinker (women: ≤20 g/d; men: ≤30 g/d)	1·20	1·04, 1·38	1·12	0·98, 1·30	1·01	0·87, 1·16	
Heavy drinker (women: >20 g/d; men: >30 g/d)	1·28	1·06, 1·56	1·09	0·89, 1·33	0·93	0·76, 1·15	
BMI (kg/m²)							0·0009
<25 (normal)	1		1		1		
≥25 and <30 (overweight)	1·09	0·95, 1·25	1·22	1·06, 1·41	1·32	1·14, 1·54	
≥30 (obese)	0·97	0·77, 1·23	1·23	0·97, 1·55	1·45	1·14, 1·84	
Former dieter (yes v. no)	0·81	0·70, 0·95	0·87	0·74, 1·02	0·96	0·82, 1·13	0·03
Hypertension (yes v. no)	0·90	0·77, 1·06	0·83	0·70, 0·98	0·72	0·60, 0·86	0·003
Hypertriacylglycerolaemia (yes v. no)	0·83	0·62, 1·11	0·66	0·48, 0·90	0·52	0·37, 0·75	0·002

* Multinomial logistic regression analysis was performed using the common reference (quartile 1 'low liking').

Compared with women without children, those who had at least one child were more likely to have a strong liking for the fat-and-sweet sensation. In addition, women with low income and men and women belonging to a low-level occupational category were more likely to strongly prefer the fat-and-sweet sensation than individuals with high income or a managerial position.

Men and women with high cognitive restraint were less likely to have a strong liking for the fat-and-sweet sensation compared with low cognitive restrainers, while subjects with highly uncontrolled eating or high emotional eating were more likely to have a strong liking. In addition, women who were currently dieting were more likely to have a strong liking compared with non-dieters. In both sexes, overweight and obese participants were more likely to have a strong liking for the fat-and-sweet sensation compared with those of normal weight.

Postmenopausal women were also more likely to have a strong liking for this sensation compared with non-menopausal women (Table 6). Men who declared that they had hyper-triacylglycerolaemia or hypertension were less likely to have a strong liking for the fat-and-sweet sensation than those without the diseases (Table 5).

Discussion

The present findings help to identify specific individual profiles associated with a strong liking for fat. To our knowledge, no study has investigated simultaneously the relationships between liking for fat-and-salt and fat-and-sweet sensations and various associated factors. Biological and physiological factors such as BMR, fat oxidation and insulin sensitivity, and also behavioural characteristics such as size of eating episode, frequency of eating and level of hunger have allowed to define the high-fat phenotype, according to Blundell & Cooling[28]. The originality of the present study is the distinction between fat-and-salt and fat-and-sweet sensations. Our findings thus allowed highlighting not only common factors associated with

Table 6. Multivariate multinomial logistic analysis of the associations between sociodemographic, economic, psychological, lifestyle, anthropometric and health characteristics and levels of liking for the fat-and-sweet sensation in women (n 28 504, NutriNet-Santé cohort, 2009–2010)

(Odds ratios and 95 % confidence intervals)

	Women (n 28 504)						
	Quartile 2		Quartile 3		Quartile 4 (high liking)		
Variables	OR	95 % CI	OR	95 % CI	OR	95 % CI	P*
Age (years)							<0·0001
<32	1		1		1		
32–44	0·68	0·59, 0·77	0·59	0·51, 0·67	0·53	0·47, 0·61	
44–56	0·38	0·33, 0·44	0·28	0·24, 0·33	0·25	0·21, 0·29	
>56	0·26	0·22, 0·32	0·19	0·15, 0·23	0·11	0·09, 0·14	
Matrimonial status							0·001
Single	1		1		1		
Couple	1·04	0·91, 1·18	1·02	0·90, 1·56	1·03	0·91, 1·18	
Married	1·12	0·98, 1·27	0·90	0·79, 1·03	0·98	0·86, 1·12	
Divorced/widowed	0·98	0·86, 1·14	0·81	0·69, 0·95	0·96	0·81, 1·13	
Having at least one child (yes v. no)	1·10	0·99, 1·22	1·24	1·11, 1·38	1·26	1·12, 1·41	<0·0001
Occupational category							<0·0001
Managerial staff	1		1		1		
Intermediate profession	0·99	0·91, 1·09	1·18	1·08, 1·30	1·13	1·03, 1·25	
Manual worker/employee	0·93	0·85, 1·02	1·12	1·16, 1·41	1·28	1·16, 1·41	
Farmer/self-employed/entrepreneur	0·76	0·62, 0·93	0·90	0·73, 1·11	0·85	0·68, 1·06	
Never worked	1·31	1·04, 1·65	1·76	1·41, 2·02	1·88	1·50, 2·36	
Income (€)							<0·0001
>2700	1		1		1		
1800–2700	1·03	0·93, 1·13	1·06	0·95, 1·17	1·22	1·10, 1·36	
900–1800	1·12	1·02, 1·24	1·17	1·06, 1·30	1·38	1·24, 1·54	
<900	1·04	0·90, 1·20	1·08	0·93, 1·25	1·39	1·20, 1·62	
Missing data	1·08	0·94, 1·25	1·04	0·89, 1·21	0·96	0·81, 1·13	
Cognitive restraint							<0·0001
Low	1		1		1		
Medium	0·94	0·86, 1·03	0·86	0·79, 0·94	0·75	0·69, 0·83	
High	0·82	0·75, 0·90	0·73	0·67, 0·81	0·60	0·55, 0·66	
Uncontrolled eating							<0·0001
Low	1		1		1		
Medium	1·31	1·20, 1·43	1·42	1·29, 1·55	1·66	1·50, 1·83	
High	1·47	1·33, 1·63	2·01	1·81, 2·23	2·90	2·60, 3·23	
Emotional eating							<0·0001
No	1		1		1		
Low	1·25	1·12, 1·40	1·27	1·12, 1·43	1·19	1·04, 1·35	
High	1·43	1·26, 1·62	1·71	1·49, 1·95	1·69	1·47, 1·95	
Current dieter (yes v. no)	1·09	1·01, 1·17	1·21	1·12, 1·30	1·33	1·23, 1·44	<0·0001
BMI (kg/m²)							<0·0001
<25 (normal)	1		1		1		
≥25 and <30 (overweight)	1·02	0·92, 1·12	1·00	0·91, 1·11	1·21	1·10, 1·34	
≥30 (obese)	1·08	0·95, 1·24	1·20	1·04, 1·37	1·47	1·29, 1·68	
Menopause							<0·0001
No	1		1		1		
Yes	1·09	0·88, 1·36	1·31	1·07, 1·62	1·43	1·16, 1·77	
Missing data	1·05	0·93, 1·18	0·82	0·72, 0·93	0·90	0·79, 1·02	

* Multinomial logistic regression analysis was performed using the common reference (quartile 1 'low liking').

both sensations that define the overall fat sensation, but also specific physiological and behavioural characteristics associated with the fat-and-salt or fat-and-sweet sensation only.

For both sensations, equivalent relationships were found between liking scores and age, socio-economic status, cognitive restraint, uncontrolled eating, weight status and menopause. Specific associations were also highlighted according to the sensation: smoking and alcohol consumption were associated with high liking for the fat-and-salt sensation, while emotional eating, hypertension and hypertriacylglycerolaemia (only in

men) were associated with strong liking for the fat-and-sweet sensation. Moreover, only in women, having a child and current dieting were both positively associated with the two sensations.

Liking for fat-and-salt and fat-and-sweet sensations decreased with age, as observed for intake of fatty foods in a previous study[17]. This may be linked to the predictive role of fat liking upon fat intake, as suggested previously[10]. One hypothesis is that liking and consumption of fatty foods may decline with age due to physiological changes such as altered taste and smell, slower gastric emptying, altered hormonal responses and

decreased BMR[29]. Previous studies[2,16] assessing fat liking did not report this finding concerning age, probably due to the highly selected samples compared with our population. The present study also highlighted the fact that pregnancy was associated with a higher fat-and-salt-liking score. It has been previously demonstrated that during pregnancy, there is an increase in bitter sensitivity during the first trimester so as to protect against ingesting poison, and a decrease in the perception level for salt and bitter tastes in the second and third trimesters to support ingesting a varied diet[30]. This status could also affect fat sensitivity. Moreover, the positive associations between menopause and high liking for fat-and-salt and fat-and-sweet sensations may be due to hormonal changes. This relationship has never been studied in the literature, and few studies carried out on the relationship between the menstrual cycle and preferences or dietary intake have shown no significant associations[31–33].

A positive association between having at least one child and high fat liking was found in women, probably due to maternal exposure to fatty foods intended for children. Low socio-economic status was inversely associated with liking for fat-and-salt and fat-and-sweet sensations. Higher exposure to fatty foods due to the greater affordability of these products compared with healthy foods in low socio-economic populations[34,35] could influence the liking for fat.

Uncontrolled eating was positively associated with liking for both sensations, but the strength of the relationship was higher for the fat-and-salt sensation, while restriction of eating was inversely associated with liking. Our findings in a general population are in concordance with previous studies assessing these relationships in obese populations and among dieters[14,15]. Emotional eating was positively associated with a liking for the fat-and-sweet sensation, as observed in a previous work conducted in a general population[19]. Psychological characteristics influenced the dietary intake of energy-dense foods such as butter, cheese, pastries and sweets[15,26,36], and may also influence fat liking due to modified exposure to these foods. Moreover, it showed the specificity of the associations between sensory liking and individual factors according to the sensation, i.e. emotional eating and fat-and-sweet sensation. This suggests that there are distinct phenotypes whether salt or sugar is associated with fat. We could therefore identify the high fat-and-salt and high fat-and-sweet phenotypes.

Women who were currently dieting were more likely to prefer fat; thus, a recent low-fat diet may have led to frustration due to high cognitive restraint[37] and an increased liking for fat. Elsewhere, smoking and alcohol consumption were positively associated with a strong liking for the fat-and-salt sensation. Indeed, a high dose of alcohol alters the perception of salty taste and promotes the consumption of fatty-salted foods[38]. Smoking decreases the olfactory function[39] and also affects taste sensitivity[40,41]. This may affect food preferences by increasing exposure to fatty-salted foods, as shown in a previous study[42].

Our findings showing positive relationships between weight status and fat liking, particularly the fat-and-salt sensation, are in agreement with previous studies[8,12,13], and suggest that fat liking might be involved in the obesity epidemic through overconsumption of fatty foods.

Interpretation of the present results must take into account the characteristics of the study. Subjects were volunteers in the NutriNet-Santé Study and thus probably more concerned about healthy lifestyle and nutrition than the general population. Thus, caution is needed when interpreting and generalising the results. Moreover, compared with liking as assessed by sensory analysis, self-reported liking on a questionnaire may lead to under-reporting. However, positive correlations between the present questionnaire and sensory test measurements have been previously shown in our laboratory. Coefficients of 0·4–0·5 for salt and sweet tastes and 0·2–0·3 for the fat sensation were found (A Deglaire, C Urbano, C Mejean, et al., unpublished results). Such coefficients are in line with previous results[43–45]. The present questionnaire, shown to be repeatable, feasible and valid[21], can thus serve as a proxy for sensory test measurements of liking.

In addition, the large sample size induced significant associations even when differences between groups were small. However, the sample size and the diversity of collected data, such as sociodemographic, economic, psychological, lifestyle, anthropometric and health factors, enabled a highly accurate estimate and adjustment for several confounders.

In conclusion, the present study provides original information and elucidates individual characteristics associated with high liking for fat-and-salt and fat-and-sweet sensations. Indeed, relationships between common unhealthy characteristics such as low socio-economic conditions, dieting, overweight and high fat liking were highlighted, and a strong liking for the fat-and-salt sensation was specifically associated with smoking and alcohol consumption. Likewise, pregnancy, having a child, menopause, uncontrolled eating and emotional eating were positively associated with high fat liking, while increasing age and cognitive restraint were negatively associated. These individual characteristics are likely to interact with each other in the causal chain between liking and dietary intake. Our original findings should therefore enable a more precise elucidation of the causal framework of relationships between taste sensitivity, liking, dietary intake and other characteristics.

Acknowledgements

References

1. World Health Organization (2003) *Diet, Nutrition and the Prevention of Chronic Diseases. Joint WHO/FAO Expert Consultation. WHO Technical Report Series* no. 916. Geneva: WHO.
2. Drewnowski A (1997) Why do we like fat? *J Am Diet Assoc* **97**, S58–S62.
3. Mela DJ (1999) Food choice and intake: the human factor. *Proc Nutr Soc* **58**, 513–521.
4. Mela DJ (2001) Determinants of food choice: relationships with obesity and weight control. *Obes Res* **9**, Suppl. 4, 249S–255S.
5. Glanz K, Basil M, Maibach E, *et al.* (1998) Why Americans eat what they do: taste, nutrition, cost, convenience, and weight control concerns as influences on food consumption. *J Am Diet Assoc* **98**, 1118–1126.
6. Drewnowski A & Hann C (1999) Food preferences and reported frequencies of food consumption as predictors of current diet in young women. *Am J Clin Nutr* **70**, 28–36.
7. Drewnowski A, Hann C, Henderson SA, *et al.* (2000) Both food preferences and food frequency scores predict fat intakes of women with breast cancer. *J Am Diet Assoc* **100**, 1325–1333.
8. Duffy VB, Hayes JE, Sullivan BS, *et al.* (2009) Surveying food and beverage liking: a tool for epidemiological studies to connect chemosensation with health outcomes. *Ann N Y Acad Sci* **1170**, 558–568.
9. Mejean C, Deglaire A, Kesse-Guyot E, *et al.* (2014) Association between intake of nutrients and food groups and liking for fat (The Nutrinet-Santé Study). *Appetite* **78**, 147–155.
10. Raynor HA, Polley BA, Wing RR, *et al.* (2004) Is dietary fat intake related to liking or household availability of high- and low-fat foods? *Obes Res* **12**, 816–823.
11. Mela DJ (2000) Why do we like what we like? *J Sci Food Agric* **81**, 10–16.
12. Bartoshuk LM, Duffy VB, Hayes JE, *et al.* (2006) Psychophysics of sweet and fat perception in obesity: problems, solutions and new perspectives. *Philos Trans R Soc Lond B Biol Sci* **361**, 1137–1148.
13. Duffy VB, Lanier SA, Hutchins HL, *et al.* (2007) Food preference questionnaire as a screening tool for assessing dietary risk of cardiovascular disease within health risk appraisals. *J Am Diet Assoc* **107**, 237–245.
14. Elfhag K & Erlanson-Albertsson C (2006) Sweet and fat taste preference in obesity have different associations with personality and eating behavior. *Physiol Behav* **88**, 61–66.
15. Lahteenmaki L & Tuorila H (1995) Three-factor eating questionnaire and the use and liking of sweet and fat among dieters. *Physiol Behav* **57**, 81–88.
16. Drewnowski A & Almiron-Roig E (2010) Human perceptions and preferences for fat-rich foods. In *Fat Detection – Taste, Texture, and Post Ingestive Effects* [Jean-Pierre Montmayeur and Johannes Le Coutre, editors]. Boca Raton, FL: CRC Press.
17. Mejean C, Macouillard P, Castetbon K, *et al.* (2011) Socio-economic, demographic, lifestyle and health characteristics associated with consumption of fatty-sweetened and fatty-salted foods in middle-aged French adults. *Br J Nutr* **105**, 776–786.
18. Stewart JE, Feinle-Bisset C, Golding M, *et al.* (2010) Oral sensitivity to fatty acids, food consumption and BMI in human subjects. *Br J Nutr* **104**, 145–152.
19. Keskitalo K, Tuorila H, Spector TD, *et al.* (2008) The Three-Factor Eating Questionnaire, body mass index, and responses to sweet and salty fatty foods: a twin study of genetic and environmental associations. *Am J Clin Nutr* **88**, 263–271.
20. Hercberg S, Castetbon K, Czernichow S, *et al.* (2010) The Nutrinet-Santé Study: a web-based prospective study on the relationship between nutrition and health and determinants of dietary patterns and nutritional status. *BMC Public Health* **10**, 242.
21. Deglaire A, Mejean C, Castetbon K, *et al.* (2012) Development of a questionnaire to assay recalled liking for salt, sweet and fat. *Food Qual Prefer* **23**, 110–124.
22. Stunkard AJ & Messick S (1985) The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *J Psychosom Res* **29**, 71–83.
23. Tholin S, Rasmussen F, Tynelius P, *et al.* (2005) Genetic and environmental influences on eating behavior: the Swedish Young Male Twins Study. *Am J Clin Nutr* **81**, 564–569.
24. Hercberg S, Chat-Yung S & Chauliac M (2008) The French National Nutrition and Health Program: 2001–2006–2010. *Int J Public Health* **53**, 68–77.
25. World Health Organization (1995) Physical status: the use and interpretation of anthropometry. In *Report of a WHO Expert Committee. World Health Organ Technical Report Series* no. 854, pp. 1–452. Geneva: WHO.
26. De Lauzon B, Romon M, Deschamps V, *et al.* (2004) The Three-Factor Eating Questionnaire-R18 is able to distinguish among different eating patterns in a general population. *J Nutr* **134**, 2372–2380.
27. Eigenbrodt ML, Mosley TH Jr, Hutchinson RG, *et al.* (2001) Alcohol consumption with age: a cross-sectional and longitudinal study of the Atherosclerosis Risk in Communities (ARIC) study, 1987–1995. *Am J Epidemiol* **153**, 1102–1111.
28. Blundell JE & Cooling J (1999) High-fat and low-fat (behavioural) phenotypes: biology or environment? *Proc Nutr Soc* **58**, 773–777.
29. Drewnowski A & Shultz JM (2001) Impact of aging on eating behaviors, food choices, nutrition, and health status. *J Nutr Health Aging* **5**, 75–79.
30. Duffy VB, Bartoshuk LM, Striegel-Moore R, *et al.* (1998) Taste changes across pregnancy. *Ann N Y Acad Sci* **855**, 805–809.

31. Hormes JM & Rozin P (2009) Perimenstrual chocolate craving. What happens after menopause? *Appetite* **53**, 256–259.

32. Kanarek RB, Ryu M & Przypek J (1995) Preferences for foods with varying levels of salt and fat differ as a function of dietary restraint and exercise but not menstrual cycle. *Physiol Behav* **57**, 821–826.

33. Verma P, Mahajan KK, Mittal S, *et al.* (2005) Salt preference across different phases of menstrual cycle. *Indian J Physiol Pharmacol* **49**, 99–102.

34. Drewnowski A & Specter SE (2004) Poverty and obesity: the role of energy density and energy costs. *Am J Clin Nutr* **79**, 6–16.

35. Drewnowski A & Darmon N (2005) Food choices and diet costs: an economic analysis. *J Nutr* **135**, 900–904.

36. de Castro JM & Lilenfeld LR (2005) Influence of heredity on dietary restraint, disinhibition, and perceived hunger in humans. *Nutrition* **21**, 446–455.

37. King GA, Herman CP & Polivy J (1987) Food perception in dieters and non-dieters. *Appetite* **8**, 147–158.

38. Caton SJ, Ball M, Ahern A, *et al.* (2004) Dose-dependent effects of alcohol on appetite and food intake. *Physiol Behav* **81**, 51–58.

39. Frye RE, Schwartz BS & Doty RL (1990) Dose-related effects of cigarette smoking on olfactory function. *JAMA* **263**, 1233–1236.

40. Pavlos P, Vasilios N, Antonia A, *et al.* (2009) Evaluation of young smokers and non-smokers with Electrogustometry and Contact Endoscopy. *BMC Ear Nose Throat Disord* **9**, 9.

41. Pepino MY & Mennella JA (2007) Effects of cigarette smoking and family history of alcoholism on sweet taste perception and food cravings in women. *Alcohol Clin Exp Res* **31**, 1891–1899.

42. Perrin MJ, Krut LH & Bronte-Srewart B (1961) Smoking and food preferences. *Br Med J* **1**, 387–388.

43. Beauchamp GK, Bertino M, Burke D, *et al.* (1990) Experimental sodium depletion and salt taste in normal human volunteers. *Am J Clin Nutr* **51**, 881–889.

44. Keskitalo K, Tuorila H, Spector TD, *et al.* (2007) Same genetic components underlie different measures of sweet taste preference. *Am J Clin Nutr* **86**, 1663–1669.

45. Kim GH & Lee HM (2009) Frequent consumption of certain fast foods may be associated with an enhanced preference for salt taste. *J Hum Nutr Diet* **22**, 475–480.