ROLE OF TASTE GENETIC VARIATIONS IN SWEET, FATTY AND SWEET-FATTY TASTE PERCEPTION AND FOOD INTAKE AMONGST OBESE AND NON-OBESE MALAY ADULTS IN MALAYSIA

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By

AHMAD RIDUAN BIN BAHAUDDIN

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March 2019

Chairman : Associate Professor Roselina Karim, PhD
Faculty : Food Science and Technology

The genetic variation of taste could explain the variations observed in human perceptions and predict individuals' food choices and intake. However, the current understanding of how taste genetic could affect individual's taste function and perception in various food systems and their relationship towards dietary intke is limited. Thus, the study was conducted to examine the effects of genetic variation on taste (in terms of taste of receptor polymorphism and Propylthiouracil (PROP) status on sweet and / or fat perceptions of different food models and also food intake between obese and obese subjects.

A total of 88 obese subjects (means age of 27.6 ± 6.24 years and BMI of 33.46 ± 3.60 kgm^2) and 92 non-obese subjects (means age of 25.86 ± 5.28years and BMI of 21.79 ± 2.35 kgm^2) were genotyped for TAS1R2 gene at rs35874116, rs9701796, and rs12033832, TAS1R3 gene at rs307355, rs35744813), CD36 gene at rs1761667, rs1527483, and rs1049673 and TAS2R38 gene at rs613798. PROP taster status (e.g. supertaster, medium taster and non-taster) were determined using paper disk rating. Three type of samples namely blank taste solution (sweet taste - sucrose solution; fatty taste (oiliness) - linoleic acid solution), singular taste food (sweet – rose flavored pudding; fatty (creaminess) – *'bubur chacha'*) and binary taste food (sweet-fatty taste – 'bubur chacha') were evaluated for taste intensity and hedonic responses using general Labelled Magnitude scale (gLMS) and general Labeled Hedonic Scale (gLHS). Subjects completed 3 days food record (2 weekdays, 1 weekend) and 2 set of food frequency questionnaires (sweet food and fatty food) to assess their habitual food consumption and dietary intake.

Overall, there are significant differences in term of weight and BMI between obese and non-obese subjects. In contrast, no significant differences was found on socio-demographic characteristic variables between both groups. Obese and non-obese subjects

did not differ on the sweetness, oiliness and creaminess rating of tasting samples except for binary taste food, the *'bubur chacha'*. rs12033832 of TAS1R2 gene and rs1761667 of CD36 gene was associated with taste intensity and liking rating of blank solution and single taste food but not in sweet-fatty mixtures in both obese and non-obese subjects. Individuals with AA genotype for both genes perceived greater taste intensity rating and give lower liking rating of tasting samples. In contrast, PROP taster status was associated with taste intensity and liking rating of all type of samples. Regardlesss of BMI status, supertaster rated higher taste intensity and had lower mean liking ratings in most of samples. BMI status and PROP taster status seem to play a role in sweet-fatty taste optimal preference. Non-taster - obese subjects preferred higher fat content (8.75%) in stimuli compared to only 6.6% of fat in supertaster – non-obese subjects. Assessment of dietary intake revealed that obese subjects differed significantly on energy and protein intake compared to non-obese subjects. No significant difference was observed among PROP taster status on the subject's habitual sweet or fatty food consumption for both BMI groups.

In conclusion, taste receptor gene variant was shown to be responsible for the variation of individuals' taste sensitivity but are not related to taste liking and food intake. Furthermore, the influence of taste receptor gene variances on perception was demolished as the stimuli become more complex (e.g binary taste system). Thus, it can be concluded that taste receptor gene variances and PROP taster status did not seem to play a major role in human taste perception and food intake among obese and non-obese subjects.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

FUNGSI VARIASI GENETIK RASA TERHADAP PENERIMAAN RASA MANIS, BERLEMAK DAN MANIS-BERLEMAK SERTA PENGAMBILAN MAKANAN DI KALANGAN OBES DAN BUKAN OBES MELAYU DEWASA DI MALAYSIA

Oleh

AHMAD RIDUAN BIN BAHAUDDIN

Mac 2019

Pengerusi : Profesor Madya Roselina Karim, PhD
Fakulti : Sains dan Teknologi Makanan

Variasi genetik rasa dapat menjelaskan variasi yang dilihat dalam persepsi rasa manusia dan meramalkan pilihan makanan dan pengambilan individu. Walau bagaimanapun, pemahaman semasa tentang bagaimana genetik rasa boleh memeberi kesa terhadap fungsi rasa dan persepsi individu dalam pelbagai sistem makanan dan hubungan mereka terhadap pengambilan makanan adalah terhad. Oleh itu, kajian ini dijalankan untuk mengkaji kesan variasi genetik terhadap rasa (dari segi polimorfisme reseptor rasa dan Propylthiouracil (PROP) terhadap persepsi rasa manis dan / atau lemak dalam model makanan yang bebeza dan pengambilan makanan di antara subjek obes dan obes.

Seramai 88 subjek obes (min umur - 27.6 ± 6.24 tahun dan BMI - 33.46 ± 3.60 kgm^2) dan 92 subjek non-obes (min umur - 25.86 ± 5.28 tahun dan BMI - 21.79 ± 2.35 kgm^2) digenotipkan bagi gen TAS1R2 pada variasi rs35874116, rs9701796, dan rs12033832, gen TAS1R3 pada variasi rs307355, rs35744813), gen CD36 pada variasi rs1761667, rs1527483, dan rs1049673 dan gen TAS2R38 pada variasi rs613798. Status perasa PROP (cth. Superperasa, medium dan bukan perasa) telah ditentukan menggunakan perkadaran cakera kertas. Tiga jenis sampel iaitu larutan rasa kosong (rasa manis - larutan sukrosa; rasa berlemak (berminyak) - larutan asid linoleik), makanan rasa tunggal (puding berperisa ros; lemak (berkrim) - 'bubur chacha' dan rasa binary (rasa manis- lemak - 'bubur chacha') dinilai untuk intensiti rasa dan tindak balas hedonik menggunakan skala magnitud berlabel umum (gLMS) dan Skala hedonik berlabel umum (gLHS). Subjek melengkapkan 3 hari rekod makanan (2 hari bekerja, 1 hujung minggu) dan 2 set soalan berkaitan kekerapan makanan (makanan manis dan makanan berlemak) bagi menilai tabiat pengambilan makanan dan pengambilan makanan.
Secara keseluruhan, terdapat perbezaan yang signifikan bagi ukuran berat dan BMI di antara subjek obes dan bukan obes. Namun, tiada perbezaan yang signifikan diperolehi

bagi semua pembolehubah sosio-demografi di antara kedua-dua kumpulan. Subjek obes dan bukan obes adalah tidak berbeza bagi penerimaan rasa manis, rasa berminyak dan berkrim untuk penilaian sampel kecuali bagi makanan perisa binari, 'bubur chacha'. Varians rs12033832 pada gen TAS1R2 dan rs1761667 pada gen CD36 mempunyai hubungkait dengan intensiti rasa dan darjah kesukaan bagi larutan kosong (larutan sukrosa dan asid lenoleik) dan makanan rasa tunggal tetapi kaitan adalah tidak wujud dalam sampel campuran manis-lemak bagi kedua-dua subjek obes dan bukan obes. Individu yang mempunyai genotip AA untuk kedua-dua gen memberikan penilaian intensiti rasa yang lebih tinggi dan memberi tahap kesukaan sampel yang lebih rendah. Sebaliknya, status perasa PROP mempunyai hubungkait dengan intensiti rasa dan penilaian kesukaan bagi semua jenis sampel. Tanpa mengambilkira status BMI, perasa super memberikan nilai intensiti rasa yang lebih tinggi dan mempunyai nilai tahap kesukaan yang lebih rendah dalam kebanyakan sampel. Status BMI dan status perasa PROP memainkan peranan dalam penentuan nilai optima bagi penerimaan rasa lemak dan manis. Subjek bukan perasa dan obes memilih kandungan lemak yang lebih tinggi (8.75%) dalam stimuli berbanding hanya 6.6% lemak dalam superperasa dan bukan obes. Penilaian pengambilan makanan menunjukkan bahawa subjek obes adalah berbeza secara signifikan terhadap pengambilan tenaga dan protein berbanding subjek bukan obes. Tiada perbezaan yang signifikan di kalangan status PROP perasa pada tabiat makanan manis atau lemak untuk kedua-dua kumpulan BMI.

Sebagai kesimpulan, variasi gen reseptor rasa memainkan peranan terhadap variasi kepekaan rasa individu namun ianya tidak mempunyai hubungkait dengan penerimaan rasa dan pengambilan makanan. Selain itu, pengaruh variasi gen reseptor rasa adalah tidak wujud kerana rangsangan menjadi lebih kompleks (contohnya, sistem perisa binari). Oleh itu, dapat disimpulkan bahawa variasi sel reseptor rasa dan status perasa PROP adalah tidak memainkan peranan utama dalam persepsi rasa manusia dan pengambilan makanan di kalangan subjek obes dan bukan obes.

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Signature: ______________________________

Name of Member of Supervisory Committee: Professor Dr. Nazamid Shaari

Signature: ______________________________

Name of Member of Supervisory Committee: Professor Dr. Zalilah Mohdd. Shaarif

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LIST OF ABBREVIATIONS

ANOVA	analysis of variance
ATP	adenosine triphosphate
BMI	Body Mass Index
ºC	degree of Celcius
cm	centimeter
CD36	cluster of differentiation 36
DNA	Deoxyribonucleic acid
DT	Detection threshold
FFQ	Food Frequency questionnaire
g	gram
GCPR	G protein-coupled receptors
gLMS	general Labeled Magnitude Scale
h	hour
Kg	kilogram
L	liter
LCFA	long chain fatty acid
LMS	labelled magnitude scale
MAF	minor allele frequency
ME	magnitude estimation
min	minute
mL	milliliter
MT	Medium taster
NHMS	National Health and Morbidity Survey
NT	Non-taster
Nacl	sodium chloride

PROP	6-n-propylthiouracil
PTC	phenylthiocarbamide
rpm	revolutions per minute
RT	Recognition threshold
RSM	Response Surface Methodology
SNPs	Single Nucleotide Polymorphism
ST	Supertaster
TRC	taste cell receptor
w/v	weight/volume
µL	microliter

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Obesity is a major public health problem that contributes to high mortality around the globe. In 2016, it was reported that about 13.0% of adults are obese and 39.0% are overweight worldwide (WHO, 2018). Obesity is caused by the imbalance of energy intake and energy expenditure where all the energy intake is obtained from the food consumed. The changes in diet and lifestyle last three decades are believed play a role in the increase of obesity epidemic (Wardle, 2007; Ramachandran and Snehalatha, 2010). Furthermore, the excess consumption of extrinsic sugar and fat are reported the major contributors to individuals' weight gain (Seidell, 1998; Bray *et al.*, 2004; Berkey *et al.*, 2004; Mazlan *et al.*, 2006; Drewnowski, 2007; Avena *et al.*, 2009; Besnard, 2016; Proserpio *et al.*, 2016).

Taste significantly determines food choice and preference among humans. There is increase attention in taste perception and preferences to dietary behaviors. Interestingly, previous studies demonstrated that difference in taste receptor gene account for differences in taste perception and preference among individuals, which influence human food consumption and weight status (Chamoun *et al.*, 2016). Even though the differences of taste perception due to genotype and phenotype predict individuals' food preference, however, the link to habitual food consumption and weight gain remain ambiguous (Garcia-Bailo *et al.*, 2009; Dotson *et al.*, 2010; Chamoun *et al.*, 2016). Several studies had demonstrated that obesity affects individuals' taste sensitivity and food consumption due to long-term metabolic effect (Matsushita *et al.*, 2009; Newman *et al.*, 2013; Asano *et al.*, 2015).

The relationship between taste and weight gain via food intake and preference was discovered since 1960's. The recognition that tasters and non-tasters have different body shapes serves as the interest in this topic. Individuals who are sensitive toward phenylthiocarbamide (PTC) and/or 6-n-propylthiouracil (PROP) are known as 'tasters' and tend to be ectomorphs (a thin and angular body type), whereas non-tasters, individuals who are not sensitive toward PTC and/or PROP) tend to be endomorphs (generous body proportions) (Keller *et al.*, 2002; Duffy, 2004; Bartoshuk *et al.*, 2006; Tepper, 2008). This trait is inherited via a recessive pattern, with about 25.0% of the population are classified as 'non-tasters' while the remaining 75.0% are 'tasters'. The TAS2R38 gene is responsible for the variations in the PTC and PROP sensitivity (Bufe *et al.*, 2005; Kim *et al.*, 2005; Tepper *et al.*, 2008). The variations in taste sensitivity due to PTC/PROP is also associated with preferences for bitter fruits and vegetables (Drewnowski,*et al.*, 2001; Feeney, 2011; Feeney *et al.*, 2014; Nagai *et al.*, 2017), sweet foods (Gent and Bartoshuk, 1983; Prescott *et al.*, 2001; Prescot *et al.*, 2004; Zhao and Tepper, 2007; Lee *et al.*, 2008), added fats (Tepper and Nurse, 1997; Kamphuis and Westerterp-plantenga, 2003; Kirkmeyer and Tepper, 2005), spicy foods (Drewnowski *et al.*, 2001; Rupesh and Nayak; 2006) and alcoholic beverages (Duffy *et al.*, 2004; O'Brien *et al.*, 2010). Thus, the findings on the relationship between PROP status, taste perception and dietary intake pattern lead to the investigation on genetic taste as the potential marker of human food consumption and body weight status.

Recent advancements in genetic technology provide affordable instruments and tools to conduct more studies on taste genetic variation and its linkage to taste perception and food intake. The genes that encode for taste receptors have been identified, include thing the TAS2R gene family for bitter taste (Adler *et al.*, 2000; Chandrashekar *et al.*, 2000; Matsunami *et al.*, 2000) and TAS1R family for sweet and umami tastes (Bachmanov and Beauchamp, 2007; Bachmanov *et al.*, 2011). In addition, the fatty acid transporter, CD36 is identified as the putative taste receptor for fat (Laugerette *et al.*, 2005).

However, the association between taste perception via genetic polymorphism with food consumption and individuals' weight status is not straightforward (Duffy, 2004; Hayes *et al.*, 2008; Chamoun *et al.*, 2016). Moreover, most of the previous studies focus on the relationship between taste perception and body mass index (BMI) rather than comparing body weight status (e.g. obese vs. non-obese) (Stewart *et al.*, 2010; Cox *et al.*, 2015). Apart from that, the literature focus on the conventional sensory methodology (e.g. taste threshold) in response to genetic variations in taste between individuals (Fushan *et al.*, 2010; Daoudi *et al.*, 2015; Dias *et al.*, 2015; Melis *et al.*, 2015; Mrizak *et al.*, 2015; Sayed *et al.*, 2015). Thus, there are questions regarding the reliability and practicality of the method in predicting real taste experience, which involves stimuli's concentration and different types of food (Bartoshuk *et al.*, 2006; Webb *et al.*, 2015).

Food is complex and exists in myriads of taste and flavor. The oral sensations from the sensory attributes influence how much the food is liked and consumed, in which affects the energy density of the diet (Cox et al., 1998; Birch, 1999; Kato, 2012; Overberg *et al.*, 2012; Jayasinghe *et al.*, 2017). However, the preference for simple or complex foods may involve the interaction either between taste-taste component in simple food or taste-odor, color, texture in complex food (Keast and Breslin, 2003). The interactions result in suppression or synergy between the taste components (e.g. sweet, fatty taste) or between the sensory attributes (e.g. texture, odor, color). It is unclear how taste variations in terms of genetic perspectives influence taste perception of taste interactions in food system and translate them to human food preference and intake (Hayes and Duffy, 2007; Hayes and Duffy, 2008; Li *et al.*, 2014). Thus, further studies are required to determine the influence of taste variation on human food preference using single and mixture of food system to provide understand the potential interactions that may increase or decrease specific sensations within the food (Liang *et al.*, 2012; Zhou *et al.*, 2016; Proserpio *et al.*, 2017).

A better understanding of the role of genetic variation in taste on human taste perception and preference is necessary because the response depends on food intake behavior and linked to body weight regulation. Furthermore, the knowledge in the influence of taste receptor gene variants and PROP taster status on taste perception and food intake behavior is useful to identify the strategy to overcome the rising prevalence of obesity in the future. However, there are many issues in human feeding behavior due to several factors (e.g. metabolic condition and food properties). Hence, more studies are needed to clarify and provide better understanding regarding this matter.

1.2 Problem Statement

Genetic variations in taste receptor and PROP taster status are highlighted as the potential marker in human taste perception and link to obesity via food intake (Garcia-Bailo *et al.*, 2009; Grimm and Steinle, 2011; Chamoun *et al.*, 2016). However, it is unclear how variation in taste receptor affects taste perception of different types of food (e.g. simple food vs. complex food), particularly for sweet-fatty food. In fact, little is known on how the taste genetic (e.g. taste receptor polymorphism) and long-term metabolic effect (e.g. obesity) are involved in human taste perception and preference. There are gaps in the current knowledge of the use of taste genetic as valuable marker for human food consumption and obesity development.

To date, out of six taste modalities, sweet and fatty taste are extensively studied due to their linkage to the current energy-dense food (high in sugar and fat) consumption pattern and weight gain worldwide, which becomes the focus of this research. Earlier studies employed the conventional method to measure taste sensitivity; e.g. taste threshold in response to genetic variation in taste perception between individuals, particularly on taste gene receptor variants. However, taste threshold is a poor predictor of suprathreshold response because low level of taste stimulus does not represent the real taste experience. In addition, food does not always have singular taste (simple system), most of them are comprised of a combination of tastes, flavors or sensory characteristics (complex system), which contribute to either suppression or synergy interactions in food. Therefore, the investigation on the genetic variation in taste receptor at suprathreshold concentration in food system can provide better understanding of how genetic variations in taste receptor plays a role in determining human taste perception and how it is related to food consumption and obesity occurrence.

Meanwhile, some studies show that obesity reduces taste sensitivity among individuals due to the habitual sweet or fatty food intake. The reduction in taste signaling cascade from the taste receptor to brain is due to the habitual intake (Newman *et al.*, 2013). However, the effects vary between the obese subjects, which imply there are other 'variation factors' that drive the taste sensitivity and perception among obese individuals. In addition, the factors can be responsible for the variations in food intake and preferences between humans (including lean individuals), which influence body weight regulation.

There is evidence that variations in taste gene receptors play a role in taste variability and food intake among individuals. Candidate polymorphism study on taste receptor genes involving PROP taster status can serve as potential marker in explaining any potential association. However, the difference in the effect of genetic variation between obese and non-obese due to their metabolic regulation is unknown. Furthermore, genetic variation also varies in the population, most studies done before on this matter are only limited to Caucasian and African populations. Currently, there are no data on the association between genetic variation on taste with taste perception and food intake in Asian population, especially Malaysia. Therefore, more studies are needed to develop better understanding of taste receptor polymorphisms, taste perception and food intake measures in a population such as Malaysia. With the use of obese (treatment) and non-obese (control) samples to compare their taste receptor polymorphisms, taste perception and food intake measures, a better understanding of how taste receptor gene variation and PROP taster status are linked to food intake and weight gain or management can be obtained.

1.3 Research Hypothesis

The hypotheses in this study are as follows: –

1. Sociodemographic characteristic are comparable between the obese and non-obese subjects
2. Obese subjects have significantly lower sweet and fatty taste sensitivity as compared to lean subjects;
3. PROP taster status and genetic variation have significant influence on sweet and fatty taste perception of the obese and non-obese Malay subjects;
4. PROP taster status and genetic variation have significant influence on binary combination of sweet-fatty taste perception of the obese and non-obese Malay subjects;
5. PROP taster status significantly affect the sweet and fatty food intake pattern of the obese and lean subjects.

1.4 Objectives

The main objective of this research is to develop better understanding of the effect of genetic variation in taste and PROP taster status on sweet and fatty taste perception and food intake among the obese and non-obese subjects. Therefore, the specific objectives of this study are: -

1. To determine and compare the sociodemographic characteristics and taste perception differences between obese and non-obese Malay subjects
2. To determine the effect of genetic variation in taste on sweet and fatty taste perception of obese and non-obese Malay subjects;
3. To examine the effect of genetic variation in taste on binary combination of sweet-fatty taste perception of obese and non-obese Malay subjects;
4. To measure the influence of PROP taster status on dietary intake and habitual consumption between obese and non-obese Malay subjects

1.5 Conceptual Framework

Figure 1.1 shows the overall study concept. Individuals' body mass index is reflected by the variation in taste receptor gene and PROP taster status. In addition, sociodemographic factors are also associated with BMI status. Obese individuals have lower taste sensitivity and prefer higher taste in products. However, the variations in taste receptor gene and/or PROP taster status between the individuals (obese vs. non-obese) may trigger different sensitivity and perception between the groups, thus leads to different taste perception and preferences for food products. On the other hand, the effect varies based on food system (single vs. binary). The association between those variables is consistent in simple food system as compared to the binary food system. The association between any variables (variations in taste receptor gene and/or PROP taster status and/or BMI status) plays a role in individuals' habitual food intake and dietary intake.

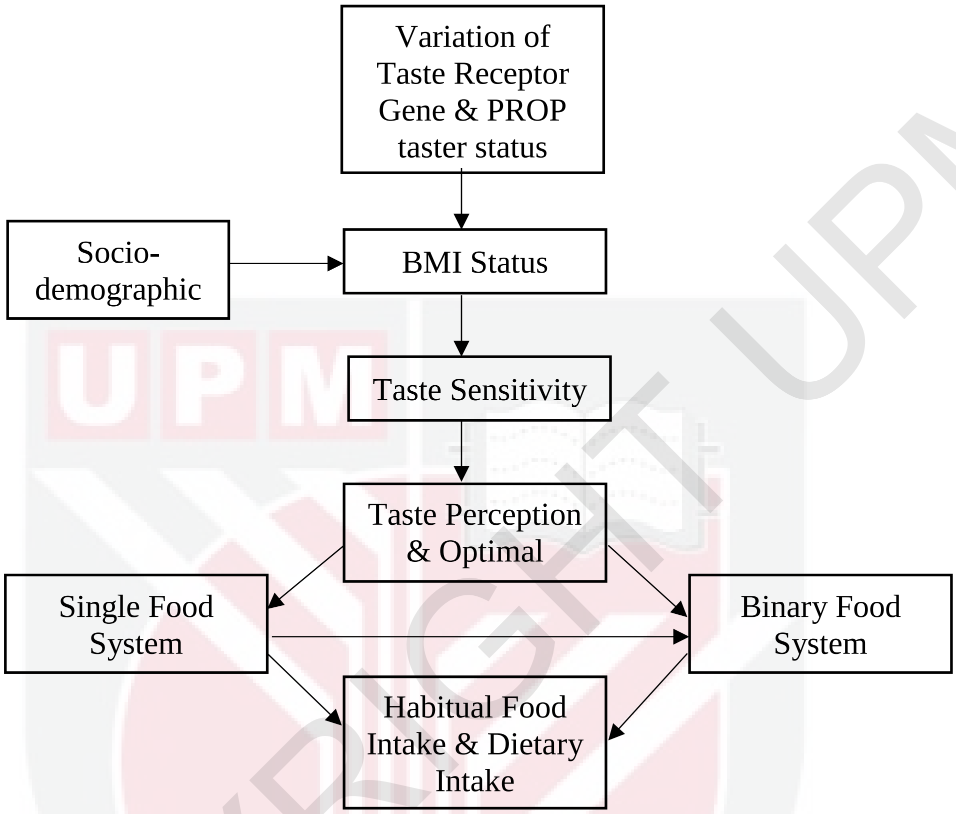

Figure 1.1 : Conceptual framework of the study

1.6 Scope of Study

This study aims to determine to what extent the genetic variation in taste receptor and PROP taster status determines sweet and/or fatty taste perception and food consumption between the Malay obese and non-obese subjects. At first, the screening of subjects was conducted to obtain obese (BMI >30) and non-obese subjects (BMI ranged from 18 to 25) via a questionnaire set. Individuals who meet the inclusion requirement were invited to participate in this study. Genotyping analysis was carried out to determine the subjects' genotype for several taste receptor gene polymorphisms. This included five variants from two sweet taste receptor genes (rs35874116, rs9701796, and rs12033832–TAS1R2 gene; rs307355, rs35744813–TAS1R3), three variants from one fatty taste receptor gene (rs1761667, rs1527483, and rs1049673–CD36) and one variant from bitter taste receptor gene (rs713598–TAS2R38). Meanwhile, PROP disc intensity rating was used to determine the subjects' PROP taster status.

The subjects' taste response was assessed via sensory evaluation. In the first phase, subjects were asked to rate the taste intensity of blank solution (sweetness – sucrose solution; linoleic acid solution - oiliness) and food samples (sweetness – rose-flavored pudding; creaminess – 'bubur chacha'), as well as hedonic rating of food samples at 5 concentrations of the respective taste stimuli. The effect of gene polymorphisms and PROP taster status toward subjects' taste response was analyzed using repeated Analysis of Variance (ANOVA) measure.

Gene polymorphisms including PROP taster status that are associated with taste response in the first phase was further analyzed for their effect of sweet-fatty mixture taste response (binary taste) in the phase two. Subjects reported the sweetness, creaminess and hedonic rating of 4x4 factorial design of sweet-fatty mixtures ('bubur chacha'), which are varied in terms of levels of added sugar (5%-20% w/v) and fat (32%-65% v/v). Again, the repeated ANOVA measure was used to evaluate the effect of gene polymorphism and PROP taster status on taste response of sweet-fatty mixture. In addition, response surface modelling (RSM) was used to identify the levels of sugar and fat for maximal liking.

In the final phase, subjects recorded the food they consumed for 3 days (2 weekdays, 1 weekend) and completed 2 sets of questionnaires (sweet food and fatty food). Macronutrient and total sugar intake were analyzed from 3 days food intake and the total intake (serving size) for each group were analyzed from FFQ. At this stage, only gene polymorphisms or PROP taster status that are associated with taste responses in the phase 1 and phase 2 were analyzed to further investigate their effect on the habitual food intake and dietary intake among the subjects. Figure 1.2 shows the operational framework of this study.

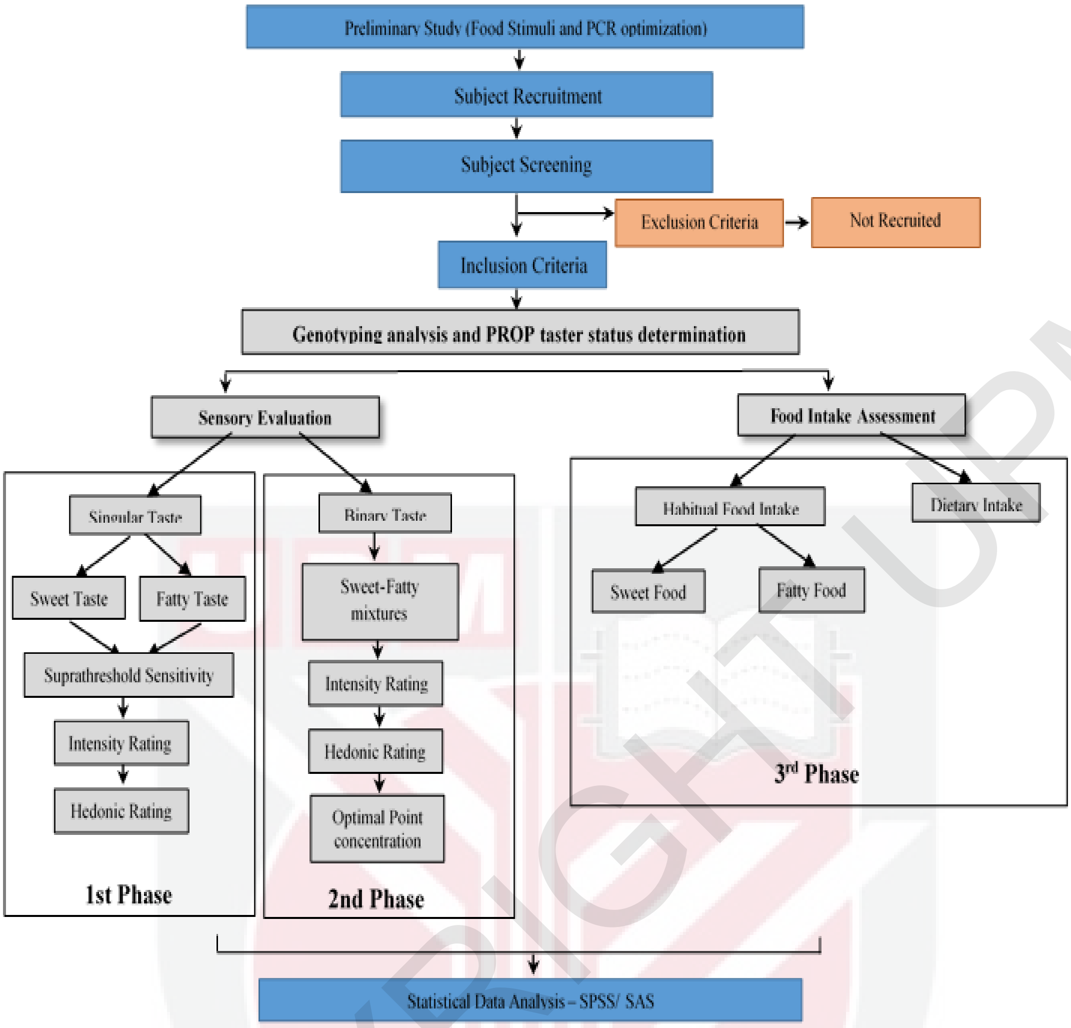

Figure 1.2 : Operational framework of study

1.7 Significance of the Study

In this research, the influence of genetic variations in taste (including PROP taster status) on sweet or/and fatty taste and their association with human consumption were obtained. A better insight on genetic variation, particularly the taste receptor gene variants, their interaction and the influence of the human sweet or/and fatty taste perception; either of the singular or binary taste food system can be discovered. In addition, the association between the genetic variants and individual food consumption was studied to have a better understanding of the overall relationship between genetic variation and eating behavior. The findings from this study can provide insight for health institutions to tailor a better obesity prevention mechanism and develop personalized nutrition products by food industries for the Malaysian population. This can be done by identifying specific groups or individuals who are at risk of unhealthy diet with high fatty food consumption based on their genetic background and taste responses.

REFERENCES

Abdallah, L., Chabert, M., Le Roux, B., and Louis-Sylvestre, J. (1998). Is pleasantness of biscuits and cakes related to their actual or to their perceived sugar and fat contents?. *Appetite*, *30*(3), 309-324.

Abumrad, N. A. (2005). CD36 may determine our desire for dietary fats. *The Journal Of Clinical Investigation*, *115*(11), 2965-2967.

Adler, E., Hoon, M. A., Mueller, K. L., Chandrashekar, J., Ryba, N. J., and Zuker, C. S. (2000). A novel family of mammalian taste receptors. *Cell*, *100*(6), 693-702.

Ahijevych, K. L., & Barbarossa, I. T. (2017). *Factors Influencing the Phenotypic Characterization of the Oral Marker , PROP*. 1–15.

Akhtar, M., Murray, B. S., & Dickinson, E. (2006). Perception of creaminess of model oil-in-water dairy emulsions: Influence of the shear-thinning nature of a viscosity-controlling hydrocolloid. *Food Hydrocolloids*, *20*(6), 839–847.

Amrein, H., and Bray, S. (2003). Bitter-sweet solution in taste transduction. *Cell*, *112*(3), 283-284.

Anderson, G. H. (1995). Sugars, sweetness, and food intake. *The American Journal of Clinical Nutrition*, *62*(1), 195S-201S.

Anliker J.A., Bartoshuk L., Ferris A.M. and Hooks L.D. (1991). Children's food preferences and genetic sensitivity to the bitter taste of 6-n-propylthiouracil (prop). *The American Journal of Clinical Nutrition* 54,316–320.

Antmann, G., Ares, G., Salvador, A., Varela, P., & Fiszman, S. M. (2011). Exploring and explaining creaminess perception: Consumers' underlying concepts. *Journal of Sensory Studies*, *26*(1), 40–47.

Asano, M., Hong, G., Matsuyama, Y., Wang, W., Izumi, S., Izumi, M., Toda, T. and Kudo, T. A. (2016). Association of oral fat sensitivity with body mass index, taste preference, and eating habits in healthy Japanese young adults. *The Tohoku Journal of Experimental Medicine*, *238*(2), 93-103.

Assadi-Porter, F. M., Maillet, E. L., Radek, J. T., Quijada, J., Markley, J. L., and Max, M. (2010). Key amino acid residues involved in multi-point binding interactions between brazzein, a sweet protein, and the T1R2–T1R3 human sweet receptor. *Journal Of Molecular Biology*, *398*(4), 584-599.

Atzingen, V., and Campos, M. C. B. (2012). 6-n-propyltiouracil (PROP) taster status in Brazilian adults. *Food Science and Technology*, *32*(4), 673-678.

Avena, N. M., Rada, P., & Hoebel, B. G. (2009). Sugar and fat bingeing have notable differences in addictive-like behavior. *The Journal of Nutrition*, *139*(3), 623–628.

Azmi, M. Y., Junidah, R., Siti Mariam, a, Safiah, M. Y., Fatimah, S., Norimah, A.K., and Tahir, A. (2009). Body Mass Index (BMI) of Adults: Findings of the Malaysian Adult Nutrition Survey (MANS). *Malaysian Journal of Nutrition*, *15*(2), 97–119.

Bachmanov, A. A., Reed, D. R., Li, X., & Beauchamp, G. K. (2002). Genetics of sweet taste preferences. *Pure and Applied Chemistry*, *74*(7), 1135-1140.

Bachmanov, A. A., & Beauchamp, G. K. (2007). Taste Receptor Genes. *Annual Review of Nutrition*, *27*, 389–414.

Bajec, M. R., & Pickering, G. J. (2010). Association of thermal taste and PROP responsiveness with food liking, neophobia, body mass index, and waist circumference. *Food Quality and Preference*, *21*(6), 589–601.

Bakke, A., & Vickers, Z. (2011). Effects of bitterness, roughness, PROP taster status, and fungiform papillae density on bread acceptance. *Food Quality and Preference*, *22*(4), 317–325.

Barajas-Ramírez, J. A., Quintana-Castro, R., Oliart-Ros, R. M., and Angulo-Guerrero, O. (2016). Bitter taste perception and TAS2R38 genotype: effects on taste sensitivity, food consumption and anthropometry in Mexican adults. *Flavour and Fragrance Journal*, *31*(4), 310-318.

Barbarossa, I. T., Carta, G., Murru, E., Melis, M., Zonza, A., Vacca, C., Muroni, P. Di Marzo, V. and Banni, S. (2013). Taste sensitivity to 6-n-propylthiouracil is associated with endocannabinoid plasma levels in normal-weight individuals. *Nutrition*, *29*(3), 531-536.

Bartel, D. L., Sullivan, S. L., Lavoie, É. G., Sévigny, J., and Finger, T. E. (2006). Nucleoside triphosphate diphosphohydrolase-2 is the ecto-ATPase of type I cells in taste buds. *Journal of Comparative Neurology*, *497*(1), 1-12.

Bartoshuk, L. M. (1993). The biological basis of food perception and acceptance. *Food Quality and Preference*, *4*(1-2), 21-32.

Bartoshuk, L. M., and Beauchamp, G. K. (1994). Chemical senses. *Annual Review of Psychology*, *45*, 419–49.

Bartoshuk, L. M., Duffy, V. B., and Miller, I. . (1994). PTC / PROP Tasting : Anatomy , Psychophysics , and Sex Effects. *Physiology and Behavior*, *56*(6), 1165–1171.

Bartoshuk, L. M. (2000). Comparing sensory experiences across individuals: recent psychophysical advances illuminate genetic variation in taste perception. *Chemical Senses*, *25*(4), 447–60.

Bartoshuk, L. M., Duffy, V. B., Fast, K., Green, B. G., Prutkin, J., and Snyder, D. J. (2002). Labeled scales (e . g ., category , Likert , VAS) and invalid across-group comparisons : what we have learned from genetic variation in taste. *Food Quality and Preference*, *14*, 125–138.

Bartoshuk, L. M. (2004). Psychophysics: a journey from the laboratory to the clinic. *Appetite*, *43*(1), 15–8.

Bartoshuk, L. M., Duffy, V. B., Green, B. G., Hoffman, H. J., Ko, C. W., Lucchina, L. A., Marks, L.E., Snyder, D.J. and Weiffenbach, J. M. (2004). Valid across-group comparisons with labeled scales: The gLMS versus magnitude matching. *Physiology and Behavior*, *82*(1), 109–114.

Bartoshuk, L. M., Duffy, V. B., Hayes, J. E., Moskowitz, H. R., and Snyder, D. J. (2006). Psychophysics of sweet and fat perception in obesity: problems, solutions and new perspectives. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *361*(1471), 1137–48.

Behrens, M., Foerster, S., Staehler, F., Raguse, J.-D., & Meyerhof, W. (2007). Gustatory Expression Pattern of the Human TAS2R Bitter Receptor Gene Family Reveals a Heterogenous Population of Bitter Responsive Taste Receptor Cells. *Journal of Neuroscience*, *27*(46), 12630–12640.

Behrens, Maik, Gunn, H. C., Ramos, P. C. M., Meyerhof, W., & Wooding, S. P. (2013). Genetic, functional, and phenotypic diversity in TAS2R38-mediated bitter taste perception. *Chemical Senses*, *38*(6), 475–484.

Berkey, C. S., Rockett, H. R. H., Field, A. E., Gillman, M. W., & Colditz, G. a. (2004). Sugar-added beverages and adolescent weight change. *Obesity Research*, *12*(5), 778–788.

Besnard, P. (2016). Lipids and obesity: Also a matter of taste? *Reviews in Endocrine and Metabolic Disorders*, 1–12.

Birch, L. L. (1999). Development of food preferences. *Annual Review of Nutrition*, *19*, 41–62.

Black, A. E. (2000). Critical evaluation of energy intake using the Goldberg cut-off for energy intake: basal metabolic rate. A practical guide to its calculation, use and limitations. *International Journal of Obesity*, *24*(9), 1119.

Bolhuis, D. P., Costanzo, A., & Keast, R. S. J. (2018). Preference and perception of fat in salty and sweet foods. *Food Quality and Preference*, *64*(September 2017), 131–137.

Borazon, E. Q., Villarino, B. J., Magbuhat, R. M. T., & Sabandal, M. L. (2012). Relationship of PROP (6-n-propylthiouracil) taster status with body mass index, food preferences, and consumption of Filipino adolescents. *Food Research International*, *47*(2), 229–235.

Bouchard, C., & Ordovas, J. M. (2012). Fundamentals of nutrigenetics and nutrigenomics. In *Progress in Molecular Biology and Translational Science* (1st ed., Vol. 108).

Bouhlal, S., Issanchou, S., and Nicklaus, S. (2011). The impact of salt, fat and sugar levels on toddler food intake. *British Journal of Nutrition*, *105*(4), 645-653.

Bouthoorn, S. H., van Lenthe, F. J., Kiefte-de Jong, J. C., Taal, H. R., Wijtzes, a I., Hofman, A., Jaddoe, V.W.V., Glymour, M.M., Rivadeneira, F., and Raat, H. (2013). Genetic taste blindness to bitter and body composition in childhood: a Mendelian randomization design. *International Journal of Obesity*, *38*(7), 1005-1010.

Bufe B, Breslin PA, Kuhn C, Reed DR, Tharp CD, Slack JP, Kim UK, Drayna D, Meyerhof W. (2005). The molecular basis of individual differences in phenylthiocarbamide and propylthiouracil bitterness perception. *Current Biology*. 15:322–327

Bray, G., Paeratakul, S., and Popkin, B. (2004). Dietary fat and obesity: a review of animal, clinical and epidemiological studies. *Physiology and Behavior*. *83*(4), 549-555

Breen, F. M., Plomin, R., and Wardle, J. (2006). Heritability of food preferences in young children. *Physiology and Behavior*, *88*(4-5), 443-447.

Brown, L., & van der Ouderaa, F. (2007). Nutritional genomics: food industry applications from farm to fork. *British Journal of Nutrition*, *97*(6), 1027–1035.

Calvino, A. M., GArcia-Medina, M. R., & Cometto-Muniz, J. E. (1990). Interactions in caffeine—sucrose and coffee—sucrose mixtures: evidence of taste and flavor suppression. *Chemical Senses*, *15*, 505–519.

Cardello, A. V. (1996). The role of the human senses in food acceptance. In *Food choice, acceptance and consumption* (pp. 1-82). Springer, Boston, MA.

Cardello, A., Lawless, H. T., and Schutz, H. G. (2008). Effects of extreme anchors and interior label spacing on labeled affective magnitude scales. *Food Quality and Preference*, *19*(5), 473-480.

Carta, G., Melis, M., Stefano, P., Pintus, P., Piras, C. A., Muredda, L., Demurtas, D., Di Marzo, V. and Barbarossa I.T. (2017). Participants with Normal Weight or with Obesity Show Different Relationships of 6-n-Propylthiouracil (PROP) Taster Status with BMI and Plasma Endocannabinoids. *Scientific Reports*, *7*(1), 1361

Cartoni, C., Yasumatsu, K., Ohkuri, T., Shigemura, N., Yoshida, R., Godinot, N., le Coutre, J., Ninomiya, Y. and Damak, S. (2010). Taste preference for fatty acids is mediated by GPR40 and GPR120. *Journal of Neuroscience*, *30*(25), 8376-8382.

Chalé-Rush, A., Burgess, J. R., and Mattes, R. D. (2007). Evidence for human orosensory (taste?) Sensitivity to free fatty acids. *Chemical Senses*, *32*(5), 423–431.

Chamoun, E., Mutch, D. M., Allen-Vercoe, E., Buchholz, A. C., Duncan, A. M., Spriet, L. L., Haines, and Ma, D.W.L. (2018). A review of the associations between single nucleotide polymorphisms in taste receptors, eating behaviors, and health. *Critical Reviews In Food Science and Nutrition*, *58*(2), 194-207.

Chandrashekar, J., Mueller, K. L., Hoon, M. A., Adler, E., Feng, L., Guo, W., ... and Ryba, N. J. (2000). T2Rs function as bitter taste receptors. *Cell*, *100*(6), 703-711.

Chandrashekar, J., Hoon, M. a, Ryba, N. J. P., & Zuker, C. S. (2006). The receptors and cells for mammalian taste. *Nature*, *444*(7117), 288–294.

Chang, W., Chung, J., Kim, Y., Chung, S., & Kho, H. (2006). The relationship between phenylthiocarbamide (PTC) and 6- n -propylthiouracil (PROP) taster status and taste thresholds for sucrose and quinine. *Archives of Oral Biology*, *51*, 427–432.

Chaudhari, N., and Kinnamon, S. C. (2001). Molecular basis of the sweet tooth?. *The Lancet*, *358*(9299), 2101-2102.

Chaudhari, N., and Roper, S. D. (2010). The cell biology of taste. *The Journal Of Cell Biology*, *190*(3), 285-296.

Chen, S., Bobe, G., Zimmerman, S., Hammond, E. G., Luhman, C. M., Boylston, T. D., Freeman, A.E. and Beitz, D. C. (2004). Physical and sensory properties of dairy products from cows with various milk fatty acid compositions. *Journal of Agricultural and Food Chemistry*, *52*(11), 3422–3428.

Chen, J., & Eaton, L. (2012). Multimodal mechanisms of food creaminess sensation. *Food and Function*, *3*(12), 1265–1270.

Chevrot, M., Passilly-Degrace, P., Ancel, D., Bernard, A., Enderli, G., Gomes, M., … Besnard, P. (2014). Obesity interferes with the orosensory detection of long-chain fatty acids in humans. *American Journal of Clinical Nutrition*, *99*(5), 975–983.

Chew, W. F., Masyita, M., Leong, P. P., Boo, N. Y., Zin, T., Choo, K. B., & Yap, S. F. (2014). Prevalence of obesity and its associated risk factors among Chinese adults in a Malaysian suburban village. *Singapore Medical Journal*, *55*(2), 84–91.

Choi, S. E. (2014). Racial Differences between African Americans and Asian Americans in the Effect of 6-n-propylthiouracil Taste Intensity and Food Liking on Body Mass Index. *Journal of the Academy of Nutrition and Dietetics*, 1–7.

Cicerale, S., Riddell, L. J., & Keast, R. S. J. (2012). The association between perceived sweetness intensity and dietary intake in young adults. *Journal of Food Science*, *77*(1), H31-5.

Cooling, J., and Blundell, J. E. (2001). High-fat and low-fat phenotypes: habitual eating of high-and low-fat foods not related to taste preference for fat. *European Journal of Clinical Nutrition*, *55*(11), 1016.

Costanzo, A., Orellana, L., Nowson, C., Duesing, K., and Keast, R. (2017). Fat taste sensitivity is associated with short-term and habitual fat intake. *Nutrients*, *9*(7), 781.

Cox, D. N., Van Galen, M., Hedderley, D., Perry, L., Moore, P. B., and Mela, D. J. (1998). Sensory and hedonic judgments of common foods by lean consumers and consumers with obesity. *Obesity Research*, *6*(6), 438-447.

Cox, D. N., Hendrie, G. A., and Carty, D. (2015). Sensitivity, hedonics and preferences for basic tastes and fat amongst adults and children of differing weight status: A comprehensive review. *Food Quality and Preference*, *41*, 112–120.

Cui, M., Jiang, P., Maillet, E., Max, M., Margolskee, R. F., and Osman, R. (2006). The heterodimeric sweet taste receptor has multiple potential ligand binding sites. *Current Pharmaceutical Design*, *12*(35), 4591-4600.

Cygankiewicz, A. I., Maslowska, A., and Krajewska, W. M. (2014). Molecular basis of taste sense: involvement of GPCR receptors. *Critical Reviews in Food Science and Nutrition*, *54*(6), 771-780.

Daoudi, H., Plesník, J., Sayed, A., Šerý, O., Rouabah, A., Rouabah, L., & Khan, N. A. (2015). Oral Fat Sensing and CD36 Gene Polymorphism in Algerian Lean and Obese Teenagers. *Nutrients*, *7*(11), 9096–9104.

Daş, S., Durna, Y. M., & Da, T. (2015). The relationships between phenylthiocarbamide taste perception and smoking , work out habits and susceptibility to depression. *Food Science and Technology*, *3*(6), 418–424.

Dastan, S. D., Degerli, N., Dastan, T., Yildiz, F., Yildir, Y., Muhammed, Y., Athesahin, D. and Karan, T. (2015). Phenylthiocarbamide taste perception as a possible genetic association marker for nutritional habits and obesity tendency of people. *Pakistan Journal of Pharmaceutical Sciences*, *28*(3), 1141–1150.

Davis, B., and Carpenter, C. (2009). Proximity of fast-food restaurants to schools and adolescent obesity. *American Journal of Public Health*, *99*(3), 505-510.

Deglaire, A., Méjean, C., Castetbon, K., Hercberg, S., & Schlich, P. (2015). Associations between weight status and liking scores for sweet , salt and fat according to the gender in adults (The Nutrinet-Santé study). *European Journal of Clinical Nutrition*, *69*(July 2013), 40–46.

Delwiche, J. F., Buletic, Z., & Breslin, P. a. (2001). Relationship of papillae number to bitter intensity of quinine and PROP within and between individuals. *Physiology & Behavior*, *74*(3), 329–337.

Deshaware, S., and Singhal, R. (2017). Genetic variation in bitter taste receptor gene TAS2R38, PROP taster status and their association with body mass index and food preferences in Indian population. *Gene, 627*, 363-368.

Dias, A. G., Eny, K. M., Cockburn, M., Chiu, W., Nielsen, D. E., Duizer, L., & El-Sohemy, A. (2015). Variation in the TAS1R2 Gene, Sweet Taste Perception and Intake of Sugars. *Journal of Nutrigenetics and Nutrigenomics*, *8*(2), 81–90.

Divert, C., Chabanet, C., Schoumacker, R., Martin, C., Lange, C., Issanchou, S., & Nicklaus, S. (2017). Relation between sweet food consumption and liking for sweet taste in French children. *Food Quality and Preference*, *56*, 18–27.

Donaldson, L. F., Bennett, L., Baic, S., & Melichar, J. K. (2009). Taste and weight : is there a link ? *The American Journal of Clinical Nutrition*, *90*, 800–803.

Dotson, C. D., Babich, J., & Steinle, N. I. (2012). Genetic Predisposition and Taste Preference: Impact on Food Intake and Risk of Chronic Disease. *Current Nutrition Reports*, *1*(3), 175–183.

Dotson, C. D., Shaw, H. L., Mitchell, B. D., Munger, S. D., & Steinle, N. I. (2010). Variation in the gene TAS2R38 is associated with the eating behavior disinhibition in Old Order Amish women. *Appetite*, *54*(1), 93–99.

Doty, R. L., Chen, J. H., and Overend, J. (2017). Taste quality confusions: influences of age, smoking, PTC taster status, and other subject characteristics. *Perception*, *46*(3-4), 257-267.

Drayna, D. (2005). Human taste genetics. *Annual Review of Genomics and Human Genetics*, *6*, 217–35. Drewnowski, A., and Greenwood, M. R. (1983). Cream and sugar: human preferences for high-fat foods. *Physiology and Behavior*, *30*(4), 629–633.

Drewnowski, A., Brunzell, J. D., Sande, K., Iverius, P. H., and Greenwood, M. R. C. (1985). Sweet tooth reconsidered: Taste responsiveness in human obesity. *Physiology and Behavior*, *35*(4), 617–622.

Drewnowski, A. (1989). Sensory preferences for fat and sugar in adolescence and adult life. *Annals of the New York Academy of Sciences*, *561*, 243–250.

Drewnowski, A., Eileen, E., Lipsky, C., and Stellar, E. (1989). Sugar and Fat : Sensory and Hedonic Evaluation of Liquid and Solid Foods, *Physiology and Behavior*,*45*(16), 177–183.

Drewnowski, A., and Schwartz, M. (1990). Invisible fats: Sensory assessment of sugar/fat mixtures. *Appetite*, *14*(3), 203–217

Drewnowski, A., Ellen, J. R., and Kurth, L. C. (1991). Taste preferences in human obesity : environmental and familial factors. *The American Journal of Clinical Nutrition*, *54*, 635–541.

Drewnowski, A., Kurth, C., Holden-Wiltse, J., and Saari, J. (1992). Food preferences in human obesity: carbohydrates versus fats. *Appetite*, *18*(3), 207-221.

Drewnowski, A. (1997a). Taste preference and food intake. *Annual Review of Nutrition*, *17*, 237–253.

Drewnowski, A., Henderson, S. A., Shore, A. B., and Barratt-Fornell, A. (1997b). Nontasters, tasters, and supertasters of 6-n-propylthiouracil (PROP) and hedonic response to sweet. *Physiology and Behavior*, *62*(3), 649–655.

Drewnowski, A., Ahlstrom Henderson, S., and Barratt-Fornell, A. (1998a). Genetic sensitivity to 6-n-propylthiouracil and sensory responses to sugar and fat mixtures. *Physiology and Behavior*, *63*(5), 771–777.

Drewnowski, A., Henderson, S. A., Shore, A. B., and Barratt-Fornell, A. (1998b). Sensory responses to 6-n-propylthiouracil (PROP) or sucrose solutions and food preferences in young women. *Annals of the New York Academy of Sciences*, *855*, 797–801.

Drewnowski, A., Henderson, S. A., Levine, A., and Hann, C. (1999). Taste and food preferences as predictors of dietary practices in young women. *Public Health Nutrition*, *2*(4), 513–519.

Drewnowski, a, Kristal, a, and Cohen, J. (2001a). Genetic taste responses to 6-n-propylthiouracil among adults: a screening tool for epidemiological studies. *Chemical Senses*, *26*(5), 483–9.

Drewnowski, A., Henderson, S. A., and Barratt-Fornell, A. (2001). Genetic taste markers and food preferences. *Drug Metabolism and Disposition*, *29*(4), 535-538.

Drewnowski, A. (2007a). The real contribution of added sugars and fats to obesity. *Epidemiologic Reviews*, *29*(1), 160–171.

Drewnowski, A., Henderson, S. a, and Cockroft, J. E. (2007b). Genetic sensitivity to 6-n-propylthiouracil has no influence on dietary patterns, body mass indexes, or plasma lipid profiles of women. *Journal of the American Dietetic Association*, *107*(8), 1340–8.

Duffy, V. B., and Bartoshuk, L. M. (2000). Food acceptance and genetic variation in taste. *Journal of the American Dietetic Association*, *100*(6), 647-655.

Duffy, V. B. (2004a). Associations between oral sensation, dietary behaviors and risk of cardiovascular disease (CVD). *Appetite*, *43*(1), 5-9.

Duffy, V. B., Peterson, J. M., and Bartoshuk, L. M. (2004b). Associations between taste genetics, oral sensation and alcohol intake. *Physiology and Behavior*, *82*(2–3), 435–445.

Duffy, V. B. (2007). Variation in oral sensation: implications for diet and health. *Current Opinion in Gastroenterology*, *23*(2), 171-177.

Duffy, V. B., Hayes, J. E., Sullivan, B. S., and Faghri, P. (2009). Surveying food and beverage liking: a tool for epidemiological studies to connect chemosensation with health outcomes. *Annals of the New York Academy of Sciences*, *1170*, 558–68.

Egger, G., and Swinburn, B. (1997). An" ecological" approach to the obesity pandemic. *BMJ: British Medical Journal*, *315*(7106), 477.

Elfhag, K., & Erlanson-Albertsson, C. (2006). Sweet and fat taste preference in obesity have different associations with personality and eating behavior. *Physiology & Behavior*, *88*(1–2), 61–66.

Eng, J. Y., and Moy, F. M. (2011). Validation of a food frequency questionnaire to assess dietary cholesterol, total fat and different types of fat intakes among Malay adults. *Asia Pacific Journal of clinical nutrition*, *20*(4), 639-645.

Eny, K. M., Wolever, T. M. S., Corey, P. N., & El-sohemy, A. (2010). Genetic variation in TAS1R2 (Ile191Val) is associated with consumption of sugars in overweight and obese individuals in 2. *The American Journal of Clinical Nutrition*, *2*, 1501–1510.

Essick, G. K., Chopra, A., Guest, S., and McGlone, F. (2003). Lingual tactile acuity, taste perception, and the density and diameter of fungiform papillae in female subjects. *Physiology and Behavior*, 80(2-3), 289–302.

Etemad, A., Ramachandran, V., Pishva, S., Heidari, F., Aziz, A., Yusof, A. & Ismail, P. (2013). Analysis of Gln223Agr polymorphism of Leptin Receptor Gene in type II diabetic mellitus subjects among Malaysians. *International journal of molecular sciences*, *14*(9), 19230-19244.

Ettinger, L., Duizer, L., & Caldwell, T. (2012). Body fat, sweetness sensitivity, and preference: Determining the relationship. *Canadian Journal of Dietetic Practice and Research*, *73*(1), 45–48.

Faam, B., & Hedayati, M. (2012). Association of CD36 Gene Variants and Metabolic Syndromes in Iranians. *Genetic Testing and Molecular Biomarkers*, *16*(4), 234–238.

Falciglia, G. A., and Norton, P. A. (1994). Evidence for a genetic influence on preference for some foods. *Journal of the American Dietetic Association*, *94*(2), 154-158.

Faul, F., Erdfelder, E., Lang, A. G., and Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175-191.

Feeney, E., O'Brien, S., Scannel, a., Markey, a., and Gibney, E. R. (2010). Associations between 6- n-propylthiouracil (PROP) bitterness, macronutrient intake and variations in bitter-taste receptor gene TAS2R38. *Proceedings of the Nutrition Society, 69*(OCE1), E50.

Feeney, E. (2011a). The impact of bitter perception and genotypic variation of TAS2R38 on food choice. *Nutrition Bulletin*, *36*(1), 20-33.

Feeney, E., O'Brien, S., Scannell, a, Markey, a, and Gibney, E. R. (2011b). Genetic variation in taste perception: does it have a role in healthy eating? *The Proceedings of the Nutrition Society*, *70*(1), 135–43.

Feeney, E. L., O'Brien, S. a., Scannell, A. G. M., Markey, A., and Gibney, E. R. (2014). Genetic and environmental influences on liking and reported intakes of vegetables in Irish children. *Food Quality and Preference*, *32*, 253–263.

Felsted, J., O'Malley, S., Nachtigal, D., Gant, P., and Small, D. (2007). Relationships between BMI, perceived pleasantness and ad lib consumption of food in smokers and non-smokers. In *List of Abstracts from the Twenty-Ninth Annual Meeting of the Association for Chemoreception Sciences* (p. A17).

Finger, T. E. (2005). Cell types and lineages in taste buds. *Chemical Senses*, *30*(suppl_1), i54-i55.

Finkelstein, E. A., Trogdon, J. G., Cohen, J. W., and Dietz, W. (2009). Annual medical spending attributable to obesity: payer-and service-specific estimates. *Health Affairs*, *28*(5), w822-w831.

Foote, J. A., Murphy, S. P., Wilkens, L. R., Basiotis, P. P., and Carlson, A. (2004). Dietary variety increases the probability of nutrient adequacy among adults. *The Journal of nutrition*, *134*(7), 1779-1785.

Frank, R. A., Ducheny, K., & Mize, S. J. S. (1989). Strawberry odor, but not red color, enhances the sweetness of sucrose solutions. *Chemical Senses*, *14*(3), 371–377.

Frijters, J. E. R., & Rasmussen-Conrad, E. L. (1982). Sensory Discrimination, Intensity Perception, and Affective Judgment of Sucrose-Sweetness in the Overweight. *The Journal of General Psychology*, *107*(2), 233–247.

Fukuwatari, T., Kawada, T., Tsuruta, M., Hiraoka, T., Iwanaga, T., Sugimoto, E., and Fushiki, T. (1997). Expression of the putative membrane fatty acid transporter (FAT) in taste buds of the circumvallate papillae in rats. *FEBS letters*, *414*(2), 461-464.

Fukuwatari, T., Shibata, K., Iguchi, K., Saeki, T., Iwata, A., Tani, K. and Fushiki, T. (2003). Role of gustation in the recognition of oleate and triolein in anosmic rats. *Physiology and Behavior*, *78*(4-5), 579-583

Fushan, A. A., Simons, C. T., Slack, J. P., Manichaikul, A., & Drayna, D. (2009). Allelic Polymorphism within the TAS1R3 Promoter Is Associated with Human Taste Sensitivity to Sucrose. *Current Biology*, *19*(15), 1288–1293.

Fushan, A. a, Simons, C. T., Slack, J. P., & Drayna, D. (2010). Association between common variation in genes encoding sweet taste signaling components and human sucrose perception. *Chemical Senses*, *35*(7), 579–592.

Gaillard, D., Laugerette, F., Darcel, N., El-Yassimi, A., Passilly-Degrace, P., Hichami, A., Khan, N.A., Montmayeur, J. and Besnard, P. (2008). The gustatory pathway is involved in CD36-mediated orosensory perception of long-chain fatty acids in the mouse. *The FASEB Journal*, *22*(5), 1458-1468.

Galindo-Cuspinera, V., Waeber, T., Antille, N., Hartmann, C., Stead, N., & Martin, N. (2009). Reliability of Threshold and Suprathreshold Methods for Taste Phenotyping: Characterization with PROP and Sodium Chloride. *Chemosensory Perception*, *2*(4), 214–228.

Galindo, M. M., Voigt, N., Stein, J., van Lengerich, J., Raguse, J. D., Hofmann, T., Meyrhof, W. and Behrens, M. (2011). G protein–coupled receptors in human fat taste perception. *Chemical Senses*, *37*(2), 123-139.

Garba, J. A., Rampal, L., Hejar, A. R., & Salmiah, M. S. (2014). Major dietary patterns and their associations with socio-demographic characteristics and obesity among adolescents in Petaling District, Malaysia. *Malaysian Journal of Medicine and Health Sciences*, *10*(1), 13–21.

Garcia-Bailo, B., Toguri, C., Eny, K. M., & El-Sohemy, A. (2009). Genetic variation in taste and its influence on food selection. *Omics : A Journal of Integrative Biology*, *13*, 69–80.

Garneau, N. L., Nuessle, T. M., Sloan, M. M., Santorico, S. A., Coughlin, B. C., & Hayes, J. E. (2014). Crowdsourcing taste research: genetic and phenotypic predictors of bitter taste perception as a model. *Frontiers in Integrative Neuroscience*, *8*(May), 33.

Gay, C., and Mead, R. (1992). A statistical appraisal of the problem of sensory measurement. *Journal of Sensory Studies*, *7*(3), 205-228.

Gent, J. F., & Bartoshuk, L. M. (1983). Sweetness of sucrose, neohesperidin dihydrochalcone, and saccharin is related to genetic ability to taste the bitter substance 6- n -propylthiouracil. *Chemical Senses*, *7*(3–4), 265–272.

German, J. B., Zivkovic, A. M., Dallas, D. C., & Smilowitz, J. T. (2011). Nutrigenomics and personalized diets: What will they mean for food? *Annual Review of Food Science and Technology*, *2*, 97–123.

Gilbertson, T. A., Fontenot, D. T., Liu, L. I. D. O. N. G., Zhang, H. U. A. I., and Monroe, W. T. (1997). Fatty acid modulation of K+ channels in taste receptor cells: gustatory cues for dietary fat. *American Journal of Physiology-Cell Physiology*, *272*(4), C1203-C1210.

Gilbertson, T. A., Liu, L., York, D. A., and Bray, G. A. (1998). Dietary fat preferences are inversely correlated with peripheral gustatory fatty acid Sensitivitya. *Annals of the New York Academy of Sciences*, *855*(1), 165-168.

Gilbertson, T. A., Liu, L., Kim, I., Burks, C. A., and Hansen, D. R. (2005). Fatty acid responses in taste cells from obesity-prone and-resistant rats. *Physiology and Behavior*, *86*(5), 681-690.

Gilbertson, T. A., and Khan, N. A. (2014). Cell signaling mechanisms of oro-gustatory detection of dietary fat: advances and challenges. *Progress in Lipid research*, *53*, 82-92.

Gillis, L. J., Kennedy, L. C., Gillis, A. M., and Bar-Or, O. (2002). Relationship between juvenile obesity, dietary energy and fat intake and physical activity. *International Journal of Obesity*, *26*(4), 458.

Glendinning, J. I., Breinager, L., Kyrillou, E., Lacuna, K., Rocha, R., and Sclafani, A. (2010). Differential effects of sucrose and fructose on dietary obesity in four mouse strains. *Physiology and Behavior*, *101*(3), 331–43

Go, Y., Satta, Y., Takenaka, O., & Takahata, N. (2005). Lineage-specific loss of function of bitter taste receptor genes in humans and nonhuman primates. *Genetics*, *170*(1), 313–326.

Goldberg, G. R., Black, A. E., Jebb, S. A., Cole, T. J., Murgatroyd, P. R., Coward, W. A., & Prentice, A. M. (1991). Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. *European Journal of Clinical Nutrition*, *45*(12), 569-581.

Goldstein, G. L., Daun, H., and Tepper, B. J. (2005). Adiposity in middle-aged women is associated with genetic taste blindness to 6-n-propylthiouracil. *Obesity Research*, *13*(6), 1017-1023.

Green, B. G., Shaffer, G. S., and Gilmore, M. M. (1993). Derivation and evaluation of a semantic scale of oral sensation magnitude with apparent ratio properties. *Chemical Senses*, *18*(6), 683-702.

Green, B. G., Dalton, P., Cowart, B., Shaffer, G., Rankin, K., and Higgins, J. (1996). Evaluating the “labeled magnitude scale” for measuring sensations of taste and smell. *Chemical Senses*, *21*(3), 323–334.

Greenberg, D., and Smith, G. P. (1996). The controls of fat intake. *Psychosomatic Medicine*, *58*(6), 559-569.

Greene, J. L., Bratka, K. J., Drake, M. A., and Sanders, T. H. (2006). Effectiveness of category and line scales to characterize consumer perception of fruity fermented flavor in peanuts. *Journal of Sensory Studies*, *21*(2), 146-154.

Grimm, E. R., & Steinle, N. I. (2011). Genetics of eating behavior: established and emerging concepts. *Nutrition Reviews*, *69*(1), 52–60.

Guido, D., Perna, S., Carrai, M., Barale, R., Grassi, M., and Rondanelli, M. (2016). Multidimensional evaluation of endogenous and health factors affecting food preferences, taste and smell perception. *The Journal of Nutrition, Health And Aging*, *20*(10), 971-981.

Habberstad, C., Drake, I., and Sonestedt, E. (2017). Variation in the sweet Taste receptor gene and Dietary intake in a swedish Middle-aged Population. *Frontiers in Endocrinology*, *8*, 348.

Han, P., Keast, R. S. J., & Roura, E. (2017). Salivary leptin and TAS1R2/TAS1R3 polymorphisms are related to sweet taste sensitivity and carbohydrate intake from a buffet meal in healthy young adults. *British Journal of Nutrition*, 1–8.

Hansen, J. L., Reed, D. R., Wright, M. J., Martin, N. G., and Breslin, P. A. (2006). Heritability and genetic covariation of sensitivity to PROP, SOA, quinine HCl, and caffeine. *Chemical Senses*, *31*(5), 403-413.

Hardikar, S., Höchenberger, R., Villringer, A., and Ohla, K. (2017). Higher sensitivity to sweet and salty taste in obese compared to lean individuals. *Appetite*, *111*, 158-165.

Hayes, J. E., and Duffy, V. B. (2008). Oral sensory phenotype identifies level of sugar and fat required for maximal liking. *Physiology and Behavior*, *95*(1-2), 77-87.

Hayes, J. E., Allen, A. L., and Bennett, S. M. (2013). Direct comparison of the generalized visual analog scale (gVAS) and general labeled magnitude scale (gLMS). *Food Quality and Preference*, *28*(1), 36–44.

Hayes, J. E., Bartoshuk, L. M., Kidd, J. R., and Duffy, V. B. (2008). Supertasting and PROP bitterness depends on more than the TAS2R38 gene. *Chemical Senses*, *33*(3), 255–65.

Hayes, J. E., and Duffy, V. B. (2007a). Revisiting sugar-fat mixtures: Sweetness and creaminess vary with phenotypic markers of oral sensation. *Chemical Senses*, *32*(3), 225–236.

Hayes, J. E., Sullivan, B. S., and Duffy, V. B. (2010). Explaining variability in sodium intake through oral sensory phenotype , salt sensation and liking. *Physiology and Behavior*, *100*(4), 369–380.

Haznedaroğlu, E., Koldemir-Gündüz, M., Bakır-Coşkun, N., Bozkuş, H. M., Çağatay, P., Süsleyici-Duman, B., and Menteş, A. (2015). Association of sweet taste receptor gene polymorphisms with dental caries experience in school children. *Caries Research*, *49*(3), 275-281.

Health Promotion Board. Energy and Nutrient Composition of Foods. Health Promotion Board, Singapore; 2008

Heinze, J. M., Preissl, H., Fritsche, A., and Frank, S. (2015). Controversies in fat perception. *Physiology and Behavior*, *152*, 479-493.

Heinze, J. M., Costanzo, A., Baselier, I., Fritsche, A., & Lidolt, M. (2017). Oil Perception – Detection thresholds for varying fatty stimuli and inter-individual differences. *Chemical Senses*, *42*(7), 585–592.

Hetherington, M. M., Foster, R., Newman, T., Anderson, A. S., and Norton, G. (2006). Understanding variety: tasting different foods delays satiation. *Physiology and Behavior*, *87*(2), 263-271.

Hill, J. O., Peters, J. C., Catenacci, V. A., and Wyatt, H. R. (2008). International strategies to address obesity. *Obesity Reviews*, *9*, 41-47.

Hirasawa, A., Tsumaya, K., Awaji, T., Katsuma, S., Adachi, T., Yamada, M., Sugimoto, Y., Miyazaki, S. and Tsujimoto, G. (2005). Free fatty acids regulate gut incretin glucagon-like peptide-1 secretion through GPR120. *Nature Medicine*, *11*(1), 90.

Holt, S. H. A., Cobiac, L., Beaumont-Smith, N. E., Easton, K., & Best, D. J. (2000). Dietary habits and the perception and liking of sweetness among Australian and Malaysian students: A cross-cultural study. *Food Quality and Preference*, *11*(4), 299–312.

Hong, J. H., Chung, J. W., Kim, Y. K., Chung, S. C., Lee, S. W., & Kho, H. S. (2005). The relationship between PTC taster status and taste thresholds in young adults. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, *99*(6), 711–715.

Hoon, M. A., Adler, E., Lindemeier, J., Battey, J. F., Ryba, N. J., and Zuker, C. S. (1999). Putative mammalian taste receptors: a class of taste-specific GPCRs with distinct topographic selectivity. *Cell*, *96*(4), 541-551.

House, K. A., & Acree, T. E. (2002). Sensory impact of free fatty acids on the aroma of a model Cheddar cheese. *Food Quality and Preference*, *13*(7-8), 481-488.

Hu, F. B. (2002). Dietary pattern analysis: a new direction in nutritional epidemiology. *Current Opinion in Lipidology*, *13*(1), 3-9.

Ishimaru, Y. (2009). Molecular mechanisms of taste transduction in vertebrates. *Odontology*, 97(1), 1-7.

Ismail, M., Chee, S., Roslee, R., & Zawiah, H. (1998). Predictive equations for the estimation of basal metabolic rate in Malaysian adults. *Malaysian Journal of Nutrition*, *4*(1), 73–80.

Jayasinghe, S. N., Kruger, R., Walsh, D. C. I., Cao, G., Rivers, S., Richter, M., & Breier, B. H. (2017). Is sweet taste perception associated with sweet food liking and intake? *Nutrients*, *9*(7), 1–19.

Jeffery, R. W., Baxter, J., McGuire, M., and Linde, J. (2006). Are fast food restaurants an environmental risk factor for obesity?. *International Journal of Behavioral Nutrition and Physical Activity*, *3*(1), 2.

Jiang, P., Ji, Q., Liu, Z., Snyder, L. A., Benard, L. M., Margolskee, R. F., and Max, M. (2004). The cysteine-rich region of T1R3 determines responses to intensely sweet proteins. *Journal of Biological Chemistry*, *279*(43), 45068-45075.

Joseph, P. V., Reed, D. R., & Mennella, J. A. (2015). Individual Differences Among Children in Sucrose Detection Thresholds: Relationship With Age, Gender, and Bitter Taste Genotype. *Nursing Research*, 3–12.

Kalva, J. J., Sims, C. A., Puentes, L. A., Snyder, D. J., and Bartoshuk, L. M. (2014). Comparison of the hedonic general labeled magnitude scale with the hedonic 9-point scale. *Journal of Food Science*, *79*(2), S238-S245.

Kaminski, L. C., Henderson, S. A., and Drewnowski, A. (2000) Young women's food preferences and taste responsiveness to 6-n-propylthiouracil (PROP). *Physiology and Behaviour*, 68: 691–697.

Kamphuis, M. M. J. W., & Westerterp-plantenga, M. S. (2003). PROP sensitivity affects macronutrient selection. *Physiology and Behavior*, *79*(January), 167–172.

Karhunen, L. J., Lappalainen, R. I., Haffner, S. M., Valve, R. H., Tuorila, H., Miettinen, H., & Uusitupa, M. I. J. (1998). Serum leptin, food intake and preferences for sugar and fat in obese women. *International Journal of Obesity*, *22*(8), 819.

Karmous, I., Plesník, J., Khan, A. S., Šerý, O., Abid, A., Mankai, A., Aouidet, A. and Khan, N. A. (2017). Orosensory detection of bitter in fat-taster healthy and obese participants: Genetic polymorphism of CD36 and TAS2R38. *Clinical Nutrition*, 4–11.

Kato, Y. (2012). Relationship between Taste Sensitivity and Eating Style in Japanese Female University Students. *Food and Nutrition Sciences*, *03*(03), 302–309.

Keast, R. S. J., Azzopardi, K. M., Newman, L. P., and Haryono, R. Y. (2014). Impaired oral fatty acid chemoreception is associated with acute excess energy consumption. *Appetite*, *80*, 1–6.

Keast, R. S. J., and Breslin, P. A. S. (2003). An overview of binary taste-taste interactions. *Food Quality and Preference*, *14*(2), 111–124.

Keast, R. S. J., and Roper, J. (2007). A Complex Relationship among Chemical Concentration , Detection Threshold , and Suprathreshold Intensity of Bitter Compounds. *Chemical Senses*, (February), 245–253.

Keast, R. S., and Costanzo, A. (2015). Is fat the sixth taste primary? Evidence and implications. *Flavour*, *4*(1), 5.

Keller, K. L., Liang, L. C. H., Sakimura, J., May, D., Belle, C. Van, Breen, C., Driggin, E., Tepper, B.J., Lanzano, P.C., Deng, L. and Chung, W. K. (2009). Common Variants in the CD36 Gene Are Associated With Oral Fat Perception , Fat Preferences , and Obesity in African Americans. *Obesity*, *20*(5), 1066–1073.

Keller, K. L., Pietrobelli, A., Must, S., and Faith, M. S. (2002). Genetics of eating and its relation to obesity. *Current Atherosclerosis Reports*, *4*(3), 176–182.

Keller, K. L., Reid, A., MacDougall, M. C., Cassano, H., Song, J. L., Deng, L., Lanzano, P., Chung, W.K. and Kissileff, H. R. (2010). Sex Differences in the Effects of Inherited Bitter Thiourea Sensitivity on Body Weight in 4–6-Year-Old Children. *Obesity*, *18*(6), 1194-1200.

Keller, K. L., Steinmann, L., Nurse, R. J., and Tepper, B. J. (2002). Genetic taste sensitivity to 6-n-propylthiouracil influences food preference and reported intake in preschool children. *Appetite*, *38*, 3–12.

Keller, K. L., and Tepper, B. J. (2004). Inherited taste sensitivity to 6-n-propylthiouracil in diet and body weight in children. *Obesity Research*, *12*(6), 904–912.

Keskitalo, K., Tuorila, H., Spector, T. D., Cherkas, L. F., Knaapila, A., Silventoinen, K., and Perola, M. (2007). Same genetic components underlie different measures of sweet taste preference.*The American Journal of Clinical Nutrition*, *86*(6), 1663–1669.

Keskitalo, K., Tuorila, H., Spector, T. D., Cherkas, L. F., Knaapila, A., Kaprio, J., Silventoinen, K. and Perola, M. (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. *The American Journal of Clinical Nutrition*, *88*(2), 263-271.

Kim, U. K., Jorgenson, E., Coon, H., Leppert, M., Risch, N., and Drayna, D. (2003). Positional cloning of the human quantitative trait locus underlying taste sensitivity to phenylthiocarbamide. *Science*, *299*(5610), 1221-1225.

Kim, U. K., Breslin, P. A. S., Reed, D., and Drayna, D. (2004). Genetics of human taste perception. *Journal of Dental Research*, *83*(6), 448-453.

Kim, U. K., and Drayna, D. (2005). Genetics of individual differences in bitter taste perception: lessons from the PTC gene. *Clinical Genetics*, *67*(4), 275–80.

Kim, U., Wooding, S., Riaz, N., Jorde, L. B., and Drayna, D. (2006). Variation in the Human TAS1R Taste Receptor Genes, 599–611Kirkmeyer, S. V., & Tepper, B. J. (2005). Consumer reactions to creaminess and genetic sensitivity to 6-n-propylthiouracil: A multidimensional study. *Food Quality and Preference*, *16*(6), 545–556.

Kirkmeyer, S. V., and Tepper, B. J. (2003). Understanding creaminess perception of dairy products using free-choice profiling and genetic responsivity to 6-n-propylthiouracil. *Chemical Senses*, *28*(6), 527-536.

Kirkmeyer, S. V., and Tepper, B. J. (2005). Consumer reactions to creaminess and genetic sensitivity to 6-n-propylthiouracil: A multidimensional study. *Food Quality and Preference*, *16*(6), 545–556.

Koressaar, T., & Remm, M. (2007). Enhancements and modifications of primer design program Primer3. *Bioinformatics*, *23*(10), 1289-1291.

Kourouniotis, S., Keast, R. S. J., Riddell, L. J., Lacy, K., Thorpe, M. G., & Cicerale, S. (2016). The importance of taste on dietary choice, behaviour and intake in a group of young adults. *Appetite*, *103*, 1–7.

Krueger, Anna C., Galen D. Eldridge, Malinda M. Gehrke, Jennifer C. Lovejoy, Samer Koutoubi, Erica B. Oberg, Janelle M. Johnson, Kate E. Schenk, and M. A. M. (2006). Taste preferences and taste sensitivity: associations with food preferences, dietary intake and body composition. *FASEB J., 20,* A175–A175.

Laugerette, F., Passilly-degrace, P., Patris, B., Niot, I., Febbraio, M., Montmayeur, J., & Besnard, P. (2005). CD36 involvement in orosensory detection of dietary lipids , spontaneous fat preference , and digestive secretions. *The Journal of Clinical Investigation 115*(11), 3177–3184.

Lawless, H. T., and Malone, G. J. (1986). The discriminative efficiency of common scaling methods. *Journal of Sensory Studies*, 1, 85–98.

Lawless, H. T., Popper, R., and Kroll, B. J. (2010). A comparison of the labeled magnitude (LAM) scale, an 11-point category scale and the traditional 9-point hedonic scale. *Food Quality and Preference*, *21*(1), 4-12.

Lease, H., Hendrie, G. A., Poelman, A. A. M., Delahunty, C., & Cox, D. N. (2016). A Sensory-Diet database: A tool to characterise the sensory qualities of diets. *Food Quality and Preference*, *49*, 20–32.

Lee, Y. M., Prescott, J., and Kim, K. O. (2008). PROP taster status and the rejection of foods with added tastants. *Food Science and Biotechnology*, *17*(5), 1066-1073.

Li, F., Harmer, P., Cardinal, B. J., Bosworth, M., and Johnson-Shelton, D. (2009). Obesity and the built environment: does the density of neighborhood fast-food outlets matter?. *American Journal of Health Promotion*, *23*(3), 203-209.

Li, B., Hayes, J. E., & Ziegler, G. R. (2014). Interpreting consumer preferences: Physicohedonic and psychohedonic models yield different information in a coffee-flavored dairy beverage. *Food Quality and Preference*, *36*, 27–32.

Liang, L. C. H., Sakimura, J., May, D., Breen, C., Driggin, E., Tepper, B. J., … Keller, K. L. (2012). Fat discrimination: a phenotype with potential implications for studying fat intake behaviors and obesity. *Physiology and Behavior*, *105*(2), 470–475.

Lim, J. (2011). Hedonic scaling: A review of methods and theory. *Food Quality and Preference*, *22*(8), 733-747.

Lindroos, A. K., Lissner, L., Mathiassen, M. E., Karlsson, J., Sullivan, M., Bengtsson, C., & Sjöström, L. (1997). Dietary intake in relation to restrained eating, disinhibition, and hunger in obese and non-obese Swedish women. *Obesity research*, 5(3), 175-182.

Liu, L., Hansen, D. R., Kim, I., and Gilbertson, T. A. (2005). Expression and characterization of delayed rectifying K+ channels in anterior rat taste buds. *American Journal of Physiology-Cell Physiology*, *289*(4), C868-C880.

Liu, P., Shah, B. P., Croasdell, S., and Gilbertson, T. A. (2011). Transient receptor potential channel type M5 is essential for fat taste. *Journal of Neuroscience*, *31*(23), 8634-8642.

Liu, D., Archer, N., Duesing, K., Hannan, G., and Keast, R. (2016). Mechanism of fat taste perception: Association with diet and obesity. *Progress in Lipid Research*, *63*, 41–49. h

Looy, H., & Weingarten, H. P. (1991). Effects of metabolic state on sweet taste reactivity in humans depend on underlying hedonic response profile. *Chemical Senses*, *16*(2), 123–130.

Looy, H., & Weingarten, H. P. (1992). Facial expressions and genetic sensitivity to 6-n-propylthiouracil predict hedonic response to sweet. *Physiology and Behavior*, *52*(1), 75-82.

Lorenz, T. C. (2012). Polymerase chain reaction: basic protocol plus troubleshooting and optimization strategies. *JoVE (Journal of Visualized Experiments)*, (63), e3998.

Louis-Sylvestre, J., Giachetti, I., & Le Magnen, J. (1984). Sensory versus dietary factors in cafeteria-induced overweight. *Physiology and Behavior*, *32*(6), 901-905.

Low, J. Y. Q., Lacy, K. E., McBride, R., & Keast, R. S. J. (2016). The association between sweet taste function, anthropometry, and dietary intake in adults. *Nutrients*, *8*(4), 1–14.

Lucchina, L. A., Curtis, O. F., Putnam, P., Drewnowski, A., Prutkin, J. M., & Bartoshuk, L. M. (1998). Psychophysical measurement of 6-n-propylthiouracil (PROP) taste perception. *Annals of the New York Academy of Sciences*, *855*, 816–819.

Ly, a, & Drewnowski, a. (2001). PROP (6-n-Propylthiouracil) tasting and sensory responses to caffeine,sucrose, neohesperidin dihydrochalcone and chocolate. *Chemical Senses*, *26*(1), 41–47.

Ma, X., Bacci, S., Mlynarski, W., Gottardo, L., Soccio, T., Menzaghi, C. & Nesto, R. W. (2004). A common haplotype at the CD36 locus is associated with high free fatty acid levels and increased cardiovascular risk in Caucasians. *Human Molecular Genetics*, *13*(19), 2197-2205.

Macdiarmid, J. I., Vail, A., Cade, J. E., and Blundell, J. E. (1998). The sugar–fat relationship revisited: differences in consumption between men and women of varying BMI. *International Journal of Obesity*, *22*(11), 1053.

Mahar, A., & Duizer, L. M. (2007). *The Effect of Frequency of Consumption of Artificial Sweeteners*. *72*(9), 714–718.

Martin, C., Passilly-Degrace, P., Gaillard, D., Merlin, J. F., Chevrot, M., and Besnard, P. (2011). The lipid-sensor candidates CD36 and GPR120 are differentially regulated by dietary lipids in mouse taste buds: impact on spontaneous fat preference. *PLoS One*, *6*(8), e24014.

Martinez-Cordero, E., Malacara-Hernandez, J. M., & Martinez-Cordero, C. (2015). Taste perception in normal and overweight Mexican adults. *Appetite*, *89*, 192–195.

Martínez-Ruiz, N. R., López-Díaz, J. a., Wall-Medrano, A., Jiménez-Castro, J. A., & Angulo, O. (2014). Oral fat perception is related with body mass index, preference and consumption of high-fat foods. *Physiology and Behavior*, *129*, 36–42.

Matsunami, H., Montmayeur, J. P., and Buck, L. B. (2000). A family of candidate taste receptors in human and mouse. *Nature*, *404*(6778), 601.

Matsushita, Y., Mizoue, T., Takahashi, Y., Isogawa, A., Kato, M., Inoue, M., Tsugane, S. (2009). Taste preferences and body weight change in Japanese adults : the JPHC Study. *International Journal of Obesity*, *33*(10), 1191–1197.

Mattes, R. D., & Mela, D. J. (1986). Relationships between and among selected measures of sweet-taste preference and dietary intake. *Chemical Senses* , *11*(4), 523–539.

Mattes, R. D. (2001). The taste of fat elevates postprandial triacylglycerol. *Physiology and Behavior*, *74*(3), 343–348.

Mattes, R. D. (2005). Fat taste and lipid metabolism in humans. *Physiology and Behavior*, *86*(5), 691–7.

Mattes, R. D. (2009). Oral detection of short-, medium-, and long-chain free fatty acids in humans. *Chemical Senses*, *34*(2), 145–150.

Mattes, R. D. (2011). Accumulating evidence supports a taste component for free fatty acids in humans. *Physiology and Behavior*, *104*(4), 624–631.

Max, M., Shanker, Y. G., Huang, L., Rong, M., Liu, Z., Campagne, F., Weinstein, H., Damak, S. and Margolskee, R. F. (2001). Tas1r3, encoding a new candidate taste receptor, is allelic to the sweet responsiveness locus Sac. *Nature genetics*, *28*(1), 58.

Mazlan, N., Horgan, G., Whybrow, S., & Stubbs, J. (2006). Effects of increasing increments of fat- and sugar-rich snacks in the diet on energy and macronutrient intake in lean and overweight men. *The British Journal of Nutrition*, *96*(3), 596–606.

McCrory, M. A., Fuss, P. J., Hays, N. P., Vinken, A. G., Greenberg, A. S., & Roberts, S. B. (1999). Overeating in America: association between restaurant food consumption and body fatness in healthy adult men and women ages 19 to 80. *Obesity research*, *7*(6), 564-571.

Mela, J., and Sacchetti, A. (1991). Sensory preferences for fats : relationships and body composition, *The American Journal of Clinical Nutrition*, 53 (4), 908-915

Mela, D. J. (1996). Eating behaviour , food preferences and dietary intake in relation to obesity and body-weight status, *Proceedings of the Nutrition Society*, 55 (3), 803–816.

Mela, D. J. (2001). Determinants of food choice: relationships with obesity and weight control. *Obesity Research*, *9*(S11), 249S-255S.

Mela, D. J. (2006). Eating for pleasure or just wanting to eat? Reconsidering sensory hedonic responses as a driver of obesity. *Appetite*, *47*(1), 10–17.

Melis, M., Sollai, G., Muroni, P., & Crnjar, R. (2015). Associations between Orosensory Perception of Oleic Acid, the Common Single Nucleotide Polymorphisms (rs1761667 and rs1527483) in the CD36 Gene, and 6-n-Propylthiouracil (PROP) Tasting. *Nutrients*, *7*, 2068–2084.

Melo, S. V, Agnes, G., Vitolo, M. R., Mattevi, V. S., Campagnolo, P. D. B., and Almeida, S. (2017). Evaluation of the association between the TAS1R2 and TAS1R3 variants and food intake and nutritional status in children, *Genetics and Molecular Biology*, *40*(2), 415-420.

Mennella, Julie A., Pepino, M. Yanina, and Reed, D. R. (2006). Genetic and Environmental Determinants of Bitter Perception and Sweet Preferences. *Pediatrics*, *115*(2), e216–e222.

Mennella, J. a, Pepino, M. Y., Duke, F. F., & Reed, D. R. (2010). Age modifies the genotype-phenotype relationship for the bitter receptor TAS2R38. *BMC Genetics*, *11*, 60.

Mennella, J A, Finkbeiner, S., & Reed, D. R. (2012). The proof is in the pudding: children prefer lower fat but higher sugar than do mothers. *International Journal of Obesity (2005)*, *36*(10), 1285–1291.

Mennella, Julie A., & Bobowski, N. K. (2015). The sweetness and bitterness of childhood: Insights from basic research on taste preferences. *Physiology and Behavior*. *152*, 502-507.

Meyerhof, W. (2005). Elucidation of mammalian bitter taste. *Reviews of Physiology, Biochemistry and Pharmacology* (Vol. 154).

Miller, W. C., Lindeman, A. K., Wallace, J., & Niederpruem, M. (1990). Diet composition, energy intake, and exercise in relation to body fat in men and women. *The American Journal of Clinical Nutrition*, *52*(3), 426-430.

Mizushige, T., Inoue, K., & Fushiki, T. (2007). Why is fat so tasty? Chemical reception of fatty acid on the tongue. *Journal of Nutritional Science and Vitaminology*, *53*(1), 1–4.

Monneuse, M. O., Bellisle, F., & Louis-Sylvestre, J. (1991). Impact of sex and age on sensory evaluation of sugar and fat in dairy products. *Physiology and Behavior*, *50*(6), 1111–1117.

Montmayeur, J. P., Liberles, S. D., Matsunami, H., and Buck, L. B. (2001). A candidate taste receptor gene near a sweet taste locus. *Nature Neuroscience*, *4*(5), 492.

Montmayeur, J. P., and Le Coutre, J. (2009). *Fat detection: Taste, texture, and post ingestive effects*. CRC Press.

Morton, G. J., Cummings, D. E., Baskin, D. G., Barsh, G. S., & Schwartz, M. W. (2006). Central nervous system control of food intake and body weight. *Nature*, *443*(7109), 289–295.

Mrizak, I., Šerý, O., Plesnik, J., Arfa, A., Fekih, M., Bouslema, A., Tabka, Z. and Khan, N. A. (2015). The A allele of cluster of differentiation 36 (CD36) SNP 1761667 associates with decreased lipid taste perception in obese Tunisian women. *British Journal of Nutrition*, *113*(08), 1330–1337.

Mutch, D. M., Wahli, W., & Williamson, G. (2005). Nutrigenomics and nutrigenetics: the emerging faces of nutrition. *The FASEB Journal*, *19*(12), 1602–1616.

Mulot, C., Stücker, I., Clavel, J., Beaune, P., and Loriot, M. A. (2005). Collection of human genomic DNA from buccal cells for genetics studies: comparison between cytobrush, mouthwash, and treated card. *BioMed Research International*, *2005*(3), 291-296.

Nachtsheim, R., & Schlich, E. (2013). The influence of 6-n-propylthiouracil bitterness, fungiform papilla count and saliva flow on the perception of pressure and fat. *Food Quality and Preference*, *29*(2), 137–145.

Nagai, A., Kubota, M., Morinaga, K., & Higashiyama, Y. (2017). Food acceptance and anthropometry in relation to 6-npropylthiouracil sensitivity in Japanese college women. *Asia Pacific Journal of Clinical Nutrition*, *26*(5), 856.

Nasser, J. (2001). Taste, food intake and obesity. *Obesity Reviews*, *2*(4), 213-218.

Nasser, J. a, Kissileff, H. R., Boozer, C. N., Chou, C. J., & Pi-Sunyer, F. X. (2001). PROP taster status and oral fatty acid perception. *Eating Behaviors*, *2*(3), 237–245.

Navarro-allende, A., & Khataan, Nora, El-Sohemy, A. (2008). Impact of Genetic and Environmental Determinants of Taste with Food Preferences in Older Adults. *Journal of Nutrition For the Elderly*, *27*(3/4), 267–276.

National Centre for Biotechnology Information (NCBI), Reference SNP (refSNP) Cluster Report:rs1761667,2016.https://www.ncbi.nlm.nih.gov/variation/tools/1000genomes/?gts=rs1761667 (Accessed 17.05.18)

Negri, R., Di Feola, M., Di Domenico, S., Scala, M.G., Artesi, G., Valente, S., Smarrazo, A., Turco, F. Morini, G. and Greco, L. (2012). Taste Perception and Food Choices. *Journal of Pediatric Gastroenterology & Nutrition*, *54*(5), 624–629.

Nelson, G., Hoon, M. A., Chandrashekar, J., Zhang, Y., Ryba, N. J., and Zuker, C. S. (2001). Mammalian sweet taste receptors. *Cell*, *106*(3), 381-390.

Newman, L., Haryono, R., and Keast, R. (2013a). Functionality of fatty acid chemoreception: A potential factor in the development of obesity? *Nutrients*, *5*(4), 1287–1300.

Newman, L. P., and Keast, R. S. J. (2013b). The test-retest reliability of fatty acid taste thresholds. *Chemosensory Perception*, *6*(2), 70–77.

Newman, L. P., Bolhuis, D. P., Torres, S. J., and Keast, R. S. J. (2016). Dietary fat restriction increases fat taste sensitivity in people with obesity. *Obesity*, *24*(2), 328–334.

Newman, L. P., Torres, S. J., Bolhuis, D. P., and Keast, R. S. J. (2016a). The influence of a high-fat meal on fat taste thresholds. *Appetite*, *101*, 199–204.

Nik Shanita, S.; Norimah, A. K. and Abu Hanifah S. (2012). Development and validation of a Food Frequency Questionnaire (FFQ) for assessing sugar consumption among adults in Klang Valley, Malaysia. *Malaysian Journal of Nutrition*, *18*(3). 283-293.

Norimah, A. K., Safiah, M., Jamal, K., Siti, H., Zuhaida, H., Rohida, S., … Azmi, M. Y. (2008). Food consumption patterns: Findings from the Malaysian Adult Nutrition Survey (MANS). *Malaysian Journal of Nutrition*, *14*(1), 25–39.

Nurliyana, A. R., Nasir, M. T. M., Zalilah, M. S., & Rohani, A. (2015). Dietary patterns and cognitive ability among 12-to 13 year-old adolescents in Selangor, Malaysia. *Public Health Nutrition*, *18*(2), 303-312.

O'Brien, S., Feeney, E., Scannell, a., Markey, a., & Gibney, E. R. (2010). Are 6- n-propylthiouracil (PROP) taster status and fungiform papillae (FP) density related to alcohol intake in a group of Irish adults? *Proceedings of the Nutrition Society*, *69*(OCE1), E24.

Oftedal, K. N., & Tepper, B. J. (2013a). Influence of the PROP bitter taste phenotype and eating attitudes on energy intake and weight status in pre-adolescents: A 6-year follow-up study. *Physiology and Behavior*, *118*, 103–111.

Oka, Y., Butnaru, M., von Buchholtz, L., Ryba, N. J. P., & Charles, S. (2013). High salt recruits aversive taste pathways. *Nature*, *494*(7438), 472–475.

Ong, H.-H., Tan, Y.-N., & Say, Y.-H. (2017). Fatty acid translocase gene CD36 rs1527483 variant influences oral fat perception in Malaysian subjects. *Physiology and Behavior*, *168*, 128–137.

Ooi, S.-X., Lee, P.-L., Law, H.-Y., & Say, Y.-H. (2010). Bitter receptor gene (TAS2R38) P49A genotypes and their associations with aversion to vegetables and sweet/fat foods in Malaysian subjects. *Asia Pacific Journal of Clinical Nutrition*, *19*(4), 491–498.

Overberg, J., Hummel, T., Krude, H., & Wiegand, S. (2012). Differences in taste sensitivity between obese and non-obese children and adolescents. *Archives of Disease in Childhood*, *97*(12), 1048–1052.

Overton, H. A., Fyfe, M. C. T., and Reynet, C. (2008). GPR119, a novel G protein-coupled receptor target for the treatment of type 2 diabetes and obesity. *British Journal of Pharmacology*, *153*(S1), S76-S81.

Pangborn, R. M., and Pecore, S. D. (1982). Taste perception of sodium chloride in relation to dietary intake of salt. *The American Journal of Clinical Nutrition*, *35*(3), 510-520.

Paradis, A. M., Godin, G., Pérusse, L., & Vohl, M. C. (2009). Associations between dietary patterns and obesity phenotypes. *International Journal of Obesity*, *33*(12), 1419–1426.

Pasquet, P., Laure Frelut, M., Simmen, B., Marcel Hladik, C., & Monneuse, M. O. (2007). Taste perception in massively obese and in non-obese adolescents. *International Journal of Pediatric Obesity*, *2*(4), 242-248.

Passilly-Degrace, P., Chevrot, M., Bernard, A., Ancel, D., Martin, C., and Besnard, P. (2014). Is the taste of fat regulated? *Biochimie*, *96*, 3–7.

Pawellek, I., Grote, V., Rzehak, P., Xhonneux, A., Verduci, E., Stolarczyk, A., Closa-Monasterolo, R., Reischl, E., and Koletzko, B. (2016). Association of TAS2R38 variants with sweet food intake in children aged 1–6 years. *Appetite, 107*, 126-134.

Pepino, M Yanina, Finkbeiner, S., Beauchamp, G. K., & Mennella, J. A. (2009). Obese Women Have Lower Monosodium Glutamate Taste Sensitivity and Prefer Higher Concentrations Than Do Normal-weight Women. *Obesity*, *18*(5), 959–965.

Pepino, M. Y., Love-Gregory, L., Klein, S., & Abumrad, N. A. (2012). The fatty acid translocase gene CD36 and lingual lipase influence oral sensitivity to fat in obese subjects. *Journal of Lipid Research*, *53*(3), 561-566.

Perna, S., Riva, A., Nicosanti, G., Carrai, M., Barale, R., Vigo, B., … Rondanelli, M. (2018). Association of the bitter taste receptor gene TAS2R38 (polymorphism RS713598) with sensory responsiveness, food preferences, biochemical parameters and body-composition markers. A cross-sectional study in Italy. *International Journal of Food Sciences and Nutrition*, *69*(2), 245–252.

Pereira, M. A. (2006). The possible role of sugar-sweetened beverages in obesity etiology: a review of the evidence. *International Journal of Obesity*, *30*, S28–S36.

Peterson, J. M., Bartoshuk, L. M., & Duffy, V. B. (1999). Intensity and Preference for Sweetness is Influenced by Genetic Taste Variation. *Journal of the American Dietetic Association*, Vol. 99, p. A28.

Pioltine, M. B., de Melo, M. E., Santos, A., Machado, A. D., Fernandes, A. E., Fujiwara, C. T., Cercato, C. and Mancini, M. C. (2016). Genetic Variation in CD36 is Associated with Decreased Fat and Sugar Intake in Obese Children and Adolescents. *Journal of Nutrigenetics and Nutrigenomics*, *903*, 300–305.

Pirastu, N., Robino, A., Lanzara, C., Athanasakis, E., Esposito, L., Tepper, B. J., & Gasparini, P. (2012). Genetics of Food Preferences: A First View from Silk Road Populations. *Journal of Food Science*, *77*(12), S413-S418.

Prescott, J., Ripandelli, N., & Wakeling, I. (2001). Binary taste mixture interactions in prop non-tasters, medium-tasters and super-tasters. *Chemical Senses*, *26*(8), 993–1003.

Prescott, J., Soo, J., Campbell, H., and Roberts, C. (2004). Responses of PROP taster groups to variations in sensory qualities within foods and beverages. *Physiology and Behavior*, *82*(2-3), 459-469.

Priego, T., Sánchez, J., Picó, C., Ahrens, W., De Henauw, S., Kourides, Y., … Palou, A. (2015). TAS1R3 and UCN2 transcript levels in blood cells are associated with sugary and fatty food consumption in children. *Journal of Clinical Endocrinology and Metabolism*, *100*(9), 3556–3564.

Proserpio, C., Laureati, M., Bertoli, S., Battezzati, A., & Pagliarini, E. (2016). Determinants of obesity in Italian adults: The role of taste sensitivity, food liking, and food neophobia. *Chemical Senses*, *41*(2), 169–176.

Proserpio, C., Laureati, M., Invitti, C., Cattaneo, C., & Pagliarini, E. (2017). BMI and gender related differences in cross-modal interaction and liking of sensory stimuli. *Food Quality and Preference*, *56*, 49–54.

Prutkin, J., Fisher, E. M., Etter, L., Fast, K., Gardner, E., Lucchina, L. a, … Bartoshuk, L. M. (2000). Genetic variation and inferences about perceived taste intensity in mice and men. *Physiology and Behavior*, *69*(1–2), 161–173.

Qi, Q., Chu, A. Y., Kang, J. H., Jensen, M. K., Curhan, G. C., Pasquale, L. R., Ridker, P.M., Hunter, D.J, Willett, W.C., Rimm, E.B., Chasman, D. I., Hu, F.B. and Qi, L. (2012). Sugar-sweetened beverages and genetic risk of obesity. *New England Journal of Medicine*, *367*(15), 1387-1396.

Qu, W., Zhou, Y., Zhang, Y., Lu, Y., Wang, X., Zhao, D., Yang, Y. and Zhang, C. (2012). MFEprimer-2.0: a fast thermodynamics-based program for checking PCR primer specificity. *Nucleic Acids Research*, *40*(W1), W205-W208.

Ramachandran, A., & Snehalatha, C. (2010). Rising burden of obesity in Asia. *Journal of Obesity*, *2010*. 1-8.

Ramirez, I. 1993 . Role of olfaction in starch and oil preference. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, *265*(6), R1404-R1409.

Ramos-Lopez, O, Panduro, A., Martinez-Lopez, E., Fierro, N., Ojeda-Granados, C., Sepulveda-Villegas, M., & Roman, S. (2015). Genetic Variant in the CD36 Gene (rs1761667) is Associated with Higher Fat Intake and High Serum Cholesterol among the Population of West Mexico. *Journal of Nutrition & Food Sciences*, *05*(02), 1–5.

Ramos-Lopez, Omar, Roman, S., Martinez-Lopez, E., Fierro, N. A., Gonzalez-Aldaco, K., Jose-Abrego, A., & Panduro, A. (2016). *CD36* genetic variation, fat intake and liver fibrosis in chronic hepatitis C virus infection. *World Journal of Hepatology*, *8*(25), 1067.

Ramos-Lopez, O., Milagro, F. I., Allayee, H., Chmurzynska, A., Choi, M. S., Curi, R., De Caterina, R., Ferguson, L.R., Goni, L., Kang, J.X., Marti, A., Moreno, L.A., San-Cristobal, R., Santos, J.L., Martinez, J.A. and Kohlmeier, M. (2017). Guide for current nutrigenetic, nutrigenomic, and nutriepigenetic approaches for precision nutrition involving the prevention and management of chronic diseases associated with obesity. *Lifestyle Genomics*, *10*(1-2), 43-62.

Rashid, Z. M., Rahman, S. A., Kasim, Z. M., Mustapha, W. A. W., Halip, M. H. M., Arifin, Z., and Rauf, U. F. A. 2011. Nutritional status and physical activities among army trainees in public institutions of higher education in Malaysia. *Food and Nutrition Sciences*, 2(06), 511.

Reed, Danielle R and McDaniel, A. H. (2006). The Human Sweet Tooth. *BMC Oral Health*, *Suppl 1*, S1–S17.

Reed, D. R., Tanaka, T., and McDaniel, A. H. (2006). Diverse tastes: Genetics of sweet and bitter perception. *Physiology and Behavior*, *88*(3), 215–26.

Reed, D. R., Zhu, G., Breslin, P. A., Duke, F. F., Henders, A. K., Campbell, M. J., Montogery, G.W., Medland, S.E. Martin, N.G., and Wright, M. J. (2010). The perception of quinine taste intensity is associated with common genetic variants in a bitter receptor cluster on chromosome 12. *Human Molecular Genetics*, *19*(21), 4278-4285.

Reed, D. R., Bachmanov, A. A., Beauchamp, G. K., Tordoff, M. G., and Price, R. A. (2013). Heritable Variation in Food Preferences and Their Contribution to Obesity, *Behavior genetics*, *27*(4), 373–387.

Risso, D. S., Giuliani, C., Antinucci, M., Morini, G., Garagnani, P., Tofanelli, S., & Luiselli, D. (2017). A bio-cultural approach to the study of food choice : The contribution of taste genetics , population and culture. *Appetite*, *114*, 240–247.

Robino, A., Bevilacqua, L., Pirastu, N., Situlin, R., Di Lenarda, R., Gasparini, P., & Navarra, C. O. (2015). Polymorphisms in sweet taste genes (TAS1R2 and GLUT2), sweet liking, and dental caries prevalence in an adult Italian population. *Genes & Nutrition*, *10*(5), 485.

Robino, A., Mezzavilla, M., Pirastu, N., Dognini, M., Tepper, B. J., & Gasparini, P. (2014). A Population-Based Approach to Study the Impact of PROP Perception on Food Liking in Populations along the Silk Road. *PloS One*, *9*(3), e91716.

Rolls, B. J., Rowe, E. A., Rolls, E. T., Kingston, B., Megson, A., & Gunary, R. (1981). Variety in a meal enhances food intake in man. *Physiology and Behavior*, *26*(2), 215-221.

Rolls, E. T. (2015). Taste, olfactory, and food reward value processing in the brain. *Progress in Neurobiology*, *127–128*, 64–90.

Roper, S. D. (2013, January). Taste buds as peripheral chemosensory processors. In *Seminars in cell and developmental biology* (Vol. 24, No. 1, pp. 71-79). Academic Press.

Roper, S. D., & Chaudhari, N. (2017). Taste buds: Cells, signals and synapses. *Nature Reviews Neuroscience*, *18*(8), 485–497.

Rozin, P. (1991). Family resemblance in food and other domains: The family paradox and the role of parental congruence. *Appetite*, *16*(2), 93-102.

Rupesh, S., and Nayak, U. A. (2006). Genetic sensitivity to the bitter taste of 6-n propylthiouracil: a new risk determinant for dental caries in children. *Journal of Indian Society of Pedodontics and Preventive Dentistry*, *24*(2), 63.

Running, C. A. (2014). High false positive rates in common sensory threshold tests. *Attention, Perception & Psychophysics*, *77*(November 2014), 692–700.

Running, C. A., Mattes, R. D., & Tucker, R. M. (2013). Fat taste in humans: sources of within- and between-subject variability. *Progress in Lipid Research*, *52*(4), 438–445.

Sainz, E., Korley, J. N., Battey, J. F., and Sullivan, S. L. (2001). Identification of a novel member of the T1R family of putative taste receptors. *Journal of Neurochemistry*, *77*(3), 896-903.

Salbe, A. D., DelParigi, A., Pratley, R. E., Drewnowski, A., & Tataranni, P. A. (2004). Taste preferences and body weight changes in an obesity-prone population. *American Journal of Clinical Nutrition*, *79*(3), 372–378.

Sandell, M., Hoppu, U., Mikkil??, V., Mononen, N., K??h??nen, M., M??nnist??, S., … Raitakari, O. T. (2014). Genetic variation in the hTAS2R38 taste receptor and food consumption among Finnish adults. *Genes and Nutrition*, *9*(6), 1–8.

Sanematsu, K., Yoshida, R., Shigemura, N., and Ninomiya, Y. (2014). Structure, function, and signaling of taste G-protein-coupled receptors. *Current Pharmaceutical Biotechnology*, *15*(10), 951-961.

Sanematsu, K., Nakamura, Y., Nomura, M., Shigemura, N., and Ninomiya, Y. (2018). Diurnal Variation of Sweet Taste Recognition Thresholds Is Absent in Overweight and Obese Humans. *Nutrients*, *10*(3), 297.

Sartor, F., Donaldson, L. F., Markland, D. a, Loveday, H., Jackson, M. J., & Kubis, H.-P. (2011). Taste perception and implicit attitude toward sweet related to body mass index and soft drink supplementation. *Appetite*, *57*(1), 237–246.

Sayed, A., Šerý, O., Plesnik, J., Daoudi, H., Rouabah, A., Rouabah, L., & Khan, N. A. (2015). CD36 AA genotype is associated with decreased lipid taste perception in young obese, but not lean, children. *International Journal of Obesity*, *39*(6), 920–924.

Schiffman, S. S., Graham, B. G., Sattely-Miller, E. A., and Peterson-Dancy, M. (2000). Elevated and sustained desire for sweet taste in African-Americans: a potential factor in the development of obesity. *Nutrition*, *16*(10), 886-893.

Schutz, H. G., and Cardello, A. V. (2001). A labeled affective magnitude (LAM) scale for assessing food liking/disliking. *Journal of Sensory Studies*, 16, 117–159

Sclafani, A., Ackroff, K., and Abumrad, N. A. (2007). CD36 gene deletion reduces fat preference and intake but not post-oral fat conditioning in mice. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, *293*(5), R1823-R1832.

Sclafani, A., Ackroff, K., and Abumrad, N. A. (2007). CD36 gene deletion reduces fat preference and intake but not post-oral fat conditioning in mice. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, *293*(5), R1823-R1832.

Seidell, J. C. (1998). Dietary fat and obesity: an epidemiologic perspective. *The American Journal of Clinical Nutrition*, *67*(3), 546S-550S.

Shafaie, Y., Hoffman, D. J., and Tepper, B. J. (2015). Consumption of a high-fat soup preload leads to differences in short-term energy and fat intake between PROP non-taster and super-taster women. *Appetite*, *89*, 196–202.

Shahar, S., Earland, J., and Rahman, S. A. (2000). Food intakes and habits of rural elderly Malays. *Asia Pacific Journal of Clinical Nutrition*, *9*(2), 122-129.

Shen, Y., Kennedy, O. B., & Methven, L. (2016). Exploring the effects of genotypical and phenotypical variations in bitter taste sensitivity on perception, liking and intake of brassica vegetables in the UK. *Food Quality and Preference*, *50*, 71–81.

Shen, Y., Kennedy, O. B., & Methven, L. (2017). The effect of genotypical and phenotypical variation in taste sensitivity on liking of ice cream and dietary fat intake. *Food Quality and Preference*, *55*, 79–90.

Shim, J. S., Oh, K., and Kim, H. C. (2014). Dietary assessment methods in epidemiologic studies. *Epidemiology and Health*, *36*.

Sia, B. T., Low, S. Y., Foong, W. C., Pramasivah, M., Khor, C. Z., & Say, Y. H. (2013). Demographic differences of preference, intake frequency and craving hedonic ratings of sweet foods among Malaysian subjects in Kuala Lumpur. *Malaysian Journal of Medicine and Health Sciences*, *9*(1), 55–64.

Sigman-Grant, M., and Morita, J. (2003). Defining and interpreting intakes of sugars. *The American Journal of Clinical Nutrition*, *78*(4), 815S-826S.

Simchen, U., Koebnick, C., Hoyer, S., Issanchou, S., and Zunft, H. J. (2006). Odour and taste sensitivity is associated with body weight and extent of misreporting of body weight. *European Journal of Clinical Nutrition*, *60*(6), 698.

Smagghe, K., & Louis-Sylvestre, J. (1998). Influence of PROP-sensitivity on taste perceptions and hedonics in French women. A study performed without retronasal olfaction. *Appetite*, *30*(3), 325–339.

Snyder, D. J., & Bartoshuk, L. M. (2009). Epidemiological studies of taste function: discussion and perspectives. *Annals of the New York Academy of Sciences*, *1170*, 574–580.

Sonnenberg, L., Pencina, M., Kimokoti, R., Quatromoni, P., Nam, B. H., D'Agostino, R., and Millen, B. (2005). Dietary patterns and the metabolic syndrome in obese and non-obese Framingham women. *Obesity Research*, *13*(1), 153–162.

Stieger, M., and van de Velde, F. (2013). Microstructure, texture and oral processing: new ways to reduce sugar and salt in foods. *Current opinion in colloid and interface science*, *18*(4), 334-348.

Stewart, J. E., Feinle-Bisset, C., Golding, M., Delahunty, C., Clifton, P. M., and Keast, R. S. J. (2010). Oral sensitivity to fatty acids, food consumption and BMI in human subjects. *The British Journal of Nutrition*, *104*(1), 145–52.

Stewart, J. E., Feinle-Bisset, C., and Keast, R. S. J. (2011a). Fatty acid detection during food consumption and digestion: Associations with ingestive behavior and obesity. *Progress in Lipid Research*, *50*(3), 225–33.

Stewart, J. E., Newman, L. P., and Keast, R. S. J. (2011b). Oral sensitivity to oleic acid is associated with fat intake and body mass index. *Clinical Nutrition*, *30*(6), 838–844.

Stewart, J. E., Seimon, R. V., Otto, B., Keast, R. S. J., Clifton, P. M., and Feinle-Bisset, C. (2011c). Marked differences in gustatory and gastrointestinal sensitivity to oleic acid between lean and obese men. *American Journal of Clinical Nutrition*, *93*(4), 703–711.

Stewart, J. E., and Keast, R. S. J. (2012). Recent fat intake modulates fat taste sensitivity in lean and overweight subjects. *International Journal of Obesity*, *36*(6), 834–842.

Stubbs, R. J., Johnstone, A. M., Mazlan, N., Mbaiwa, S. E., & Ferris, S. (2001). *Effect of altering the variety of sensorially distinct foods , of the same macronutrient content , on food intake and body weight in men*.

Takeda, M., Sawano, S., Imaizumi, M., and Fushiki, T. (2001). Preference for corn oil in olfactory-blocked mice in the conditioned place preference test and the two-bottle choice test. *Life sciences*, *69*(7), 847-854.

Tee E.S., Mohd. Ismail N., Mohd. Nasir A. and Khatijah I. Nutrient composition of Malaysian foods. 4th ed. Kuala Lumpur: Institute for Medical Research; 1997

Temple, E. C., Hutchinson, I., Laing, D. G., and Jinks, A. L. (2002). Taste development: differential growth rates of tongue regions in humans. *Developmental brain research*, *135*(1-2), 65-70.

Temussi, P. A. (2009). Sweet, bitter and umami receptors: a complex relationship. *Trends in Biochemical Sciences*, *34*(6), 296–302.

Tepper, B. J., and Nurse, R. J. (1997). Fat perception is related to PROP taster status. *Physiology and Behavior*, *61*(6), 949–54.

Tepper, B. J., and Ullrich, N. V. (2002). Influence of genetic taste sensitivity to 6-n-propylthiouracil (PROP), dietary restraint and disinhibition on body mass index in middle-aged women. *Physiology and Behavior*, *75,* 305–312.

Tepper, B. J. (2008). Nutritional Implications of Genetic Taste Variation : The Role of PROP Sensitivity and Other Taste Phenotypes. *Annual Review of Nutrition*, *28,* 367–388.

Tepper, B. J., Koelliker, Y., Zhao, L., Ullrich, N. V., Lanzara, C., d'Adamo, P., Ferrara, A., Ulivi, S., Esposito, L and Gasparini, P. (2008). Variation in the bitter-taste receptor gene TAS2R38, and adiposity in a genetically isolated population in Southern Italy. *Obesity*, *16*(10), 2289-2295.

Tepper, B. J., White, E. A., Koelliker, Y., Lanzara, C., d'Adamo, P., & Gasparini, P. (2009). Genetic variation in taste sensitivity to 6-n-propylthiouracil and its relationship to taste perception and food selection. *Annals of the New York Academy of Sciences*, *1170*(1), 126-139.

Tepper, B., Banni, S., Melis, M., Crnjar, R., & Tomassini Barbarossa, I. (2014). Genetic sensitivity to the bitter taste of 6-n-propylthiouracil (PROP) and its association with physiological mechanisms controlling body mass index (BMI). *Nutrients*, *6*(9), 3363-3381.

Tepper, B., Melis, M., Koelliker, Y., Gasparini, P., Ahijevych, K., & Tomassini Barbarossa, I. (2017). Factors influencing the phenotypic characterization of the oral marker, PROP. *Nutrients*, *9*(12), 1275.

Thompson, F. E., and Byers, T. (1994). Dietary assessment resource manual. *The Journal of Nutrition*, *124*(suppl_11), 2245s-2317s.

Thompson, F. E., and Subar, A. F. (2017). Dietary assessment methodology. In *Nutrition in the Prevention and Treatment of Disease* (pp. 5-48). Academic Press.

Timpson, N. J., Christensen, M., Lawlor, D. A., Gaunt, T. R., Day, I. N., Ebrahim, S., and Smith, G. D. (2005). TAS2R38 (phenylthiocarbamide) haplotypes, coronary heart disease traits, and eating behavior in the British Women's Heart and Health Study. *The American Journal of Clinical Nutrition*, *81*(5), 1005-1011.

Tomassini Barbarossa, I., Carta, G., Murru, E., Melis, M., Zonza, A., Vacca, C., and Banni, S. (2013). Taste sensitivity to 6-n-propylthiouracil is associated with endocannabinoid plasma levels in normal-weight individuals. *Nutrition*, *29*(3), 531–536.

Tournier, C., Martin, C., Guichard, E., Issanchou, S., & Sulmont-Rossé, C. (2007). Contribution to the understanding of consumers' creaminess concept: A sensory and a verbal approach. *International Dairy Journal*, *17*(5), 555–564.

Tomchik, S. M., Berg, S., Kim, J. W., Chaudhari, N., and Roper, S. D. (2007). Breadth of tuning and taste coding in mammalian taste buds. *Journal of Neuroscience*, *27*(40), 10840-10848.

Tucker, R. M., Edlinger, C., Craig, B. a, and Mattes, R. D. (2014). Associations Between BMI and Fat Taste Sensitivity in Humans. *Chemical Senses*, *39*(4), 349–57.

Tucker, R. M., Kaiser, K. A., Parman, M. A., George, B. J., Allison, D. B., & Mattes, R. D. (2017). Comparisons of fatty acid taste detection thresholds in people who are lean vs. overweight or obese: a systematic review and meta-analysis. *PloS one*, *12*(1), e0169583.

Tucker, R. M., Nuessle, T. M., Garneau, N. L., Smutzer, G., & Mattes, R. D. (2015). No difference in perceived intensity of linoleic acid in the oral cavity between obese and nonobese individuals. *Chemical senses*, *40*(8), 557-563.

Turner-McGrievy, G., Tate, D. F., Moore, D., and Popkin, B. (2013). Taking the bitter with the sweet: Relationship of supertasting and sweet preference with metabolic syndrome and dietary intake. *Journal of food science*, *78*(2), S336-S342.

van Strien, T., Herman,C.P., Engels, C.M.E, Larsena, J.K. and van Leeuwed, J.F. (2008). Construct validation of the Restraint Scale in normal-weight and overweight females. *Appetite*, 109-121.

Veluswami, D., Ambigai Meena, B., Latha, S., Gayathri Fathima, I., Soundariya, K., and Senthamil Selvi, K. (2015). A study on prevalence of phenyl thiocarbamide (PTC) taste blindness among obese individuals. *Journal of Clinical and Diagnostic Research*, *9*(5), CC04-CC06.

Verhagen, J. V, Rolls, E. T., & Kadohisa, M. (2003). Neurons in the Primate Orbitofrontal Cortex Respond to Fat Texture Independently of Viscosity. *Journal of Neurophysiology*, *90*, 1514–1525.

Villanueva, N. D., Petenate, A. J., and Da Silva, M. A. (2000). Performance of three affective methods and diagnosis of the ANOVA model. *Food Quality and Preference*, *11*(5), 363-370.

Villarino, B. J., Fernandez, C. P., Alday, J. C., and Cubelo, C. G. R. (2009). Relationship of PROP (6-n-propylthiouracil) taster status with the body mass index and food preferences of Filipino adults. *Journal of Sensory Studies*, *24*(3), 354-371

Vincze, T., Posfai, J., and Roberts, R. J. (2003). NEBcutter: a program to cleave DNA with restriction enzymes. *Nucleic Acids Research*, *31*(13), 3688-3691.

Walters, D. E., and Hellekant, G. (2006). Interactions of the sweet protein brazzein with the sweet taste receptor. *Journal of Agricultural and Food Chemistry*, *54*(26), 10129-10133.

Wang, Y., Cai, L., Wu, Y., Wilson, R. F., Weston, C., Fawole, O., Blecich, S.N., Cheskin, L.J., Showell, N.N., Lau, B.D., Zhang, A., Segal, J. and Chiu, D. T. (2015). What childhood obesity prevention programmes work? A systematic review and meta-analysis. *Obesity Reviews*, *16*(7), 547-565.

Wardle, J. (2007). Eating behaviour and obesity in children. *International Journal of Obesity*, *31*(1), S13.

Warwick, Z. S., & Schiffman, S. S. (1990). Sensory evaluations of fat-sucrose and fat-salt mixtures: Relationship to age and weight status. *Physiology and Behavior*, *48*(5), 633–636.

Webb, J., Bolhuis, D. P., Cicerale, S., Hayes, J. E., & Keast, R. (2015). The Relationships Between Common Measurements of Taste Function. *Chemosensory Perception*, *8*(1), 11–18.

WHO. World Health Statistics 2013. Geneva, Switzerland: WHO Press; 2013

WHO. (2018, 16 February). Obesity and Overweight. Retrieved from : https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

Wijtzes, A. I., Jansen, W., Bouthoorn, S. H., Kiefte-de Jong, J. C., Jansen, P. W., Franco, O. H., Jaddoe, V.W.V., Hofman, A. and Raat, H. (2017). PROP taster status, food preferences and consumption of high-calorie snacks and sweet beverages among 6-year-old ethnically diverse children. *Maternal and Child Nutrition*, *13*(2), e12240.

Willett, W. C. (1998). Invited commentary: comparison of food frequency questionnaires. *American Journal of epidemiology*, *148*(12), 1157-1159.

Williams, F., Diaz, M., Misha, C., Gideon, S., Bell, R., Hill, N., Huang, C., Kelly, M., Momjian, D., Morales,-Miranda, D., Liu, H.S., Udow, H. and Yermanos, A. (2014). The Genetic Basis for Taste Perception: A Review. *The Undergraduate Journal of Biological Athropology*, *2*, 8–12.

Wise, P. M., Nattress, L., Flammer, L. J., & Beauchamp, G. K. (2016). Reduced dietary intake of simple sugars alters perceived sweet taste intensity but not perceived pleasantness. *American Journal of Clinical Nutrition*, *103*(1), 50–60.

Yackinous, C., & Guinard, J. X. (2001). Relation between PROP taster status and fat perception, touch, and olfaction. *Physiology and Behavior*, *72*(3), 427–437.

Yackinous, Carol a, & Guinard, J.-X. (2002). Relation between PROP (6-n-propylthiouracil) taster status, taste anatomy and dietary intake measures for young men and women. *Appetite*, *38*(3), 201–209.

Yanovski, S. (2003). Sugar and fat: cravings and aversions. *The Journal of Nutrition, 133*(3), 835S–837S.

Yeomans, M. R., Tepper, B. J., Rietzschel, J., & Prescott, J. (2007). Human hedonic responses to sweetness: Role of taste genetics and anatomy. *Physiology and Behavior*, *91*(2–3), 264–273.

Zalilah, M. S., Khor, G. L., Mirnalini, K., Norimah, A. K., & Ang, M. (2006). Dietary intake, physical activity and energy expenditure of Malaysian adolescents. *Singapore Medical Journal*, *47*(6), 491–498.

Zhang, X. J., Zhou, L. H., Ban, X., Liu, D. X., Jiang, W., and Liu, X. M. (2011). Decreased expression of CD36 in circumvallate taste buds of high-fat diet induced obese rats. *Acta Histochemica*, *113*(6), 663-667.

Zhao, G. Q., Zhang, Y., Hoon, M. A., Chandrashekar, J., Erlenbach, I., Ryba, N. J., and Zuker, C. S. (2003a). The receptors for mammalian sweet and umami taste. *Cell*, *115*(3), 255-266.

Zhao, L., Kirkmeyer, S. V., and Tepper, B. J. (2003b). A paper screening test to assess genetic taste sensitivity to 6-n-propylthiouracil. *Physiology and Behavior*, *78*(4-5), 625-633.

Zhao, L., and Tepper, B. J. (2007). Perception and acceptance of selected high-intensity sweeteners and blends in model soft drinks by propylthiouracil (PROP) non-tasters and super-tasters. *Food Quality and Preference*, *18*, 531–540.

Zheng, H., Lenard, N. R., Shin, A. C., & Berthoud, H. R. (2009). Appetite control and energy balance regulation in the modern world: reward-driven brain overrides repletion signals. *International Journal of Obesity*, *33*(S2), S8.

Zhou, X., Shen, Y., Parker, J. K., Kennedy, O. B., and Methven, L. (2016). Relative Effects of Sensory Modalities and Importance of Fatty Acid Sensitivity on Fat Perception in a Real Food Model. *Chemosensory Perception*, *9*(3), 105–119.

Zung, W. W. (1965). A self-rating depression scale. Archives of general psychiatry, 12(1), 63-70