Matters of taste

Dietary taste patterns in the Netherlands

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Thesis

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Content

Chapter 1

General introduction

Background

The prevalence of overweight and obesity has increased dramatically worldwide over the last decades, regardless of geographical boundaries and cultural differences. In the Netherlands, the prevalence of overweight and obesity has increased from 22.9% and 4.4% in 1981 to 31.5% and 10.1%, respectively in 2013[1]. It is widely accepted that the obesity epidemic is a result from a long-term energy imbalance, caused by a combination of excessive food intake and an inactive lifestyle. The obesogenic environment, with an ample food supply, contributes to the dysregulation of energy balance[2]. Therefore, making the desirable and appropriate food choices is important in preventing weight gain and obesity.

Food choices are to a great extent guided by the sensory properties of foods[3]. The sensory properties comprise taste, olfaction, texture and appearance. Taste is unique in its innate association with mechanisms of reward and aversion, and plays a key role in food choice and dietary patterns[4]. Besides guiding food choice, taste may serve as an early signal of its nutrient content[5,6], thereby affecting satiation[7] and subsequent food intake[8–10]. Because of these associations between taste intensity and nutrient content, diets lower in sugar, salt and saturated fat may be lower in taste intensity. Therefore, diets based on dietary guidelines may be less intense in taste and this could potentially be a key contributing factor to poor adherence to these guidelines. Thus, studying dietary patterns from a taste perspective - and not only a nutritional perspective - provides us with a deeper understanding of the role of taste in dietary intake.

Research on the role of taste in dietary intake is still in its infancy. In contrast, the relationship between single ingredients and the sensory properties of individual foods have been widely studied[11–14]. In addition, several studies have focused on the relationship between sensory properties of individual foods, preferences[15,16], food choice and intake[5,8].

Only few studies have investigated the relationship between sensory properties and daily dietary patterns[17,18]. A first study by Mattes and Mela[17] investigated associations between liking ratings of a selection of sweet foods and dietary intake. In the late 1990's, Cox et al.[15] asked obese and lean consumers to classify their dietary intake according to the dominant taste of food. Yet, these studies did not objectively quantify taste values of foods using a trained sensory panel. More recently, van Dongen et al.[5] quantified the basic taste intensities of a small selection of 50 commonly consumed foods. However, to study the role of taste in dietary intake, it is essential to objectively quantify the taste intensity values across a large range of foods consumed within a population. Moreover, the role of taste in dietary intake should be studied in various study populations, because dietary taste patterns may differ among age, gender and weight status subgroups of the population[15,18–25].

The aim of this thesis was to assess the role of taste in dietary intake in young children and adults, and to investigate how taste relates to nutrients and the extent of adherence to dietary recommendations.

This introduction continues with a short background on the sense of taste and its function, followed by a description on the compilation of a taste database, the assessment of dietary taste patterns in this thesis, and the aim and outline of this thesis.

The sense of taste and its function

Taste has a number of functions for human survival[26]. Pleasant tastes – sweet, salty and umami - may signal for desired nutrients, whereas unpleasant tastes – sour and bitter - may present a warning signal for potentially toxic substances[26]. Sweet taste is thought to signal the presence of mono- and disaccharides, salt taste may signal sodium content for maintaining the body's water balance and umami taste may serve as a signal for protein content[27]. Sour and bitter taste may be more important in detecting a low pH, present in unripe fruits and spoiled food, and preventing the consumption of bitter plant-based toxins[27,28]. It is generally accepted that fat content is detected in the oral cavity by its textural properties (e.g. mouthfeel), though recent evidence suggests fat can also be detected through the taste of its breakdown products[29–31].

Although taste is often described as having a nutrient-signalling function[26–28], there is only limited data on real-life food products available to support this notion. To our knowledge, the only study supporting this investigated the relationship between basic taste intensity and nutrient content in 50 commonly consumed Dutch foods[5]. This study found that sweet, salt and umami taste were positively associated with mono- and disaccharides, sodium, and protein content, respectively. However, it is unknown to what extent these taste-nutrient relationships exist across a wider range of foods that are commonly consumed by the general population.

Taste-nutrient relationships may be less evident than would be expected, because of food reformulations. In recent years, food manufacturers have faced an increasing demand for processed foods that are modified to reduce sugar, salt or saturated fat content[32]. To maintain sensory properties and palatability, food industry may add non-nutritive sweeteners, aroma's or flavour enhancers to foods. Furthermore, processed foods often consist of a combination of tastes that may interact, and thus may be competing. Especially sweetness is often a predominant taste, and was shown to suppress other tastes in taste mixture solutions[33,34]. These ingredient additions and taste interactions may affect the extent to which taste can signal for nutrients in processed foods.

Taste database

Numerous studies have investigated dietary intake of nutrients[35–38]. Hence, food composition databases exist globally. However, to study dietary intake from a taste perspective, a taste database is needed that includes the basic taste intensity and fat sensation values of a large range of commonly consumed foods. To adequately assess the taste values of foods, a sensory panel is needed that is trained for several months. Trained panels are commonly used as an objective measure to quantify sensory properties of foods[39]. Training of a panel increases the panel's internal consensus, reproducibility of taste values and discriminative power between taste modalities and foods[39–41]. Because of the large number of foods that are available, it is impractical to assess the taste values of all commonly consumed foods. Thus, compilation of a taste database requires an objective selection of foods that are consumed across the general population. To this aim, national food consumption data can be used. Foods can be selected based on pre-defined criteria: i.e. consumption frequency and contribution to the consumption of energy and macronutrients. In addition, foods can be selected that contribute most to the variation in energy intake. Subsequently, the selected foods are profiled on taste, resulting in a taste database with six basic taste and fat sensation values for each food.

Dietary taste patterns

Clustering of foods in taste groups

To study the role of taste in dietary intake, a taste database is needed in combination with food intake data. However, it is not possible to calculate with taste values as is done with nutrient values. For example, three bites of an apple do not result in three times the perceived taste intensity values of one bite of an apple. Yet, foods can be classified in food groups based on taste using hierarchical cluster analyses. All foods in dietary intake data can be classified in taste groups. This is similar to food groups based on nutrients, such as 'bread' and 'dairy', but then foods are grouped based on taste. Subsequently, food taste groups can be used to study the contribution to energy intake and consumed amount of food from food groups with different tastes.

Dietary assessments methods

Grouping of foods in taste groups is most straightforward in dietary intake data that reports the intake of single foods, as is done in 24-hour recalls (24hR). In 24hR, single foods can be combined easily with the taste values of foods in a taste database. However, for the assessment of nutrient intakes, dietary assessment methods such as 24hR and food frequency questionnaires (FFQ) can be used[42]. Both FFQ and multiple 24hR are used to assess habitual intake of nutrients. Large-scale epidemiological studies often use FFQ because they are relatively cheap and easy to administer. However, FFQ data contains less detailed information on food preparation and no data on single foods as 24hR data do[42]. In FFQ, foods are combined into food items, and therefore the consumption of foods are inquired on a more aggregated level. For the assessment of nutrient intakes, weighted mean nutrient values are calculated for each food item. Similarly, weighted mean taste values can be calculated for the assessment of dietary taste patterns. Although previous studies have evaluated FFQ to 24hR[43–45], this was done for the assessment of foods, energy and nutrient intakes and not for dietary taste patterns. An important question is whether FFQ are detailed enough to study dietary taste patterns by subgroups of the population.

Individual characteristics throughout the life course

Taste is a key driver of food choice and intake[46]. Already at birth, infants have a general preference for sweet taste and an aversion for bitter. However, taste preferences are also acquired[3]. For example, infants usually develop a preference for salt taste during their first year of life[47]. Moreover, taste preferences are not only related to taste quality, but also dependent on taste intensity. For example, the optimal preferred sweetness levels are higher in children than in adolescents, and higher in adolescents than in adults[48,49]. In addition, a certain degree of bitterness in products such as coffee, beer, wine and fruit juice can even become expected and enjoyed in adulthood[3]. Similarly, salt is appreciated at low and moderate concentrations, but is disliked at very high concentrations[50]. Thus, taste preferences differ throughout the life course and are dependent on both taste quality and intensity.

During the first two years of life, infants' food intake changes from milk only to more complex and solid foods. This transition may potentially have important consequences for the development of taste preferences and food choices later in life[51,52]. Already at the age of two years, food preferences were found to remain relatively stable until young adulthood[51]. Therefore, to fully understand variations in food preferences, it is important to study dietary taste patterns before the age of two years, and to identify the factors related to these patterns. Most previous studies have focused on the intake of nutrients in infants, and how nutrient intakes relate to factors such as parental BMI, education and age[53–56]. However, the factors related to dietary taste patterns during the first two years of life are still unknown.

To put dietary taste patterns of young children in perspective, it is essential to compare them with dietary taste patterns in adults. In adults, dietary taste patterns may differ by individual characteristics such as sex and weight status. Although no literature is available on dietary taste patterns, this is available for studies on taste preferences. For example, several studies have found that men liked salty and/or fatty foods more than women[19–25], whereas women liked sweet foods more than men[19,20,24,25]. However, it is less clear whether taste preferences differ by weight status. Some studies have found a positive association between liking for sweet[19,20] or salty foods and BMI[19], whereas other studies have found lower liking ratings for sweet and salty foods in obese than in lean individuals[15] or no difference in liking across BMI categories[18]. However, dietary taste patterns by subgroups of the adult's population has never been assessed.

Adherence to dietary guidelines

Worldwide, there is an enormous societal pressure to lower dietary salt, sugar and fat intake to prevent chronic diseases[57]. Some countries report dietary reductions of these nutrients, yet these reductions have been minimal and do not reach dietary recommendations[37,58–60]. Diets lower in sugar, salt and fat may be lower in taste intensity and palatability and this may be a key contributing factor for poor adherence to dietary guidelines[5]. Moreover, this could also explain why consumers are seeking alternative diets that may better satisfy their sensory needs[61]. The popularity of alternative diets, such as the Atkins diet and the Paleo diet might be in part attributable to their higher taste intensity values. However, no studies exist that have investigated the taste of healthy diets and popular diets in comparison with current Dutch dietary taste patterns.

Aim and thesis outline

The overall aim of this thesis was to assess the role of taste in energy intake in young children and adults, and to investigate how taste relates to nutrients and the extent of adherence to dietary recommendations (**Figure 1**). To this aim, five research questions were defined:

1. How is taste intensity related to nutrient content in single foods, and is this relationship modified by food form (**Chapter 2**)?
2. To what extent can different dietary assessment methods assess dietary taste patterns (**Chapter 3**)?
3. How do dietary taste patterns develop during early childhood (**Chapter 4**)?
4. Do dietary taste patterns differ by individual characteristics in adults (**Chapter 5**)?
5. How is taste related to the extent of adherence to dietary guidelines and how do healthy and popular dietary scenarios differ from the current diet concerning dietary taste patterns (**Chapter 6**)?

In **chapter 2** the first research question is addressed; the relationship between taste intensity values and nutrient content, and whether this relationship is modified by food form. In **chapter 3** we will evaluate dietary taste patterns as assessed by FFQ against 24-h recalls and biomarkers of exposure in adults. **Chapter 4** investigates the development of dietary taste patterns in early childhood and how they are related to maternal and child characteristics. In **chapter 5** dietary taste patterns are studied in different socioeconomic subgroups in two adult study populations. In **chapter 6** we determined how taste is related to the extent of adherence to dietary guidelines in the Dutch adult study population, and how dietary taste patterns of healthy and popular dietary scenarios compare with current dietary taste patterns in women. Finally, in **chapter 7** of this thesis, the main findings are discussed and put in perspective. The implications of these findings and recommendations for further research are given in the discussion.

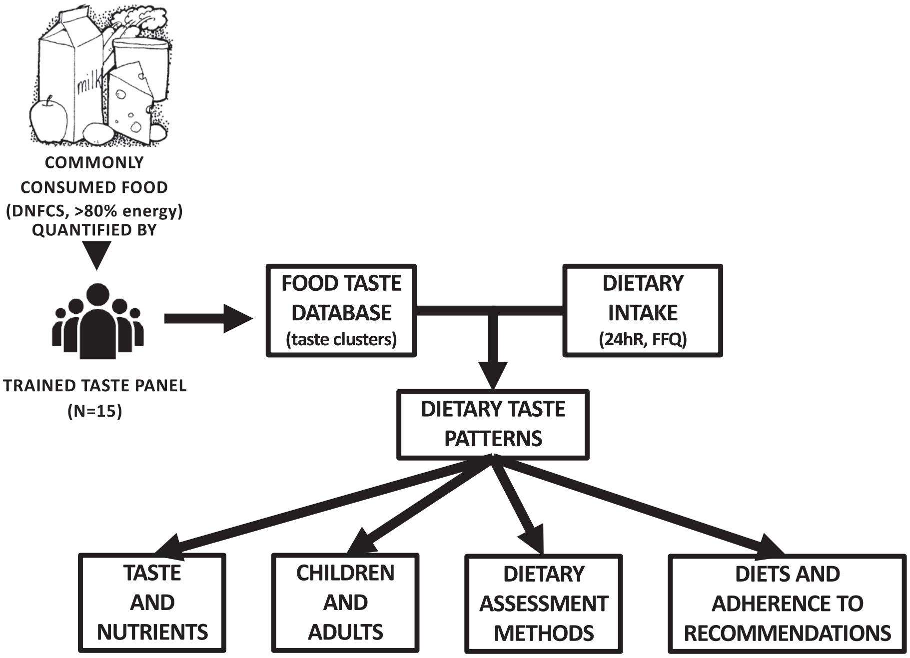

Figure 1 Overview of study design and different perspectives of dietary taste patterns described in this thesis

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Chapter 2

The relationship between taste and nutrient content in commercially available foods from the United States

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Abstract

Taste is often suggested to have a nutrient-signalling function that may be important for food intake regulation, though limited data exists to support this notion. This study aimed to investigate the relationship between taste and nutrient content, and to explore the effect of food form on this relationship (liquid, semi-solid or solid), in a range of commercially available foods from the United States. Basic taste intensities (sweetness, saltiness, sourness and bitterness) of 237 processed foods were obtained by an expert sensory panel using the Spectrum™ method. Sweet taste intensity was associated with mono- and disaccharides ($r=0.70$, $p< 0.001$), but not energy content ($r=0.11$, $p>0.05$). Salt taste intensity was associated with sodium ($r=0.72$, $p<0.001$) and protein ($r=0.39$, $p<0.001$), and fat ($r=0.37$, $p<0.001$) and energy content ($r=0.43$, $p<0.001$). Contrary to expectations, associations between taste and nutrient content were not stronger in liquids than in (semi-) solids. Cluster analysis on taste revealed three food groups: a sweet, salty and neutral tasting food group. Saltiness was associated with sodium content in salty foods ($r=0.39$, $p<0.001$) but not in sweet foods ($r=0.30$, $p>0.05$). Sweetness was associated with mono- and disaccharides in sweet foods ($r=0.55$, $p<0.001$) and in salty foods ($r=0.33$, $p<0.001$). In conclusion, our findings suggest that sweet and salt taste intensity can signal the presence of nutrients, in particular mono- and disaccharides and sodium. However, the relationship between taste and nutrients may be weaker in complex foods with competing tastes. The effect of food form on this relationship is more difficult to demonstrate in real-life foods.

Introduction

Sweet and salty tasting stimuli are considered to be pleasant from an early age[1–3]. Sweet taste is thought to signal the presence of carbohydrates and thus energy, whereas salt taste signals for sodium content which is important for maintaining the body's water balance[4]. An excessive intake of both salt and sugar are associated with negative health consequences (e.g. [5,6]). In the U.S. population aged 1 year and older, 70% exceeds the recommendations for added sugar and 89% exceeds the recommendations for sodium intake[7]. It is therefore important to understand to what extent taste may play a role in the regulation of nutrient intake.

Although taste is often described as having a nutrient-signalling function[4,8,9], there is only limited data on real-life food products available to support this notion. To our knowledge, the only studies supporting this investigated the relationship between basic taste intensity and nutrient content in 377 Australian foods and 50 commonly consumed Dutch foods[10,11]. These studies showed that the sweet, salty, savoury taste and fatty mouthfeel were positively associated with mono- and disaccharides, sodium, protein, and fat content, respectively. Moreover, Lease et al.[11] found that energy content was positively associated with fatty mouthfeel, salty and umami taste, and, to a lesser extent, to sweet taste. Many processed foods high in salt are also high in fat content (meat, cheese, crisps, pizza), and less foods exist, that are consumed in isolation, that are high in salt but low in fat content (besides soup). However, many sweet foods exist that are low in fat content (sugar-sweetened beverages, fruit and fruit juice, candy, sweetened low-fat dairy products). Since fat is the most energy-dense nutrient, energy content may indeed be more related to salty and umami taste than to the sweet taste. However, more evidence is needed to support these findings.

In recent years, food manufacturers have faced an increasing demand for processed foods that are modified to reduce energy, salt or sugar content[12]. To maintain sensory properties and palatability, food industry may add non-nutritive sweeteners, aroma's or flavour enhancers to foods. For example, sardine aroma may be used to enhance saltiness in cheese[13]. Similarly, the addition of flavour enhancers such as yeast extracts, lactates and monosodium glutamate are strategies to enhance saltiness in meat[14]. Furthermore, processed foods often consist of a combination of tastes that may interact, and thus may be competing. Especially sweetness is often a predominant taste, and was shown to suppress other tastes in taste mixture solutions[15,16]. These ingredient additions and taste interactions may affect the extent to which taste can signal for nutrients in processed foods. Yet so far, only limited evidence is available to support this notion. In a study by van Dongen et al.[10] it was found that variation in taste intensity was better explained by nutrient content in unprocessed and moderately processed foods than in highly processed foods.

Another factor that may be affecting the taste-nutrient relationship is food form, i.e. liquid, semi-solid or solid. Previous studies have found that increasing the hardness of gelled products lowers the oral release of tastants from the food matrix[17,18]. This may result in lower perceived taste intensity and thus increasing the optimum hedonic level of added tastants, such as sugar or salt. A limitation of these studies is, however, that they used model foods, which are designed to differ only in one aspect of interest (such as hardness). In real-life foods, the influence of food form on the relationship between taste and nutrient content may be less apparent, as these foods can differ in multiple aspects (e.g. taste, aroma, macronutrient composition). To our knowledge, to date no studies have explored the effect of food form on the taste-nutrient relationship in real-life food products.

The aim of the current study was to investigate the association between taste intensity and nutrient content, and to explore the modifying effect of food form (liquid, semi-solid or solid) on this relationship, in a range of commercially available processed foods from the United States. It was hypothesized that sweet taste intensity would be positively associated with total mono- and disaccharide content and salt taste intensity with sodium and protein and fat content. The associations between sweet taste intensity and mono- and disaccharides and between salt taste intensity and sodium content were expected to be stronger in liquid foods, compared to semi-solids and solids. In addition, we expected that energy content would be positively associated with the salty taste rather than the sweet taste. It was hypothesized that the presence of competing tastes in foods may modify the relationship between taste and nutrient content. This was explored by comparing the regression parameters between food clusters (sweet, salty and neutral) within food form groups (liquids, semi-solids and solids), and between food form groups within food clusters. Sensory data used for these analyses was derived from Sensory Spectrum, Inc. using an expert sensory panel.

Materials and Methods

Basic taste intensity ratings

Sensory Spectrum's Foods and Beverages Descriptive analysis panel (n=8-10) reached consensus on four basic taste intensities (sweetness, saltiness, sourness and bitterness) of 264 commercially available food items in the United States using Spectrum™ Descriptive Analysis (SDA) method. The SDA method allows for the objective description of product sensory properties and is a scientific method designed to provide analytical sensory data[(19)]. The SDA method uses detailed lexicons including attributes (descriptors), definitions and character references, as well as standard rating scales to document the intensity of each attribute for each sample tested. Furthermore, the SDA method uses a trained and calibrated panel to provide highly reproducible data over time. Panellists typically receive over 100 hours of training and practice in each sensory modality of interest (flavour, appearance, texture of foods and beverages). The training, initial validation and ongoing mentoring of panellists is rigorous for both terminology (qualitative) use and the scaling of intensity (quantitative). References, standards for clarification of descriptors and intensity, are used extensively. These Flavor and Texture Spectra can then be compared and contrasted.

For the current study, the attributes of interest were the basic tastes: sweetness, saltiness, sourness and bitterness. A range of foods were evaluated using the rating scales from the SpectrumTM method. The scale used is considered a universal scale (applicable to all food items) and ranged from 0 to 15. The scale is meant to incorporate the broad range of processed foods, but foods may go beyond the high-end of the scale(19). For each taste, four reference solutions were provided containing increasing concentrations of sucrose for sweetness, sodium chloride for saltiness, citric acid for sourness and caffeine for bitterness, dissolved in demineralised water. The concentrations and taste intensities of the references used in the SDA method are shown in Table 1. The resulting database of product basic taste spectra, that was provided by Sensory Spectrum, Inc., was then augmented with nutrient contents for these products.

Table 1 Concentrations and taste intensities of the reference solutions, used in the Spectrum method™

Reference	Taste intensity†	Sweet	Salt‡	Sour	Bitter
R0	0	0.0%	0.0%	0.0%	0.0%
R1	2	2.0%	0.2%	0.05%	0.05%
R2	5	5.0%	0.35%	0.08%	0.08%
R3	10	10.0%	0.5%	0.15%	0.15%
R4	15	16.0%	0.7%	0.20%	0.20%

†Ratings on the Spectrum scale from 0 to 15.
‡For saltiness, intensity ratings are 0, 2.5, 5, 8.5 and 15

Additional food product information

Nutrient information was obtained retrospectively by an online food search, using the specific brand and product name. The total fat (g/100 g), total protein (g/100 g), total carbohydrate (g/100 g), total mono- and disaccharide (g/100 g), total fibre (g/100 g), energy (kcal and kjoule/100 g) and sodium content (mg/100 g) was obtained from the packaging information (n = 174). In case packaging information was not available online, the USDA National Nutrient Database for Standard Reference was used (2014, n=63). No information on the nutrient content was available for 24 products, which were therefore excluded from data analyses (Table A1, Appendix A). One product was excluded because of missing taste values. Two products which were profiled in 2006 were left out of the analyses because of recipe reformulations. The food items used in this study, were from the following food groups: chicken, beef & pork, eggs, dairy, mixed dishes, pasta, vegetables, ketchup & other sauces, fats & oils, salty snacks, alcoholic beverages, soft drinks, fruit juice, sandwich spreads, breakfast cereals, sweets & desserts, and herbs & spices (Figure A1, Appendix A). Food grouping was based on the categorization defined by Block[20], which included categories found in the Food Guide Pyramid[7]. Food form groups were obtained using a definition described by Stieger and van de Velde[12]; i.e. liquids, semi-solids and solids (Table A2, Appendix A).

Data analysis

In total 237 foods were included in the data analyses. Analyses were performed using IBM SPSS Statistics (version 22.0, IBM Corp., Armonk, New York, USA). Pearson's correlations were calculated between energy, macronutrient, fibre and sodium content. Simple and multiple linear regression analyses were performed between taste intensity ratings (dependent) and the log-transformed nutrient content (independent). Multiple regression analyses were performed using the hierarchical (forced entry) method. After the initial analyses, multiple regressions were repeated including only the variables that were statistically significant (total model). Food items were left out of the analyses in case they did not contain the nutrient of interest. Data were analysed for all food items together and separately for the food form groups (liquids, semi-solids and solids).

Groups of products were formed using hierarchical cluster analysis on the products' taste intensity values. The number of clusters was decided using Ward's method[21]. Three clusters were identified, which accounted for 72% of the variance (R^2=0.72). Kruskal-Wallis tests were performed to investigate differences in nutrient content between the resulting clusters of food. Mann-Whitney tests were used for post hoc analyses. Bonferroni corrected p-values<0.05/3 were considered statistically significant. Taste-nutrient relationships were studied in each cluster separately in order to study the modifying effect of competing tastes. Partial least squares regression (PLS) was used to visualise the data (Unscrambler, vs. 10.3, Camo Inc., Oslo, Norway).

Results

Distribution of taste intensity and nutrient content across foods

The intensity ratings for sweetness and saltiness used the whole Spectrum scale, for sourness and bitterness the ratings were mainly in the first third of the scale (Figure 1). For sourness and bitterness, respectively 90% and 100% of the values were below the R2 Spectrum reference, for sweetness and saltiness this was about 50%. For sweetness and saltiness, another 35% and 17% of the values were between the R2 and R3 Spectrum reference and 14% and 33% were above the R3 Spectrum reference. The distribution of taste intensity and nutrient content across foods is shown in Table 2.

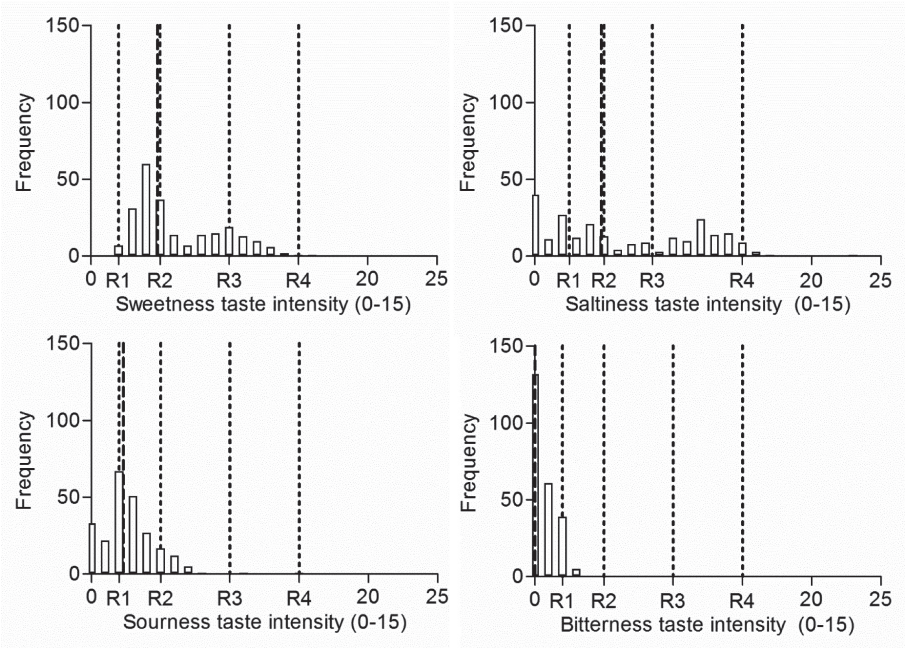

Figure 1 Distribution of taste intensity values on the Spectrum scale (0-15) of 237 food products, R1-R4 represent reference solutions, thick dashed line represents the median for each taste

Table 2 Distribution of taste intensity values and nutrient content of 237 US food products

	0% (min)	25% Q1	50% (median)	75% Q3	100% (max)
Taste intensity					
Sweetness (0-15)	1.5	3.8	4.8	8.8	16.0
Saltiness (0-15)	0.0	1.8	5.0	12.0	22.5
Sourness (0-15)	0.0	1.5	2.3	3.5	15.0
Bitterness (0-15)	0.0	0.0	0.0	1.0	3.0
Nutrient content					
Energy† (kcal/100 g)	0	61	224	382	714
Fat (g/100 g)	0.0	0.8	9.8	17.8	78.6
Carbohydrates (g/100 g)	0.0	4.8	15.8	45.3	99.7
Mono- and disaccharides (g/100 g)	0.0	1.3	5.8	14.1	74.1
Protein (g/100 g)	0.0	1.8	5.0	10.1	28.4
Dietary fibre (g/100 g)	0.0	0.0	0.0	1.3	10.3
Sodium (mg/100 g)	0	68	370	637	4152

†Distribution of energy in kjoule: minimum; 0 kJ, Q1; 254 kJ, median; 939 kJ, Q3; 1603 kJ, maximum; 3000 kJ.

Cluster analysis

Cluster 1 (22% of the data) included neutral foods that were less sweet and salty compared to the other clusters (**Table 3, Figure 2**). Food groups in this cluster differed in their level of (sensory) homogeneity: 95% of all alcoholic beverages, 59% of all dairy (butter (milk) and yoghurt) and 38% of all (low-sweet) breakfast cereals were grouped in this cluster (**Figure 2**). All sweets and desserts, 34% of all dairy (chocolate drinks and whipped-cream) and 63% of all (sweet) breakfast cereals were grouped in cluster 2 (35% of the data), which contained on average more sweet and less salty foods. Cluster 3 (43% of the data) included more salty foods, that were less sweet: 95% of all chicken, 88% of all beef and pork, 90% of all salty snacks, 95% of all mixed dishes and all sauces. Cluster 2 (sweet) was significantly higher in total mono- and disaccharide content, compared to the salty and neutral tasting cluster ($H(3)=105.7$, $p<0.001$). Cluster 3 (salty) was significantly higher in sodium content compared to the sweet and neutral tasting cluster ($H(3)=123.9$, $p<0.001$).

Table 3 Food groups after cluster analysis on the basic taste intensities, and their taste intensity values and nutrient content (median and interquartile range)

	Neutral foods (n = 52)		Sweet foods (n = 83)		Salty foods (n = 102)		Overall p-value‡
	Median	IQR	Median	IQR	Median	IQR	
Taste intensity							
Sweetness (0-15)	3.5^a	1.3	9.9^b	2.9	4.0^a	1.9	<0.001
Saltiness (0-15)	2.0^a	2.0	2.7^b	3.5	12.0^c	3.6	<0.001
Sourness (0-15)	2.0^a	1.5	2.5^a	2.1	2.2^a	1.9	0.746
Bitterness (0-15)	0.0^a	0.0	0.0^a	1.0	0.2^a	1.0	0.562
Nutrient content							
Energy† (kcal/100g)	62^a	90	261^b	333	271^b	257	<0.001
Fat (g/100g)	1.7^a	3.3	4.4^a	15.2	12.6^b	21.0	<0.001
Carbohydrates (g/100g)	4.9^a	10.9	30.8^b	49.4	17.3^c	26.7	<0.001
Mono- and disaccharides (g/100g)	5.1^a	6.0	19.7^b	25.8	2.0^a	5.2	<0.001
Protein (g/100g)	7.1^a	7.4	3.3^b	4.3	8.4^a	10.2	<0.001
Dietary fibre (g/100g)	0.0^a	0.0	0.3^b	1.3	0.0^b	1.6	0.002
Sodium (mg/100g)	105^a	144	70^a	272	633^b	396	<0.001

† Median (IQR) of energy in kjoule: 260 (378) neutral foods, 1097 (1399) sweet foods, 1137 (1079) salty foods.
‡ Kruskal-Wallis p-values are shown for the overall group comparisons.
^{a,b,c} Superscript letters indicate significant differences ($p<0.05/3$, Mann-Whitney), same letters indicate no significant difference between median values.

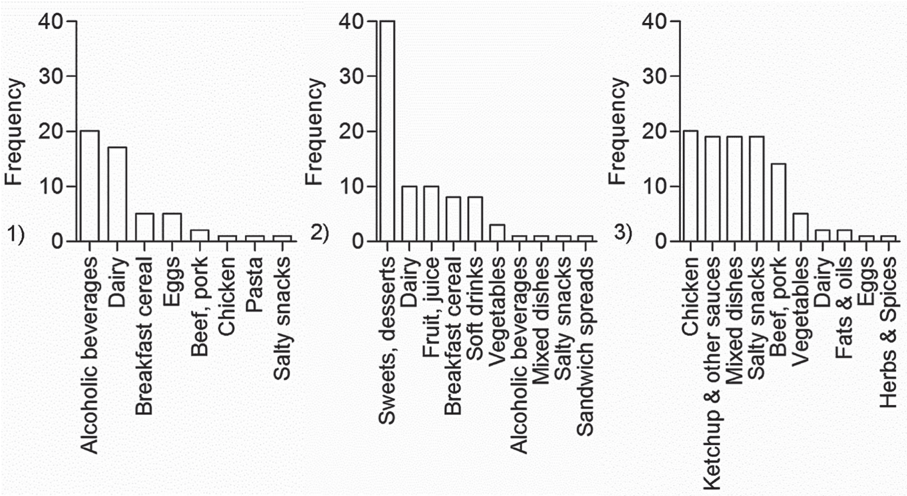

Figure 2 Frequency (number of food products) from each food group for cluster 1 (neutral), 2 (sweet) and 3 (salty)

The association between taste intensity and nutrient content

A positive association was found between sweetness and total mono- and disaccharide content (Figure 3 and Table 4) and between sweetness and carbohydrate content. An inverse association was found between sweetness and protein content, dietary fibre and sodium content. Sweetness was not associated with any of the other nutrients (including energy content). In the total model ($r=0.71$), sweetness was best explained by mono- and disaccharide content ($\beta=3.7$, $p<0.01$) and sodium content ($\beta=-1.1$, $p<0.01$); other nutrients did not show any significant associations.

Salt taste intensity was positively associated with sodium (Figure 3) and protein and fat and energy content. A negative association was found between salt taste intensity and total mono- and disaccharide content. In the total model ($r=0.82$), saltiness was best explained by sodium content ($\beta=4.7$, $p<0.01$), total mono- and disaccharide content ($\beta=-4.7$, $p<0.01$) and carbohydrate content ($\beta=1.4$, $p<0.05$).

Sourness was negatively associated with carbohydrate content, energy content, protein content and dietary fibre content. Combining all predictors into one model ($r=0.38$), sourness was best explained by protein content ($\beta=-1.7$, $p<0.01$) and sodium content ($\beta=1.0$, $p<0.01$). No associations were found for bitterness.

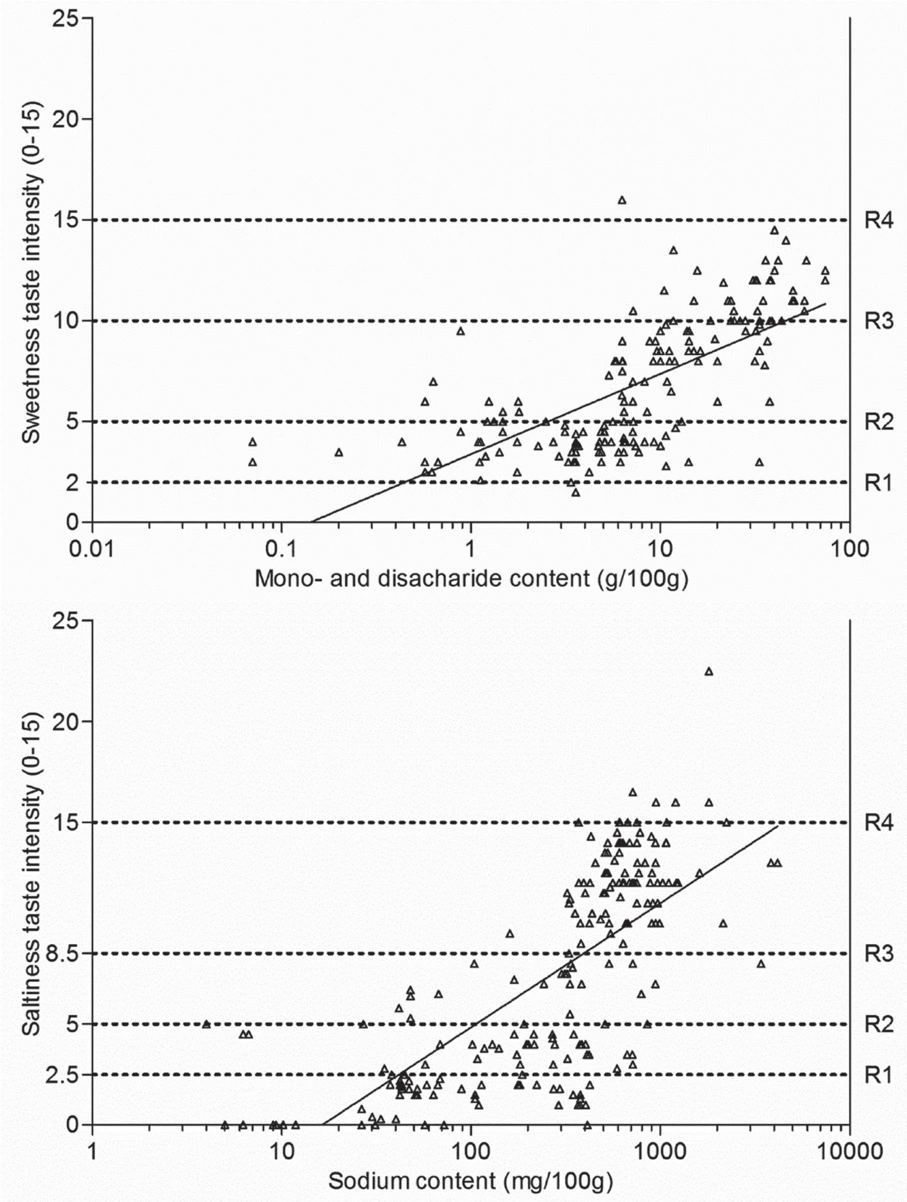

Figure 3 The associations between a) sweetness and mono- and disaccharide content (r=0.71, p<0.001, n=179) and b) saltiness and sodium content (r=0.72, p<0.001, n=208)

Table 4 Correlations (Pearson's) between taste and nutrient content across 237 food items

	Energy (kcal)	Fat (g)	Protein (g)	Total carbohydrates (g)	Mono- and disaccharides (g)	Fibre (g)	Sodium (mg)
Sweet	0.11	0.02	-0.27*	0.42*	0.71*	-0.20**	-0.37*
Salt	0.43*	0.37*	0.39*	0.02	-0.59*	0.18	0.72*
Sour	-0.15**	<0.01	-0.25*	-0.16**	0.09	-0.38*	0.01
Bitter	-0.03	0.06	-0.11	-0.03	-0.03	0.09	0.04

*p<0.001.
**p<0.05.

PLS regression analysis showed that the most discriminating tastes were sweetness and saltiness (**Figure 4**). The first component explained most of the variation (29% in X, 36% in Y) and was related to the salty taste, sodium, protein and fat content. The second component (32% in X, 12% in Y) was related to the sweet taste, mono- and disaccharide, carbohydrate, and dietary fibre content. Similarly, Pearson's correlations between nutrients showed that energy content was positively associated with fat and carbohydrate content and, to a lesser extent, with dietary fibre, mono- and disaccharide, sodium and protein content (**Table 5**). Sodium content was positively associated with protein, fat and dietary fibre content, and negatively associated with mono- and disaccharide content. Mono- and disaccharide content was positively associated with carbohydrate content and dietary fibre content, and negatively associated with protein content.

Table 5 Correlations (Pearson's) between nutrients across 237 food items

	Energy (kcal)	Fat (g)	Protein (g)	Total carbohydrates (g)	Mono- and disaccharides (g)	Fibre (g)
Energy (kcal)	-					
Fat (g)	0.79*	-				
Protein (g)	0.18*	0.13**	-			
Total carbohydrates (g)	0.67*	0.07	-0.11	-		
Mono- and disaccharides (g)	0.27*	-0.11	-0.34*	0.68*	-	
Fibre (g)	0.42*	0.10	0.09	0.57*	0.14**	-
Sodium (mg)	0.27*	0.25**	0.32*	0.06	-0.22*	0.17**

*p<0.01.
**p<0.05.

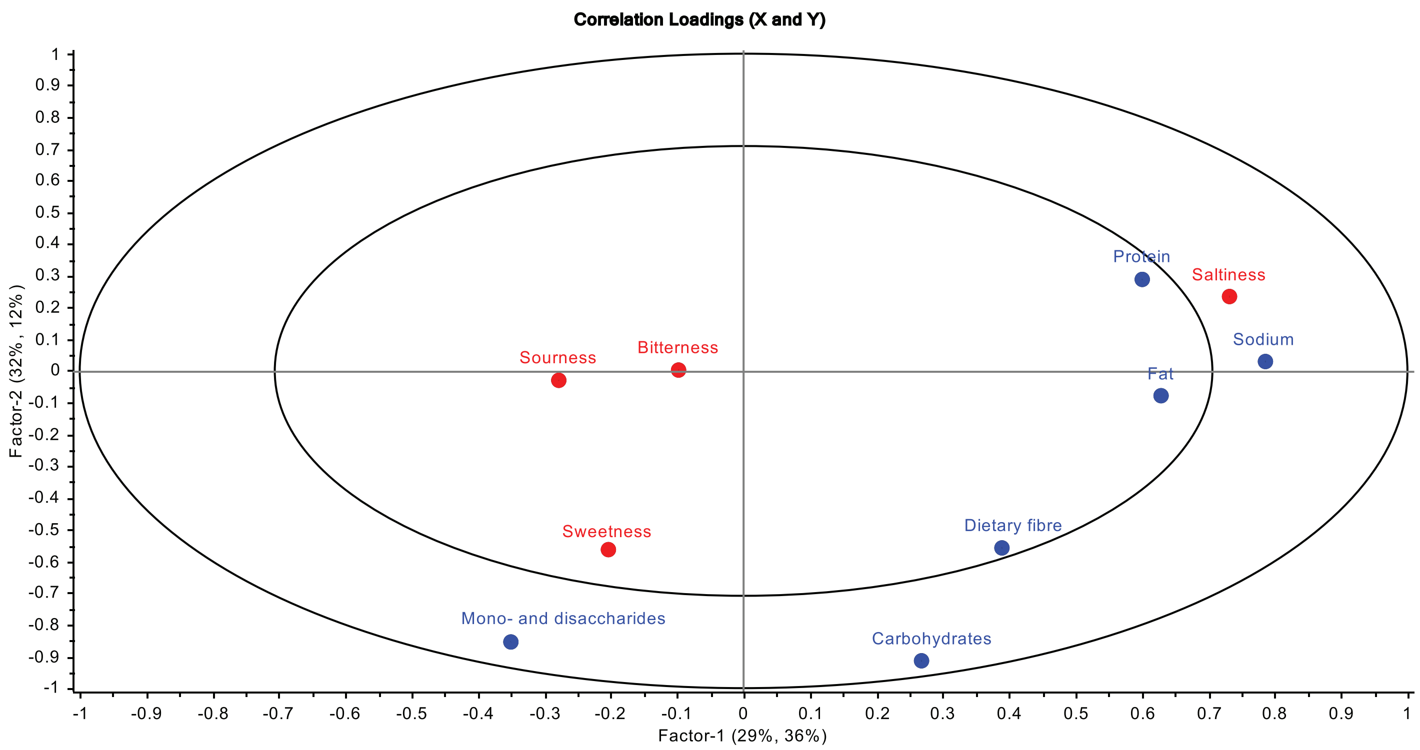

Figure 4 PLS with X as the nutrient content and taste intensity data as Y. Correlation loadings in X and Y (weighted, 1/SD). PC-1 and PC-2 explain 36% and 12% of the variation in Y and 29% and 32% of the variation in X

The modifying effect of food form and competing tastes

Total mono- and disaccharide content was positively associated with sweetness in the different food form groups ($p<0.05$, Table 6). The strength of the association between sweetness and total mono- and disaccharide content was not significantly different between liquids, semi-solids and solids. For saltiness, taste intensity was associated with sodium content in semi-solids and solids ($p<0.001$), but not in liquids ($p>0.05$).

The association between sweetness and mono- and disaccharide content was stronger in the sweet cluster (r=0.55, CI 0.37-0.69) than in the salty cluster (r=0.33, CI 0.11-0.52). The association between saltiness and sodium content was stronger in the salty tasting cluster than in the sweet tasting cluster, though this was not significant (Table 6).

Table 6 Correlation parameters (r, CI) between taste and nutrient content, shown for the total dataset, per food form group, and the sweet and the salty cluster†

	Total	Liquids	Semi-solids	Solids
Sweet taste intensity and mono – and disaccharide content (g)				
Total	0.71 (0.63, 0.78) (n=179)*	0.67 (0.40, 0.81)* (n=40)	0.43 (0.09, 0.68)** (n=31)	0.79 (0.71, 0.85)* (n=108)
Sweet cluster	0.55 (0.37, 0.69) (n=79)*	0.35 (-0.05, 0.66) (n=25)	-	0.48 (0.22, 0.68)* (n=46)
Salty cluster	0.33 (0.11, 0.52) (n=77)*	-	0.45 (0.01, 0.74)** (n=20)	0.07 (-0.20, 0.33) (n =54)
Salt taste intensity and sodium content (mg)				
Total	0.72 (0.65, 0.78) (n=208)*	0.12 (-0.21, 0.43)‡ (n=38)	0.82 (0.66, 0.91)* (n=33)	0.67 (0.57, 0.76)* (n=134)
Sweet cluster	0.30 (0.08, 0.50) (n=74)	0.36 (-0.08, 0.80) (n=23)	-	0.20 (-0.10, 0.47) (n=45)
Salty cluster	0.39 (0.21, 0.54) (n=102)*	-	0.40 (-0.01, 0.69) (n=24)	0.47 (0.27, 0.63)* (n=75)

* $p<0.001$.
** $p<0.05$.
† Data is not shown for salty liquids (n=3) and sweet semi-solids (n=8) as these food groups were not well represented in our database.
‡ After removing three salty food items, Pearson's correlation coefficient did not remain significant.

Discussion

The current study aimed to investigate the association between taste intensity and nutrient content, and to explore a possible effect of food form on this relationship, in a range of commercially available foods from the United States. As hypothesized, a positive association was found between sweet taste intensity and total mono- and disaccharide content, and between salt taste intensity and sodium and fat and protein content. Energy content was positively associated with saltiness but not with sweetness. Contrary to expectations, associations between taste intensity and nutrient content were not stronger in liquids compared to semi-solids and solids. However, we did find a potentially modifying effect of competing tastes on the relationship between taste intensity and nutrient content.

Our results are in line with earlier findings by Lease et al.[(11)] and van Dongen et al.[(10)]; who found that sweetness was positively associated with mono- and disaccharides, and salt and umami taste intensity were both positively associated with sodium and protein content. Moreover, our results show a positive association between energy content and salt taste intensity, but not sweet taste intensity. This may be explained by the positive association found between sodium and fat content, and thus energy density, which is likely underlying these findings. Similarly, Lease et al.[(11)] found a positive association between salt taste intensity and fat and energy content, but not between sweet taste intensity and energy content. Overall, these observations indicate that in particular sweetness has a signalling role for the presence of mono-and disaccharides, and saltiness for the presence of sodium. Moreover, future studies should consider a potential role for salt taste preferences in the overconsumption of energy and the development of obesity.

It is known from studies with model foods that food form can be a modifying factor in the relationship between taste and nutrient content[(12,17,18)]. However, our results did not confirm a stronger association between taste intensity and nutrient content in liquids compared to semi-solids and solids. This suggests that the modifying effect of food form on the relationship between taste and nutrients is more difficult to demonstrate in real-life foods than in model foods, which are designed to differ in only one aspect.

Another potentially modifying factor on the relationship between taste and nutrients is the suppression of tastes by other tastes. In our study, we found that the association between sweetness and mono- and disaccharide content was significantly stronger in sweet foods than in salty foods. Similarly, a stronger association was found between saltiness and sodium content in salty foods than in sweet foods, yet this was not significant. These findings suggest a suppressive effect of sweetness on saltiness and vice versa. This may explain the weaker associations between saltiness and sodium content in processed foods found by van Dongen et al.[10], i.e. r=0.54 instead of r=0.72 in our study. That is, relatively more sweet foods (n=19) than salty-savoury foods (n=6) were studied by van Dongen, whereas our database consisted of more salty foods (n=102) than sweet foods (n=83). Indeed, previous studies have shown suppression of tastes by other tastes at higher concentrations in taste mixture solutions[15,16]. This is confirmed by recent findings by Lease et al.[11] who found that saltiness was unrelated with sodium content in more complex foods and dishes, with competing taste, texture and flavour attributes. The suppressive effect of tastes may result in a discrepancy between taste intensity and nutrient content and may potentially affect our ability to regulate food intake[10,11].

In line with previous findings, our results showed that saltiness was positively associated with both sodium and protein content, van Dongen[10] found an association of r=0.54 and r=0.52, respectively. It might be that products high in saltiness, were also high in umami taste. Umami is a taste derived from monosodium glutamate (MSG), guanosine monophosphate (GMP) and inosine monophosphate (IMP) and is described as having a savoury taste[22]. These umami-tasting compounds occur naturally in foods that are rich in protein (e.g. fish, aged or cooked meat), but also in foods that are not rich in protein (e.g. tomatoes, mushrooms). To enhance flavour, MSG may also be added to processed foods[23]. Unsurprisingly, the salty and umami taste often occur side-by-side[10,11,24]. Umami taste ratings were not obtained for the products in our database, however umami is measured by the Spectrum™ method and other methods of descriptive analysis. Therefore, using the currently available data, the observed findings could be underlying a true relationship between umami and protein content. Future studies should include the umami rating scale, for example the scale developed by Martin et al.[24], to confirm a nutrient-signalling function for the umami taste.

At this time, it is unknown to what extent the associations between taste and nutrient content can be generalized to foods that are eaten on a daily basis in the United States. Although the foods in our database were from various food groups, the majority consisted of fast foods and/or snack products. Snack foods and beverages contribute to ~25% of total energy intake in the US population[20]. Moreover, about 80% of daily salt intake is derived from packaged and restaurant foods[25]. Thus, foods in our database are important contributors to energy and sodium intake in the US diet. It remains to be investigated what it means for food intake regulation if an increasing proportion of our diet consists of processed foods[26]. Between products, large variations exist in the relationship between taste and nutrient content. For example, artificially sweetened diet soda may be similar to its regular counterpart in perceived sweet taste intensity, but is highly different in mono- and disaccharide content. Therefore, taste alone is not the only factor regulating our nutrient intake. Indeed, studies have shown that not only taste, but also the texture, sight and smell of food may serve as a (learned) signal for the post-ingestive consequences of foods[27–29].

In conclusion, our findings suggest that sweet and salt taste intensity can signal the presence of nutrients, in particular mono- and disaccharides and sodium, in a range of commercially available foods from the United States. However, the association between taste and nutrient content may be weaker in complex foods with competing tastes that may supress other tastes. The modifying effect of food form on this relationship is more difficult to demonstrate in real-life foods than in model foods. Further research should select and profile those foods that are most often consumed and that contribute to the majority of the energy intake, using food intake data that is representative of a larger population. Profiling foods on the basic tastes (including umami), but also fat taste and/or texture may provide valuable insights in the extent to which tastes signal macronutrient and sodium content in our current diet.

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Chapter 3

Evaluation of dietary taste patterns as assessed by FFQ against 24-h recalls and biomarkers of exposure

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Abstract

Taste plays a key role in food choice and dietary patterns, but studies on taste profiles are limited. We previously assessed dietary taste patterns by 24h recalls (24hR), but for epidemiological studies food frequency questionnaires (FFQ) may also be suitable. This study compared dietary taste patterns based on FFQ against 24hR and biomarkers of exposure. A taste database including 467 foods' sweet, sour, bitter, salt, umami and fat sensation values was combined with food intake data to assess dietary taste patterns: the contribution to energy intake of 6 taste clusters. The FFQ's reliability was assessed against 3-d 24hR and urinary biomarkers for sodium (Na) and protein intake (N) in Dutch men (n=449) and women (n=397) from the NQplus validation study (mean age 53±11y, BMI 26±4 kg/m^2). Correlations of dietary taste patterns ranged from 0.39-0.68 between FFQ and 24hR ($p<0.05$). Urinary Na levels, but not N levels, were positively associated with % energy intake from 'salt, umami & fat' tasting foods (Na; FFQ, r=0.24, 24hR, r=0.23, $p<0.001$, N; FFQ, r=0.08, p=0.1394, 24hR, r=0.05, p=0.3427). The FFQ's reliability against 24hR was acceptable to good for ranking of adults' dietary taste patterns. Associations between dietary taste patterns and urinary Na and N were similar for FFQ and 24hR. These findings suggests that both FFQ and 24hR can be used in combination with our taste database, to investigate potential relationships between dietary taste patterns and subgroups at risk of chronic diseases such as cardiovascular disease.

Introduction

The role of taste in dietary intake is of particular interest from a nutritional perspective, as taste plays a key role in food choice and development of dietary patterns[1]. In addition, the taste of food may serve as an early signal of its nutrient content[2–4]. This nutrient-signalling function of taste may affect food choice and satiation and thereby food intake[5–8]. Studying dietary patterns from a taste perspective - and not only a nutritional perspective - can provide a deeper understanding of the role of taste in dietary intake. Moreover, dietary taste patterns can provide novel insights into subgroups at risk of weight gain, obesity and chronic diseases such as cardiovascular disease and type 2 diabetes.

Research on the role of taste in dietary intake is still in its infancy. To study taste-related dietary intake, it is essential to objectively quantify the taste intensity values across foods consumed within a population using a trained panel[9]. Training increases the panel's internal consensus, reproducibility and discriminative power[10–12]. Food nutrient composition databases exist globally, yet we are aware of only three food taste databases[2,3,13].

To our knowledge, we are the first who assessed dietary taste patterns in the Netherlands[14]. In this previous study, we combined a taste database containing sweet, sour, bitter, salt, umami and fat sensation values of 476 foods with 2-day 24-hour recalls (24hR) in two Dutch study populations. The percentage of energy intake from 6 taste groups was similar for both study populations, suggesting that dietary taste patterns can be assessed by combining 24hR with our taste database. However, large-scale epidemiological studies often use food frequency questionnaires (FFQ). Previous studies have validated FFQ to 24hR[15–17], but this was done for the assessment of food, energy and nutrient intake and not for dietary taste patterns.

FFQ data contains less detailed information on food preparation and no data on single foods as 24hR data do[18]. Therefore, the method of dietary assessment may affect results concerning dietary taste patterns. It is therefore important to compare dietary taste patterns based on FFQ data with an often used reference method such as 24hR. In addition, because of correlated errors between FFQ and 24hR it is generally preferred to validate these methods against biomarkers of exposure[18].

The current study aimed to compare dietary taste patterns based on FFQ against 24hR and biomarkers of exposure. Previous studies have found positive associations between salt taste intensity and sodium content of foods, and between umami taste and protein content[2–4]. Therefore, it was hypothesized that urinary Na and N levels would be positively associated with the percentage of energy intake from ‘salt, umami & fat’ tasting foods.

Methods

Study design and population

The Nutrition Questionnaires (NQplus) study was conducted between May 2011 and February 2013 in Wageningen and surroundings[19], including in total 2,048 men and women aged between 20-70 years old. Half of the study population (n=1,113) completed 3-6 telephone- and 3 web-based 24 hour recalls. For the current analyses we used only the first three recalls by telephone. Telephone-based recalls were held by trained dieticians and processed using the software program Compl-eat™ (www.compleat.nl)[20]. In addition, more than half of the study population (n=1,653) completed a 180-item FFQ[16,21]. In total 858 participants completed both the FFQ and at least 3 telephone-based 24 hour recalls. Individuals who were pregnant (n=2), underweight (n=5), without information on educational level (n=4) or BMI (n=1) were excluded from the analyses. In total we included dietary intake data from 449 men and 397 women with a mean age of 53±11 y and BMI of 26±4 kg/m^2 (Table B1, Appendix B). Height and weight were measured by the investigators. Weight status subgroups were categorized as follows: normal-weight (BMI 18.5-25.0 kg/m^2), overweight and obese (BMI >25.0 kg/m^2). Educational level was categorized into low or medium (no education or primary or lower vocational education, lower secondary or intermediate vocational) and high (higher secondary or higher vocational education, or university). Age was categorized into younger individuals (20-49 y) and older individuals (50-70 y).

Biomarkers of dietary exposure

Participants were requested to collect urine during a 24-hour period for one or two days (n=821). Para-aminobenzoid acid (PABA) was used to check for completeness (PABA recovery >78%; n=726) of the urine sample(s) and was measured using the HPLC method[22]. The urinary recovery biomarker for sodium intake (Na) was measured (n=726) with an ion-selective electrode on a Roche 917 analyser (Indianapolis, USA). Total 24-hour excretion (n=355) of the urinary recovery biomarker for protein intake (N) was determined by the Kjeldahl technique (Foss Kjeltec™ 2300 analyser)[23]. More details on the 24-hour urine collection, analyses and storage have been described elsewhere[19].

Misreporting of daily energy intake

Underreporting of energy intake was evaluated by calculating the ratio between reported energy intake (EI) and basal metabolic rate (BMR) for both the FFQ and 24hR data. Schofield equations were used to estimate BMR from body weight and height, taking into account age and sex[24]. The mean ratio of EI to BMR was 1.30 (SD 0.36) in the FFQ and was 1.32 (SD 0.29) in the 24hR.

Taste database

Panellists

Panellists were trained to evaluate the intensity of sweet, salt, sour, bitter, umami and fat sensation using a modified Spectrum™ method and received this intensive training for in total 63 hours over six months.

Food selection and preparation

Foods for profiling (n=467) were selected based on the most recent Dutch National Food Consumption Survey (DNFCS 2007-2010)[25]. The DNFCS is representative of the Dutch population regarding age, sex, region, degree of urbanization and educational level. In the DNFCS, diet was assessed for in total 3,819 Dutch individuals aged 7-69 years. For the selection of foods we used dietary intake data of 1402 adults between 19-50 years old (704 men, 698 women). Foods were selected based on high consumption frequency, largest contribution to the consumption of energy and macronutrients and largest contribution to the variation in energy intake.

Dietary taste patterns

Classification of foods in taste groups

Groups of foods were formed within the taste database using hierarchical cluster analyses on foods' and food groups' mean taste intensity values. The number of clusters was decided using Ward's method[26]. Six taste groups were identified that accounted for 73% of the total variance in taste (R^2=0.73). The taste groups were named as 'neutral', 'fat', 'sweet & sour', 'bitter', 'sweet & fat' and 'salt, umami & fat' based on their mean taste intensity values (Table B2, Appendix B).

Twenty-four hour recalls

Foods reported in the 24-hour recalls and coded according to the Dutch food composition table[27] were matched with foods in the taste database. For assigning taste values to untested foods, we used the average taste intensity values of foods within food groups as described previously[14]. For example, we calculated average taste intensity values of profiled foods in the food group 'bread' and assigned these values and the corresponding cluster to all untested foods in this food group. We identified when coffee and tea were consumed with sugar and/or milk as described previously[14]. Subsequently, we assessed dietary taste patterns: the percentage of daily energy intake contributed by each of the 6 taste food groups. We assessed macronutrients' contribution to the % of energy intake and absolute protein and sodium intake, stratified by the 6 taste clusters (Tables B4 and B5, Appendix B).

Food frequency questionnaire

The relative contribution of single foods to food items, based on consumption in the DNFCS 2007-2010, was used to calculate weighted mean taste intensity values for food items[25]. Subsequently, we performed hierarchical cluster analyses on food items' mean taste intensity values, resulting in 6 taste groups that were similar to the 24hR taste groups (Tables B3, B4 and B5, Appendix B). Marmite appeared in a separate 'salt & umami' tasting cluster and this food item was therefore excluded from the cluster analyses. The 6 clusters accounted for 79% of the total variance in taste (R^2=0.79).

Statistical analyses

All statistical analyses were performed using SAS 9.3. (SAS Institute, Inc., Cary, NC, USA). Agreement of the dietary assessment methods at group level for dietary taste patterns was calculated as: {[([group mean of FFQ] / [group mean of (individual mean of) 24hR]) *100]-100} and expressed as percentage difference. Group-level differences in mean dietary taste patterns between the FFQ and 24hR were tested using paired-samples t-tests. Ranking of the participants with respect to dietary taste patterns based on FFQ and 24hR data was studied by examining the correlations and cross-classification of tertiles in dietary taste patterns.

Pearson correlations were used for normally distributed variables (that is, the percentage of energy intake from 'neutral' and 'salt, umami & fat' tasting foods) and Spearman correlations for skewed variables (the four other taste groups). The 95% CI of the correlation coefficients were calculated by Fisher's Z-transformation. Cohen's Kappa was used for testing cross-classification, significant kappa values indicate that agreement between the methods is higher than would be expected by chance. The attenuation factors of the association between dietary taste patterns based on the FFQ and 24hR were estimated as the slope in the linear regression of the reported intake from 24hR on the reported intake from FFQ. The 95% CI of the attenuation factors were calculated as: ±1.96*SE.

Results

Dietary taste patterns at group level

At group level, the percentage of energy intake from 'sweet & sour', 'fat', 'bitter' and 'sweet & fat' tasting foods was significantly different between the FFQ and 24hR (Table 1, $p<0.001$). Group-level bias ranged from -16% for 'sweet & fat' tasting foods to 29% for 'fat' tasting foods.

Ranking of participants concerning dietary taste patterns

Correct classification of participants (same tertile) ranged from 46% for energy intake from 'salt, umami & fat' tasting foods to 61% for energy intake from 'bitter' tasting foods when comparing FFQ and 24hR (Table 1). Classification of participants in the opposite tertile ranged from 5% for energy intake from 'bitter' tasting foods to 13% for energy intake from 'salt, umami & fat' tasting foods. The correlation coefficients ranged from 0.39 for energy intake from 'salt, umami & fat' to 0.68 for energy intake from 'bitter' tasting foods.

Dietary taste patterns at the individual level

At the individual level, the Bland-Altman plots showed both over- and underestimation of dietary taste patterns assessed by FFQ compared to 24hR (Figure 1).

Table 1 Comparison of food frequency questionnaires (FFQ) with three telephone-based 24-h recalls (24hR) concerning dietary taste patterns at group level, relative difference, correlation coefficients, attenuation factors and cross-classification, of 449 men and 397 women (N_{total}=846) in the NQplus study†

	FFQ		24hR							Cross-classification	
	Energy %										
Taste group	Mean	SD	Mean	SD	Group level bias %	Correlation coefficient	95% CI	Attenuation factor	95% CI	% correct	% opposite
Sweet/sour	10*	5	11*	6	-6	0.54	(0.49 – 0.59)	0.55	(0.49 - 0.61)	52	8
Neutral	39	8	39	9	0	0.47	(0.42 – 0.52)	0.49	(0.43 - 0.55)	49	10
Fat	9*	5	7*	4	29	0.40	(0.35 - 0.46)	0.33	(0.28 - 0.38)	46	12
Bitter	6*	5	5*	5	12	0.68	(0.64 – 0.71)	0.68	(0.64 - 0.73)	61	5
Salt/umami/fat	23	8	23	8	0	0.39	(0.33 – 0.44)	0.39	(0.32 - 0.45)	46	13
Sweet/fat	12*	6	14*	8	-16	0.44	(0.38 – 0.49)	0.57	(0.50 - 0.65)	50	11

* Indicates significant difference between FFQ and 24hR as measured by paired samples t-test ($p<0.001$).
†Group level bias = [([group mean of FFQ] / [group mean of (individual mean of) 24hR])*100]-100; attenuation factor (95% CI) estimated as the slope in the linear regression of the reported intake from 24hR on the reported intake from FFQ; cross-classification into tertiles

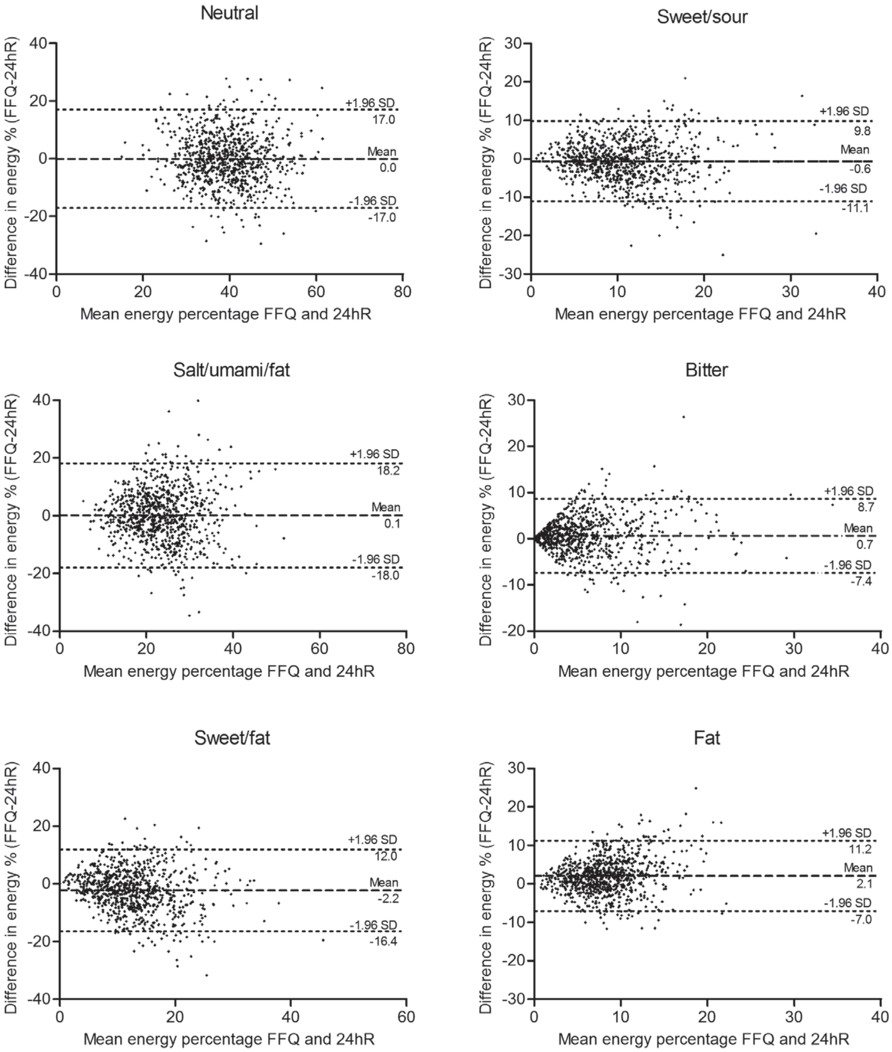

Figure 1 Comparison of the difference in the percentage of daily energy intake from 6 taste groups between FFQ and 24-h recalls (24hR) against the mean of FFQ and 24hR with 95% limits of agreement for the total population (N_{total}=846) in the NQplus study

Dietary taste patterns by individual characteristics

Sex

In both FFQ and 24hR, women consumed relatively more energy from ‘sweet & sour’ (and ‘sweet & fat’ tasting foods than men, whereas men consumed relatively more energy from ‘bitter’ and ‘salt, umami & fat’ tasting foods than women ($p<0.05$, Table B6, Appendix B), adjusted for age, BMI and educational level.

Weight status

Overweight and obese individuals consumed relatively more energy from ‘salt, umami & fat’ tasting foods than normal-weight individuals (p<0.05, Figure 2 and Table B6, Appendix B), both in FFQ and 24hR and adjusted for age and educational level.

Validation of dietary taste patterns using urinary biomarkers

Urinary Na was significantly positively associated with the percentage of energy intake from ‘salt, umami & fat’ tasting foods based on both FFQ and 24hR data (Table 2; FFQ, r=0.24, and 24hR, r= 0.23, both p<0.001). In contrast, urinary N was not significantly associated with the percentage of energy intake from ‘salt, umami & fat’ tasting foods (FFQ, r= 0.08, p=0.139, 24hR, r= 0.05, p=0.343). However, we did find significant positive associations between absolute protein intake (g) from ‘salt, umami & fat’ tasting foods and urinary N (FFQ, r 0.29, 24hR, r 0.32, both p<0.001, Table B5, Appendix B). For total absolute protein intake and urinary N we found significant positive associations of 0.44 and 0.50 for the FFQ and 24hR (p<0.001), respectively.

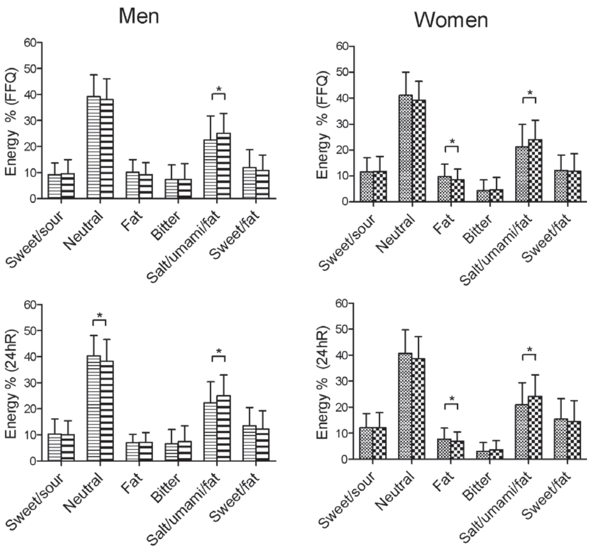

Figure 2 Percentage of daily energy intake (mean±SD) from each taste group stratified by sex and weight status[†]

[*] Indicates significant difference between subgroups as measured by MANCOVA (multivariate ANCOVA) - including all tastes and subgroups. If the overall effect was significant (p<0.05), ANCOVA was used to compare weight status subgroups within each taste group (p<0.05, Bonferroni corrected).

[†]Normal-weight men ( ), n=160, overweight and obese men ( ), n=289, normal-weight women ( ), n=216, overweight and obese women ( ), n=181.

Table 2 Spearman correlation coefficients between urinary recovery biomarkers for sodium (Na) and protein (N) intake and the percentage of daily energy intake from each taste group assessed by FFQ and 3-d 24hR

	Urinary Na (n=726)				Urinary N (n=355)			
	FFQ		24hR		FFQ		24hR	
Taste group	Correlation	95% CI	Correlation	95% CI	Correlation	95% CI	Correlation	95% CI
Sweet/sour	-0.18¥	-0.25, -0.11	-0.19¥	-0.26, -0.12	-0.07	-0.17, 0.03	-0.07	-0.17, 0.03
Neutral*	-0.12‡	-0.19, -0.05	-0.06	-0.13, 0.01	0.05	-0.05, 0.15	0.11†	0.01, 0.21
Fat	0.03	-0.04, 0.10	0.01	-0.06, 0.08	-0.06	-0.16, 0.04	-0.01	-0.11, 0.09
Bitter	0.08†	0.01, 0.15	0.14¥	0.07, 0.21	0.19¥	0.09, 0.29	0.18¥	0.08, 0.28
Salt/umami /fat*	0.24¥	0.17, 0.30	0.23¥	0.16, 0.29	0.08	-0.02, 0.18	0.05	-0.05, 0.15
Sweet/fat	-0.06	-0.13, 0.01	-0.13¥	-0.2, -0.06	-0.17‡	-0.27, -0.07	-0.22¥	-0.31, -0.12

†p<0.05, ‡p<0.01, ¥p<0.001
*Pearson's correlation

Discussion

The current study aimed to compare dietary taste patterns based on FFQ against 24hR and biomarkers of exposure. Correlations of dietary taste patterns ranged from 0.39-0.68 between FFQ and 24hR. Urinary Na levels, but not N levels, were positively associated with the percentage of energy intake from 'salt, umami & fat' tasting foods in the FFQ and 24hR. We found similar results concerning dietary taste patterns based on FFQ and 24hR by sex and weight status.

We studied ranking of participants based on FFQ and 24hR by examining the correlations and cross-classifications. Although no previous studies exist that have compared dietary taste patterns between FFQ and 24hR, we can interpret our results if compared with results from previous validation studies on Dutch food groups and macronutrient intakes. The correlations between methods were of similar magnitude as the correlations reported by Sluik et al.[(17)] and Streppel et al.[(16)], who both compared a FFQ with 3 days of 24hR within a Dutch adult population. In these studies, correlation coefficients of absolute intakes (g) of the majority of the food groups varied between 0.3 and 0.6. Correlation coefficients for the percentage of energy from macronutrients were lowest for total fat (r=0.27 and r=0.43, respectively) and highest for alcohol (r=0.83) and total carbohydrates (r=0.66). This is similar to our findings; we found low correlations for energy intake from 'fat' and higher correlations for energy intake from 'bitter' tasting foods such as alcoholic beverages.

In the current study, approximately half of the participants were classified in the same tertile of dietary taste patterns, which is similar to the results from cross-classification between a FFQ and repeated 24hR on food groups[(28)] and macronutrients[(29)]. Only a small proportion of participants were classified in the opposite tertile (~10%), which corresponds to a good outcome on cross-classification[(30)]. The weighted Kappa showed fair to moderate agreement. Thus, the results from cross-classification and the correlations between the two dietary assessment methods suggest that ranking of participants was acceptable to good based on the FFQ for dietary taste patterns.

Because of correlated errors between FFQ and 24hR we included the urinary recovery biomarkers for sodium (Na) and protein (N) intake and investigated potential associations with dietary taste patterns. As hypothesized, we found significant positive associations between urinary Na and the percentage of energy intake from 'salt, umami & fat' tasting foods in both the FFQ and 24hR. These associations are in line with previous studies on individual foods that have found significant positive associations between salt taste intensity and Na content[2–4]. However, associations between urinary Na and dietary taste patterns were modest for both FFQ and 24hR. An explanation might be that foods from other taste groups also contribute to Na intake in our study. For example, neutral tasting bread is one of the main contributors to Na intake in the Netherlands[31]. Indeed, major contributions to sodium intake were from 'neutral' (FFQ, 893±337 mg and 24hR, 961±369 mg) and 'salt, umami & fat' (FFQ, 997±507 mg and 24hR, 1247±572 mg) tasting foods in our study. Thus, our findings were within the expected range, in particular given the absence of data on salt added during cooking in the dietary assessment methods and in our taste database. Nevertheless, associations between urinary Na and dietary taste patterns were of similar strength for both dietary assessment methods, supporting the reliability of the FFQ in assessing dietary taste patterns.

In contrast with our expectations, we did not find significant positive associations between urinary N and the percentage of energy intake from 'salt, umami & fat' tasting foods. However, we found significant positive associations between total protein intake (g) and urinary N for the FFQ and 24hR. Major contributions to protein intake were both from foods tasting 'neutral' (e.g. milk; % energy, FFQ, 6±2 and 24hR, 7±2) and foods tasting 'salt, umami & fat' (e.g. meat, cheese; % energy, FFQ, 6±2 and 24hR, 6±3) and this may explain why urinary N is not clearly associated with the percentage of energy intake from these taste groups. Moreover, we did find significant positive associations between absolute protein intake (g) from 'salt, umami & fat' tasting foods and urinary N. Thus, we found similar associations between urinary N and dietary taste patterns in the FFQ and 24hR that were within the expected range because we measured % energy intake and not absolute protein intake.

At group level, energy intake from 'sweet & fat' tasting food was significantly lower and from 'fat' tasting foods was higher in the FFQ compared to 24hR. This might be explained by underreporting of foods, e.g. because of social desirable answering[18]. Yet, underreporting of energy intake was equally present in both dietary assessment methods. Moreover, the ratio of energy intake to basal metabolic rate almost reached the expected ratio of 1.35 which is needed to maintain energy balance based on a sedentary or light activity lifestyle[32]. Nevertheless, differential misreporting of specific foods remains a possible explanation for these differences in dietary taste patterns between the dietary assessment methods.

Importantly, we found similar differences in dietary taste patterns by sex and weight status based on the FFQ and 24hR, which were in line with previous findings based on 2-day 24hR in the Netherlands[14]. Women consumed relatively more energy from foods tasting ‘sweet & fat’ and ‘sweet & sour’ than men, whereas men consumed relatively more energy from foods tasting ‘bitter’ and ‘salt, umami & fat’ than women. In addition, overweight and obese men and women consumed relatively more energy from ‘salt, umami & fat’ tasting foods than normal-weight men and women. These findings suggest that both the FFQ and 24hR can be used to study differences in dietary taste patterns by population subgroups.

In conclusion, the FFQ’s reliability was acceptable to good for ranking of adults based on dietary taste patterns, as compared against 24hR. In addition, we found associations between dietary taste patterns and urinary Na and N that were similar in both dietary assessment methods. Dietary taste patterns by sex and weight status were also similar based on FFQ and 24hR. These findings suggests that both FFQ and 24hR can be used in combination with our taste database, to investigate potential relationships between dietary taste patterns and subgroups at risk of chronic diseases such as cardiovascular disease.

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Chapter 4

Development of dietary taste patterns in early childhood and its associations with maternal and child characteristics

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Abstract

Taste is a key driver of food choice and intake. The role of taste in the diet in early-life may influence later taste preferences and food choice. However, dietary taste patterns in early-life are unexplored. We aimed to assess dietary taste patterns and associations with maternal and child characteristics in children aged one and two years in a large population-based cohort. A taste database - containing 500 foods' taste intensity and fat sensation values - was combined with two similar food-frequency questionnaires in one year olds (n=3,629) and two year olds (n=844) in the Generation R Study. Subsequently, energy intake from five taste groups: 'neutral', 'sweet & sour', 'sweet & fat', 'fat' and 'salt, umami & fat' was assessed. In one year olds the majority of energy intake was obtained from 'neutral' tasting foods (64%), this was substantially higher than in two year olds (42%). Energy intake from 'sweet & fat' (18%), 'fat' (11%) and 'salt, umami and fat' (18%) tasting foods was higher in two year olds than in one year olds (7%, 6%, 11%, respectively). Higher child BMI Z-scores were associated with relatively more energy from 'salt, umami & fat' tasting foods in one year olds (adjusted model, β=0.21, 95% CI 0.05, 0.38). In conclusion, dietary taste patterns become more intense and varied in taste during the first two years of life, and were associated with child BMI. Studying dietary taste patterns increases our understanding of the role of taste in dietary intake in early-life.

Introduction

From a nutritional perspective, it is essential to enhance our understanding of the role of taste in dietary intake in early-life. During the first two years of life, there is a transition from milk only to table foods. This transition may potentially have important consequences for the development of taste preferences and food choices later in life[(1,2)].

A first step towards a better understanding of the effects of early taste exposure on eating behaviour later in life, is to identify the factors related to dietary taste patterns. In a large population-based cohort, frequent intake of sweet foods at one year of age was associated with higher maternal BMI, younger maternal age and lower parental educational level[(3)]. Similar associations were found between dietary patterns rich in savoury snacks, confectionary and sweetened beverages and BMI, age and educational level in other studies[(4–6)]. Already since the 1970s it is debated whether overweight or obese individuals have a preference for sweet or savoury tasting foods[(7–10)]. In a study on dietary taste patterns in adults, instead of preferences, we found that obese individuals consumed relatively more energy from 'salt, umami & fat' tasting foods than normal-weight individuals[(11)]. However, the role of taste in dietary intake and the factors associated with dietary taste patterns has never been studied in early childhood.

To adequately study the role of taste in dietary intake, the taste intensity values of foods consumed within an infant's diet should be objectively quantified. For this objective quantification of sensory properties of foods trained panels can be used[(12)]. Although food nutrient composition databases exist globally, we are aware of only four databases with taste properties of commonly consumed foods[(13–16)], of which only one included infant foods such as fruit purees and infant formula[(16)]. For the compilation of this latter database, Schwartz et al.[(16)] assessed the basic taste intensity values of 82 common infant foods in France using a trained sensory panel. Subsequently, this database was used in two studies to investigate taste exposure on the basis of consumption frequency, and to assess associations with maternal and child characteristics in early-life[(16,17)]. These studies found that foods were generally low in taste intensity and that taste exposure increased during the first year of life[(16,17)]. Moreover, Yuan et al.[(17)] found that exposure to sweetness and fattiness was associated with maternal educational level and feeding practices, but not with maternal or child BMI. However, these studies focused on the factors associated with only sweet and fat taste exposure during the first year of life, and not on the factors associated with all basic tastes and fat sensation in the diet in early-life.

In the current study, we aimed to assess dietary taste patterns - energy intake from five food groups with different tastes - in children aged one and two years in a large population-based cohort. In addition, we investigated whether maternal and child characteristics are associated with dietary taste patterns during early childhood.

Methods

A trained sensory panel was set-up in Wageningen to assess a large set of frequently consumed foods in terms of basic taste intensity and fat sensation values in a taste database. Taste intensity values were assigned to food items in the food-frequency questionnaires (FFQ) that were used in our study. Subsequently, we compared the contribution to energy intake from five taste groups - consisting of foods that were most similar in taste – at the age of one year and two years. In addition, we investigated associations between maternal and child characteristics and dietary taste patterns.

Compilation of the taste database

Dutch adults (18-55 y) with a self-reported normal body mass index (BMI) (18.5-25.0 kg/m^2) were recruited from Wageningen and surroundings (the Netherlands). We selected panellists (n=15) based on their taste recognition, taste discrimination, the ability to sustain attention, and sensory profiling abilities. The training procedure and selection of panellists have been described in more detail elsewhere[18,19].

Training and panel performance

Panellists were trained to evaluate the intensity of sweet, salt, sour, bitter, umami and fat sensation using modified Spectrum™ scales (0-100mm) for in total 63 hours over six months[14,20]. Panellists were able to discriminate between solutions and foods, and the majority of all taste values could be reproduced. Panellists profiled each of the foods in triplicate. Details of the panel performance can be found elsewhere[19].

Food selection and preparation for profiling

Foods for profiling were selected based on the most recent Dutch National Food Consumption Survey (DNFCS; 2007-2010, n=3,819, 7-69 years)[21]. The study population from the DNFCS is representative of the Dutch population regarding age, sex, region, degree of urbanization, and educational level. We used food intake data of 1402 adults between 19-50 years old (704 males, 698 females). Foods were selected based on pre-defined criteria, which were consumption frequency and contribution to the consumption of energy and macronutrients. In addition, we selected foods that contributed most to the variation in energy intake. In total, we selected 476 foods that contributed in total to 83% of energy intake for an average individual day of consumption. We used expert knowledge from research dieticians to select one of the most often consumed brands for profiling. Expert knowledge was also used to include 20 foods eaten by young children in our taste database: Bambix porridge flour prepared with Nutrilon follow on standard 1, Liga baby biscuits (>4 months, >6 months, >12 months), Danone children's dessert, 3 infant fruit purees, and 12 infant food meals. In addition, we used the average taste intensity values from 8 Malaysian infant formulas for Dutch infant formulas in our study, because these formulas were similar in macronutrient content[19]. Cooked foods were prepared using recipes from the product's package or were prepared according to normal household practice[22]. Cooked foods were prepared unseasoned, so without any additions of condiments, salt or spices.

Food intake data

Study population and study design

Dietary taste patterns were evaluated in children participating in the Generation R Study, an ongoing multi-ethnic population-based prospective cohort from fetal life onward in Rotterdam, the Netherlands. Pregnant women with an expected delivery date between April 2002 and January 2006 were enrolled. The study was approved by the Medical Ethics Committee of Erasmus Medical Centre and written informed consent was obtained from parents of all participating children[23]. More details on the general design of the Generation R Study can be found elsewhere[23].

A food-frequency questionnaire (FFQ) was sent to mothers of 5,088 children to assess diet around the age of one year (median age of 12.9 months (IQR: 12.7-13.9). Dietary data was available for 3,629 of these children (response 72%)[24]. Mothers of a subpopulation, consisting of 899 children with a Dutch ethnic background only, received an additional FFQ around their child's age of two years. For 844 of these children, dietary data was available (response 94%). In total, 777 children had valid dietary data at both time points[24].

Dietary assessment

Dietary intake of the one year olds was assessed using a semi-quantitative 211-item FFQ[24]. This FFQ included foods that are frequently consumed by children aged 9-18 months, according to a Dutch national food consumption survey[25]. Energy and nutrient intakes were calculated using the Dutch Food Composition Table 2006[26]. Validation against 24h recalls showed reasonable to good intraclass correlation coefficients for nutrient intakes; correlations ranged from 0.36 for fat intake to 0.74 for protein intake[24]. The FFQ that was used around the child's age of two years (median 24.9 months (IQR: 24.7 – 25.5) was similar to the one that was used at the age of one year. Compared to the FFQ used at age one year, this second FFQ included more items on specific dairy products, nuts and seeds, and toddler foods; and fewer items on specific types of infant formula[24].

Maternal and infant characteristics

At enrolment in the Generation R study, questionnaires were used to obtain information on maternal age, ethnic background (Dutch; non-Dutch), and educational level (low: ranging from no education up to lower vocational training; high: ranging from higher vocational training to higher academic education). Maternal ethnic background was based on the country of birth of her parents and categorized according to Statistics Netherlands[27]. In addition, maternal height and weight were measured, and BMI was calculated (kg/m^2).

Information on child's date of birth and sex was obtained from medical records. Information on breastfeeding duration was obtained from postnatal questionnaires. Timing of complementary feeding introduction (<3; 3-6; ≥6 months) was assessed with questionnaires. Height and weight of the children were measured at median ages of 14.3 (IQR 14.1-14.6) and 24.7 (IQR 24.2-25.6) months without shoes and heavy clothing and their age- and sex-specific BMI Z-scores were calculated.

Assigning taste values to food items

The relative contribution of single foods to food items, based on food consumption data, was used to calculate weighted mean taste intensity values for food items[25,28]. Taste values of untested foods were estimated based on mean taste intensity values of the corresponding food groups as described elsewhere[11]. For example, we calculated average taste intensity values of profiled foods in the food group 'bread' and assigned these values to all untested foods in this food group.

Statistical analyses

All statistical analyses were performed using SPSS version 21.0 software (IBM Corp.) and SAS version 9.3. (SAS Institute, Inc., Cary, NC, USA). We performed hierarchical cluster analyses on the mean taste intensity values from food items included in the FFQs, resulting in five taste clusters. The five clusters accounted for 82% of the total variance in taste (R^2=0.82). The number of clusters was decided using Ward's method[29]. The percentage of energy intake from the 5 taste clusters was assessed at children's age of one year and two years; differences in dietary taste patterns between the age of one year and two years were tested using paired-samples t-tests. Ranking of the one and two year olds with respect to dietary taste patterns was studied by examining the correlations and cross-classification of tertiles for the percentage of energy intake from each taste group. Pearson correlations were used for normally distributed variables (that is, the percentage of energy intake from 'neutral' tasting foods) and Spearman correlations for skewed variables (the four other taste groups). The 95% CI of the correlation coefficients were calculated by Fisher's Z-transformation. Cohen's Kappa was used for testing cross-classification, significant kappa values indicate that tracking of dietary taste patterns is higher than would be expected by chance.

We used multivariable linear regression models to study associations between dietary taste patterns and maternal and infant characteristics in early childhood. These models included maternal age, ethnic background, educational level, and BMI, and child's age, sex, breastfeeding duration, timing of introduction of complementary feeding, and BMI Z-scores. Model 1 was unadjusted and model 2 was adjusted for all other factors to examine whether associations were independent of each other. To reduce potential bias due to missing values on some of the determinants (ranging from 0% to 18.8%), these variables were multiple imputed (n = 10 imputations). Estimates were similar before and after imputation, and the presented effect estimates are the pooled regression coefficients of the 10 imputed datasets. As sensitivity analyses, linear regression models between determinants and dietary taste patterns were restricted to participants with a Dutch ethnic background, because the FFQs were originally developed for Dutch children. In addition, sensitivity analyses were performed by excluding potential under- and overreporters of energy intake (<2SD; 493 kcal and >2SD; 2153 kcal). This did not affect our results (data not shown).

Results

Population characteristics

Table 1 presents characteristics of the children and their mothers. Mean age of the mothers at enrolment in the study was 31.4 ± 4.6 years. The majority of them were highly educated (62.8%) and had a Dutch ethnic background (65.4%). Mean breastfeeding duration was 3.5 (IQR 1.5 - 7.8) months. Most of the children received partial breastfeeding in the first 4 months of life (59.4%) and were introduced to complementary feeding between the ages of 3 and 6 months (56.4%).

Table 1 General characteristics of the study population (n=3,629)

		N (%), mean (SD), or median (IQR)
Maternal characteristics		
Age at enrolment	Years	31.4 (4.6)
Ethnic background	% Dutch	65.4
Educational level	% high	62.8
Body mass index at enrolment	(kg/m^2)	23.5 (21.6 – 26.2)
Child characteristics		
Sex	% girls	51.0
Age	Months	12.9 (12.7 – 13.9)
Breastfeeding duration		3.5 (1.5 - 7.8)
Never	%	12.8
Partial in the first 4 months	%	59.4
Exclusive for at least 4 months	%	27.8
Introduction complementary feeding		
After 6 months	%	37.9
3-6 months	%	56.4
0-3 months	%	5.7
Body mass index at dietary assessment	(kg/m^2)	17.1 (1.3)

Classification of food items in taste clusters

We performed cluster analyses on the mean taste intensity values from food items included in the FFQs, resulting in five taste clusters. The taste clusters could be described as 'neutral', 'fat', 'sweet and sour', 'sweet and fat' and 'salt, umami and fat' based on their mean taste intensity values (Tables C1, C7 and C8, Appendix C).

Dietary taste patterns in early childhood

We combined the results from cluster analyses with food intake data to assess the contribution to energy intake of five taste clusters. Children at the age of one year (n=3,629) consumed most energy from 'neutral' tasting foods (63% of the energy intake), followed by 'sweet & sour' (13%), 'salt, umami & fat' (11%), 'sweet & fat' (7%) and 'fat' (5%) tasting foods (Figure 1). Children aged two years (n=844) consumed relatively less energy from 'neutral' (42%) and 'sweet & sour' (10%) tasting foods, but relatively more energy from 'sweet & fat' (18%), 'salt, umami & fat' (17%) and 'fat' (11%) tasting foods than children aged one year (all p<0.001). Dietary taste patterns at group level in one (n=3,629) and two year (n=844) olds were similar among the 777 children for whom we had dietary data at both ages (Table C2, Appendix C).

In this subgroup for which we had dietary data at both ages, dietary taste patterns at the age of one year and two years were significantly positively associated for all taste clusters (Table 2, p<0.001). Cross-classification of children that were classified in the same tertile ranged from 40% of energy intake from 'sweet & fat' tasting foods to 48% from 'fat' tasting foods. Cross-classification in the opposite tertiles ranged from 12% of energy intake from 'fat' tasting foods to 17% from 'sweet & fat' tasting foods. The weighted Kappa was 0.28 (95% CI 0.22-0.33) for % energy intake from 'fat' tasting foods, 0.17 (0.12-0.23) for % energy intake from 'neutral' tasting foods, 0.16 (0.10-0.21) for % energy intake from 'salt, umami & fat' tasting foods, 0.14 (0.08-0.20) for % energy intake from 'sweet & fat' tasting foods and 0.15 (0.09-0.21) for 'sweet & sour' tasting foods (all p<0.001).

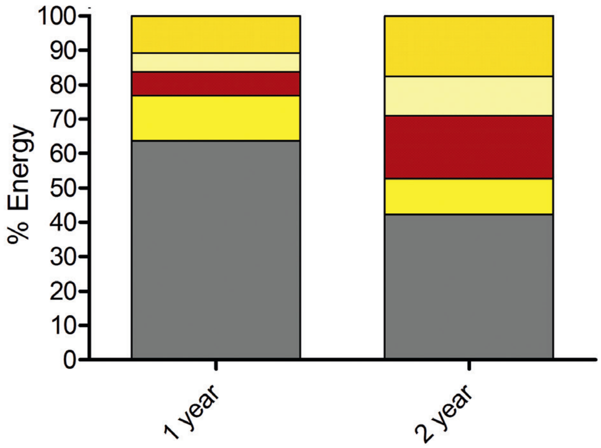

Figure 1 Development of dietary taste patterns in early childhood - the percentage of daily energy intake from each taste group in one year (n=3629) and two year (n=844) old children[1]

[1]Neutral ( ), 'sweet & sour' ( ), 'sweet & fat' ( ), 'fat' ( ), 'salt, umami & fat' ( ) tasting foods

Table 2 Comparison of children at 1 year and 2 years (n=777) concerning dietary taste patterns at group level and within child tracking of dietary taste patterns; correlation coefficients and cross-classification in the generation R study[†]

Taste group	Correlation coefficient	95% CI	% same tertile	% opposite tertile	Kappa	95% CI
Neutral	0.28[‡*]	0.21, 0.34	42	16	0.17[*]	0.12, 0.23
Sweet/sour	0.20[*]	0.13, 0.27	42	17	0.15[*]	0.09, 0.21
Sweet/fat	0.23[*]	0.16, 0.30	40	17	0.14[*]	0.08, 0.20
Fat	0.40[*]	0.34, 0.46	48	12	0.28[*]	0.22, 0.33
Salt/umami/fat	0.25[*]	0.18, 0.31	41	16	0.16[*]	0.10, 0.21

[†]Cross-classification into tertiles

[‡]Pearson's correlation coefficients, Spearman's rank correlation coefficient for the other taste groups

* p<0.001

Associations between dietary taste patterns and maternal and child characteristics

Within the group of children that were around one year old, higher child age was associated with relatively less energy from 'neutral' (adjusted model; β=-1.8 (95% CI; -2.0, -1.6)) tasting foods and relatively more energy from all other taste groups (p<0.05, adjusted). Higher child BMI Z-scores were associated with relatively more energy from 'salt, umami & fat' tasting foods (unadjusted model; β=0.2, 95% CI 0.1, 0.4, adjusted model; β=0.2, 95% CI 0.1, 0.4). Higher maternal educational level was associated with relatively more energy from 'neutral' tasting foods (unadjusted model; β=2.3 (95% CI; 1.3, 3.3), adjusted model; β=1.0 (95% CI; -0.0, 2.0)) and relatively less energy from 'fat' (adjusted model; β=-0.5 (95% CI; -0.8, -0.2)) and 'sweet & fat' (adjusted model; β=-0.9 (95% CI; -1.3, -0.4)) tasting foods (**Tables 3 and 4**). Children with mothers of non-Dutch ethnicity consumed relatively more energy from 'neutral' (adjusted model; β=2.3 (95% CI; 1.4, 3.3)) tasting foods and relatively less energy from 'sweet & sour' (adjusted model; β=-2.9 (95% CI; -3.5, -2.4)) tasting foods than children of mothers of Dutch ethnicity.

Sensitivity analyses restricted to children with a Dutch ethnic background yielded similar effect estimates (**Tables C3 and C4, Appendix C**). In this subgroup, higher educational level was associated with relatively more energy from 'neutral' tasting foods (unadjusted model; β=2.9 (95% CI; 1.6, 4.2)), which remained statistically significant in the adjusted model (β=1.5, 95% CI: 0.2, 2.8). In addition, dietary taste patterns in two year olds (n=844) showed that higher maternal BMI was associated with relatively less energy from 'neutral' tasting foods and with relatively more energy from 'salt, umami & fat' tasting foods (**Table C5, Appendix C**). Also, higher maternal age was associated with relatively less energy from 'sweet & sour' tasting foods. Girls obtained relatively more energy from 'sweet & sour' tasting foods and less from 'sweet & fat' tasting foods than boys (**Table C6, Appendix C**).

Chapter 4

Table 3 Associations of maternal characteristics (β (95%CI)) with contribution to % energy from each taste cluster at the age of one year (n=3,629)

	Neutral	Sweet/sour	Sweet/fat	Fat	Salt/umami/fat
Maternal age					
Model 1	**0.4 (0.3, 0.5)**	-0.0 (-0.1, 0.0)	**-0.2 (-0.2, -0.1)**	**-0.1 (-0.1, -0.0)**	**-0.1 (-0.2, -0.1)**
Model 2	**0.4 (0.3, 0.4)**	-0.1 (-0.2, -0.0)	**-0.1 (-0.1, -0.1)**	**-0.1 (-0.1, -0.0)**	**-0.1 (-0.2, -0.1)**
Educational level					
Low	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
High					
Model 1	**2.3 (1.3, 3.3)**	**0.6 (0.1, 1.2)**	**-1.6 (-2.1, -1.2)**	**-0.7 (-1.0, -0.4)**	**-0.6 (-1.1, -0.2)**
Model 2	1.0 (-0.0, 2.0)	0.5 (-0.1, 1.1)	**-0.9 (-1.3, -0.4)**	**-0.5 (-0.8, -0.2)**	-0.2 (-0.6, 0.3)
Maternal BMI					
Model 1	**-0.2 (-0.3, -0.1)**	0.0 (-0.0, 0.1)	**0.1 (0.1, 0.2)**	**0.0 (0.0, 0.1)**	0.0 (-0.0, 0.1)
Model 2	**-0.2 (-0.3, -0.1)**	0.0 (-0.0, 0.1)	**0.1 (0.1, 0.2)**	0.0 (-0.0, 0.1)	0.0 (-0.0, 0.1)
Ethnic background					
Dutch	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Non-Dutch					
Model 1	**1.4 (0.5, 2.3)**	**-2.9 (-3.5, -2.4)**	**0.8 (0.4, 1.2)**	**0.4 (0.1, 0.6)**	0.4 (-0.0, 0.8)
Model 2	**2.3 (1.4, 3.3)**	**-2.9 (-3.5, -2.4)**	0.3 (-0.1, 0.7)	0.1 (-0.2, 0.4)	0.2 (-0.3, 0.6)

Model 1 is unadjusted. Model 2 is adjusted for all other maternal and child characteristics. **Bold** values indicate statistically significant effect estimates.

Table 4 Associations of child characteristics (β (95%CI)) with contribution to % energy from each taste cluster at the age of one year (n=3,629)

	Neutral	Sweet/sour	Sweet/fat	Fat	Salt/umami/fat
Sex					
Boy	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Girl					
Model 1	0.6 (-0.3, 1.4)	0.1 (-0.4, 0.7)	-0.3 (-0.6, 0.1)	**-0.4 (-0.6, -0.1)**	-0.1 (-0.5, 0.3)
Model 2	0.4 (-0.4, 1.2)	0.3 (-0.3, 0.8)	-0.2 (-0.6, 0.1)	**-0.4 (-0.6, -0.1)**	-0.1 (-0.4, 0.4)
Child age at FFQ					
Model 1	**-1.8 (-2.1, -1.6)**	**0.4 (0.3, 0.6)**	**0.6 (0.5, 0.7)**	**0.3 (0.2, 0.4)**	**0.6 (0.5, 0.7)**
Model 2	**-1.8 (-2.0, -1.6)**	**0.4 (0.3, 0.5)**	**0.6 (0.5, 0.7)**	**0.3 (0.2, 0.4)**	**0.6 (0.5, 0.7)**
Child BMI Z-score*					
Model 1	-0.3 (-0.7, 0.1)	0.2 (-0.0, 0.4)	-0.1 (-0.2, 0.1)	-0.1 (-0.2, 0.1)	**0.2 (0.1, 0.4)**
Model 2	-0.2 (-0.5, 0.2)	0.2 (-0.1, 0.4)	-0.1 (-0.3, 0.0)	-0.1 (-0.2, 0.1)	**0.2 (0.1, 0.4)**
Breastfeeding duration					
Model 1	**0.4 (0.3, 0.6)**	**-0.2 (-0.3, -0.2)**	**-0.1 (-0.2, -0.1)**	0.0 (-0.0, 0.0)	**-0.1 (-0.2, -0.0)**
Model 2	**0.3 (0.2, 0.4)**	**-0.2 (-0.3, -0.1)**	**-0.1 (-0.1, -0.0)**	0.0 (-0.0, 0.0)	-0.1 (-0.1, 0.0)
Introduction of complementary feeding					
After 6 months	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
3-6 months					
Model 1	**-1.8 (-2.8, -0.9)**	0.5 (-0.1, 1.1)	**0.7 (0.3, 1.0)**	0.2 (-0.1, 0.5)	**0.5 (0.0, 0.9)**
Model 2	**-1.2 (-2.2, -0.3)**	0.3 (-0.3, 0.9)	**0.5 (0.1, 0.8)**	0.2 (-0.1, 0.4)	0.3 (-0.1, 0.8)
0-3 months					
Model 1	**-3.2 (-5.2, -1.1)**	-0.9 (-2.1, 0.4)	**2.0 (1.2, 2.8)**	**0.9 (0.2, 1.5)**	**1.2 (0.3, 2.2)**
Model 2	**-2.3 (-4.2, -0.3)**	-0.8 (-2.0, 0.4)	**1.4 (0.7, 2.3)**	**0.7 (0.1, 1.3)**	0.9 (-0.0, 1.9)

Model 1 is unadjusted. Model 2 is adjusted for all other maternal and child characteristics. **Bold** values indicate statistically significant effect estimates.
* Child age- and sex- specific BMI Z-score

Discussion

This study aimed to assess dietary taste patterns in children aged one and two years in a large population-based cohort. In addition, we investigated whether maternal and child characteristics are associated with dietary taste patterns in early childhood. In children aged one year, the majority of energy intake was obtained from 'neutral' (64%) tasting foods, which was substantially higher than in children aged two years (42%). Energy intake from 'sweet & fat', 'fat' and 'salt, umami & fat' tasting foods was higher in two year olds than in one year olds. Higher child BMI Z-scores were associated with relatively more energy from 'salt, umami & fat' tasting foods at the age of one year. Higher maternal educational level was associated with relatively more energy from 'neutral' tasting foods and less from 'fat' and 'sweet & fat' tasting foods in one year olds.

To our knowledge, this is the first study that compared the role of taste in dietary intake in one and two year old children. Two previous studies that have investigated taste exposure during the first year of life[16,17] defined taste exposure on the basis of the frequency of food consumption rather than on the contribution to energy intake. Similar to our findings, these studies found that foods were generally low in basic taste intensity during the first year of life, and that the exposure to sweetness, sourness, bitterness, saltiness, umami, and fattiness increased during the first year of life[16,17]. In the current study, we found that two year olds consumed relatively less energy from 'neutral' tasting foods, which were low in taste intensity, and relatively more from 'sweet & fat', 'fat' and 'salt, umami & fat' tasting foods than one year olds. Taken together, these findings suggest that dietary taste patterns become more intense and varied in taste during the first two years of life. This could potentially have important consequences for the development of taste preferences and food choices later in life.

In the Netherlands, it is recommended for children to eat regular table foods from the age of one year onwards[30]. In a previous study, we found that adults from the DNFCS (2007-2010) consumed most energy from 'neutral' tasting foods (men; 35%, women; 37% of the energy), followed by 'salt, umami & fat' (24%, 21%, respectively), 'sweet & fat' (12%, 15%, respectively), 'sweet & sour' (10%, 13%, respectively), 'fat' (11%, 10%, respectively) and 'bitter' (7%, 3%, respectively) tasting foods[11]. In the current study, the percentage of energy intake from 'neutral' tasting foods (42%) at the age of two years is more comparable to that of adults than at the age of one year (63%). Moreover, the percentage of energy intake from the other taste groups was also closer to that of adults at the age of two year than at the age of one year. These findings suggest that the intensity and the variety of dietary taste patterns increase during the first two years of life, and become more similar to those of adults when children reach the age of two years.

This study is the first that found positive associations between higher child BMI Z-scores and energy intake from 'salt, umami & fat' tasting foods at the age of one year. Similarly, in previous research we found that obese adults consumed relatively more energy from 'salt, umami & fat' tasting foods than normal-weight adults[11]. These findings were found in two independent study populations, of which one population was representative for the Dutch adult population regarding age, sex, region, degree of urbanization and educational level. Thus, based on dietary intake data we found that both one year old children and adults consumed relatively more energy from 'salt, umami & fat' tasting foods with increasing BMI. Previous studies on taste preferences have found inconsistent relationships between preferences for sweet or savoury foods and obesity[7–10]. An explanation might be that laboratory measures of taste preferences may not accurately predict dietary intake. It is thus of importance to study the role of taste in dietary intake in everyday life, including the consumption context. Taken together, these findings suggest a potential relationship between savoury food intake and obesity in adults and in children. Future research is needed to investigate a potential causal relationship between savoury food intake and obesity.

In our study, 'salt, umami & fat' tasting foods were on average higher in protein content than foods from other taste groups. Observational studies have found that a higher protein intake during the complementary feeding period is associated with a higher BMI in later childhood[31–34]. In addition, it has been shown that energy-adjusted protein intake at one year of age was associated with a higher fat mass index and not a higher fat free mass index at age 6 years[35]. Moreover, higher protein intake in infancy may also have a causal relationship with a higher BMI in later childhood, as shown by a large randomized trial in which children aged one year received high-protein or lower-protein infant formulas[36]. Future studies are needed to investigate associations between dietary taste patterns during infancy and child BMI and body composition in later childhood to confirm these findings from a taste perspective.

In a subgroup of our study population in which we had dietary data available at both ages, we observed significant positive associations between dietary taste patterns at the age of one year and two years for all taste clusters. To our knowledge, no studies have investigated tracking of dietary taste patterns from one year to two year old children. However, previous studies have found that the frequency of consumption of food groups such as fruits, vegetables, dairy products, eggs, fish, sweetened beverages, sweets, and sweet & savoury energy-dense snacks in toddlerhood could be predicted by the consumption frequency during infancy[37,38]. These findings suggest that early taste exposure may indeed be important for taste preferences in later childhood. However, these findings may also reflect stability in parenting practices and household food offering, rather than tracking of taste preferences over time. That is, young children have little food choice autonomy. Future studies are needed that follow children from an early age to an age where they start making their own food choices, to further confirm tracking of dietary taste patterns.

Higher educational level was associated with relatively more energy from 'neutral' tasting foods and relatively less energy from 'sweet & fat' tasting foods at the age of one year. These associations suggest that higher educated mothers may provide their children with a healthier diet. Indeed, 'neutral' tasting foods were relatively low in mono- and disaccharide, fat, and sodium content compared to the other taste clusters. In contrast, 'sweet & fat' tasting foods were relatively high in mono- and disaccharide and fat content. Future studies are needed to investigate potential associations between dietary taste patterns and diet quality, for example by using a healthy diet score to assess the extent of adherence to dietary guidelines.

Children of mothers of non-Dutch ethnicity consumed relatively more energy from 'neutral' tasting foods and relatively less energy from 'sweet & sour' tasting foods at the age of one year. These differences seemed to be driven by higher consumption of 'neutral' tasting breastmilk and formula milk and lower consumption of 'sweet & sour' tasting beverages in non-Dutch children than in Dutch children. In addition, non-Dutch children consumed relatively less energy from 'neutral' tasting bread, fruit, and infant food meals but more from grains such as rice. Previous research has found that infant feeding practices varied by maternal ethnicity[39]. In this study, non-white mothers were less likely to stop breastfeeding early or to introduce solids earlier than white mothers. In our study population, breastfeeding duration was not significantly different between Dutch and non-Dutch mothers. It is possible that the proportion of solid foods versus breastmilk and/or formula milk varied by maternal ethnicity, resulting in differences in dietary taste patterns. However, these findings should be interpreted with caution, because the FFQ was originally developed for the Dutch population and may not include all food items that are specific for non-Dutch children.

Although the selection of foods for sensory profiling was predominantly based on food consumption data of adults, these foods were also consumed by one and two year olds in our study. Moreover, foods that are consumed by infants only, were also included in our taste database. However, the FFQs were originally developed and validated for the assessment of nutrient intake in infants and not for dietary taste patterns. For example, foods such as 'sweet & sour' tasting soft drinks were combined with lemonades in one food item, which were classified in the 'sweet & fat' tasting food group. Therefore, the calculation of weighted mean taste intensity values may have resulted in less accurate taste values for such food items. However, the majority of foods within one food item belonged to the same taste food group. Importantly, dietary taste patterns in adults based on FFQ were similar to that assessed by 24hR, and both methods had similar associations with biomarkers of exposure, supporting the validity of FFQ for the assessment of dietary taste patterns(11).

In conclusion, this study is the first to assess the role of taste in energy intake in early childhood. We found that dietary taste patterns become more intense and varied in taste during the first two years of life. In addition, dietary taste patterns were associated with child BMI Z-scores and maternal educational level. Future studies are needed to investigate potential associations between dietary taste patterns in early childhood and body composition in later childhood. Moreover, future studies could investigate potential associations between dietary taste patterns and the extent of adherence to dietary guidelines, to further understand the implications of our findings. Studying dietary patterns from a taste perspective - and not only a nutritional perspective - provides us with a deeper understanding of the role of taste in dietary intake in early-life.

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Chapter 5

Dietary taste patterns by sex and weight status in the Netherlands

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Abstract

Taste is a key driver of food choice and intake. Taste preferences are widely studied, unlike the diet's taste profile. This study assessed dietary taste patterns in the Netherlands by sex, BMI, age and education. A taste database, containing 476 foods' taste values, was combined with 2-day 24-hour recalls in two study populations. The percentage of energy intake from 6 taste clusters was assessed in the Dutch National Food Consumption Survey (DNFCS 2007-2010; n=1,351) and an independent observational study: the Nutrition Questionnaires plus (NQplus) study (2011-2013; n=944). Dietary taste patterns were similar across study populations. Men consumed relatively more energy from 'salt, umami & fat' (DNFCS; 24% energy, NQplus study; 23%) and 'bitter' (7%) tasting foods than women (21%, p<0.001, 22%, p=0.005; 3%, p<0.001, 4%, p<0.001, respectively). Women consumed more % energy from 'sweet & fat' (15%) and 'sweet & sour' (13%, 12%, respectively) tasting foods than men (12%, p<0.001, 13%, p=0.001; 10%, p<0.001). Obese individuals consumed more % energy from 'salt, umami & fat' and less from 'sweet & fat' tasting foods than normal-weight individuals ('salt, umami & fat', men; obese both studies 26%, normal-weight DNFCS 23%, p=0.037, NQplus 22%, p=0.001, women; obese 23%, 24%, normal-weight 20%, p=0.004, p=0.011, respectively, 'sweet & fat', men; obese 11%, 10%, normal-weight 13%, p<0.05, 14%, p<0.01, women; obese 14%, 15%, normal-weight 16%, p=0.12, p=0.99). In conclusion, our taste database can be used to deepen our understanding of the role of taste in dietary intake in the Netherlands by sex, BMI, age and education.

Introduction

The role of taste in dietary intake is of particular interest from a nutritional perspective. That is, taste plays a key role in food choice and dietary patterns[1]. Besides guiding food choice, taste may serve as an early signal of its nutrient content[2,3], thereby affecting satiation[4] and subsequent food intake[5–7]. Studying dietary patterns from a taste perspective - and not only a nutritional perspective - provides us with a deeper understanding of the role of taste in dietary intake.

Research on the role of taste in dietary intake is still in its infancy. To study the role of taste in dietary intake, it is essential to objectively quantify the taste intensity values across foods consumed within a population. Food composition tables are globally available, however only three studies compiled a taste database[2,3,8]. Van Dongen et al.[2] quantified the basic taste intensity values of 50 frequently consumed single Dutch foods and subsequently studied taste-nutrient relationships. More recently, Martin et al.[8] described the taste profile of 590 French foods within the diet of their 12 trained panellists. Yet, these studies assessed taste values only for selected foods that were not representative of the diet of the general population. We are aware of only one study[3] that determined taste values of foods within the entire diet of a national sample of the population. However, this Australian study focused on taste-nutrient relationships in foods and did not assess the role of taste in dietary intake.

The role of taste in dietary intake may differ among sex and weight status subgroups of the population. Although no literature is available on dietary taste patterns, this is available for studies on taste preferences. For example, several studies have found that men liked salty and/or fatty foods more than women[9–15], whereas women liked sweet foods more than men[9,10,14,15]. However, it is less clear whether taste preferences differ by weight status. Some studies have found a positive association between liking for sweet[9,10] or salty foods and BMI[9], whereas other studies have found lower liking ratings for sweet and salty foods in obese than in lean individuals[16] or no difference in liking across BMI categories[17]. However, dietary taste patterns by subgroups of the population has never been assessed.

The current study is the first that aimed to assess dietary taste patterns in the Netherlands by sex, weight status, age and educational level. We combined a taste database – containing sweet, sour, bitter, salt, umami and fat sensation values of 476 foods – with the food intake data from the Dutch National Food Consumption Survey (2007-2010) – a nationally representative sample of the population[18]. In addition, we combined the taste values with the food intake data from an observational study that was independent of our food selection process: the Nutrition Questionnaires plus (NQplus) study (2011-2013).

Methods

A trained sensory panel was set-up in Wageningen (the Netherlands) to assess a large set of frequently consumed foods in terms of basic taste intensity (sweet, sour, bitter, salt and umami) and fat sensation values (section 2.2). Training of a panel increases the panel's internal consensus, reproducibility of taste values and discriminative power between taste modalities and foods[19–21]. Foods within the resulting taste database were grouped on taste using hierarchical cluster analyses. This resulted in 6 groups that consisted of foods that were most similar in taste intensity values. Subsequently, the taste database was combined with food intake data from two observational studies to assess the % of energy intake from each taste cluster across study populations (**Figure 1**).

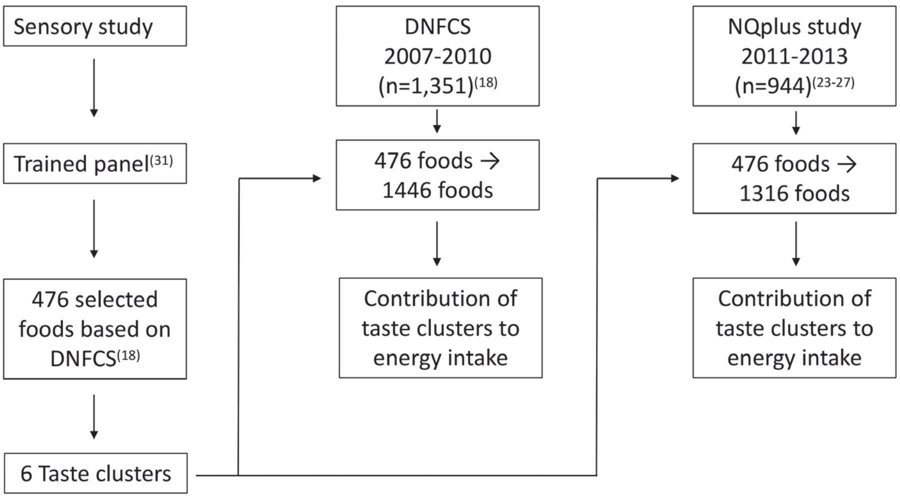

Figure 1 Diagram of the study design

Study populations

Dutch National Food Consumption Survey

We used the most recent Dutch National Food Consumption Survey (DNFCS 2007-2010)[18]. The DNFCS is representative of the Dutch population regarding age, sex, region, degree of urbanization and educational level. Diet was assessed for in total 3,819 Dutch individuals aged 7-69 years. The trained dieticians used the computer directed interview program for standardization of 2-day 24-hour recalls, GloboDiet[22]. During the interviews, weight and height was reported (not measured) to an accuracy of 0.1 kg and 0.5 cm. Based on the information on both interview days, the average body weight and height were calculated. Body mass index (BMI) was determined as the average body weight (in kg) divided by the average height (in m) squared (kg/m^2). Weight status subgroups were categorized as follows: normal-weight (BMI 18.5-25.0), overweight (BMI 25.0-30.0) and obese (BMI >30.0). Educational level was categorized into low (primary school, lower vocational, low or intermediate general education), middle (intermediate vocational education and higher general education) and high (higher vocational education and university). Age was categorized into younger individuals (19-30 y) and older individuals (31-50 y). In the present analyses, we included the food intake data from men and women aged 19-50 years (DNFCS 2007-2010, n=1,402). Individuals who were breastfeeding (n=4), seriously underweight (n=9), underweight (n=36) or without information on weight status (n=1) were excluded from the analyses. One participant was excluded because of missing food intake data at one measurement day. In total, we included the food intake data from 687 men and 664 women (n_{total}=1,351) with a mean age of 33±9 y and BMI of 26±5 kg/m^2 (Table 1).

Table 1 Total energy intake and the contribution of macronutrients to energy intake (mean±SD) stratified by sex, age, BMI and educational level in the Dutch National Food Consumption Survey[1]

	Total energy, kjoule/day		Total protein En%		Total fat En%		Total carbo-hydrates En%		Total mono- and disacch-arides En%		Alcohol En%	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Men (n=687)	11350$^{*¥}$	3317	14.8*†	3.8	34.5*†	6.3	44.7$^{*¥}$	7.3	20.1$^{*¥}$	7.5	4.0$^{*¥}$	5.6
Age (years)												
19-30 (n=343)	11773^{a‡}	3578	14.4^{a‡}	4.0	34.2	6.4	46.0$^{a¥}$	7.1	21.3$^{a¥}$	7.9	3.5^{a†}	5.4
30-50 (n=344)	10928^{b}	2980	15.2^{b}	3.4	34.8	6.3	43.5^{b}	7.3	18.8^{b}	6.9	4.4^{b}	5.7
BMI (kg/m^2)												
18.5-25.0 (normal, n=363)	11689	3472	14.5^{a}	4.2	33.9	6.1	45.8^{a}	7.0	21.1^{a}	7.8	3.8	5.5
25-30 (overweight, n=244)	11046	3000	14.8^{ab}	3.2	35.0	6.7	44.0^{b‡}	7.5	19.3^{b†}	6.8	4.2	5.6
>30 (obese, n=80)	10736	3380	15.9^{b‡}	3.2	35.6	6.0	42.5^{b‡}	6.9	17.7^{b‡}	7.4	3.8	6.1
Education (highest completed)												
Low (1-3, n=186)	11832^{a}	3537	14.6	3.4	34.7	6.6	45.4	7.4	20.9	8.0	3.5	5.5
Medium (4-5, n=351)	11330^{ab}	3146	14.8	4.3	34.3	6.4	44.8	7.3	20.0	7.5	4.1	5.7
High (6-7, n=150)	10798^{b†}	3357	15.0	2.9	34.8	5.9	43.8	7.1	19.2	6.7	4.2	5.4
Women (n=664)	8257$^{*¥}$	2253	15.2*†	3.5	33.8*†	6.8	47.0$^{*¥}$	7.7	22.3$^{*¥}$	7.5	1.7$^{*¥}$	4.0
Age (years)												
19-30 (n=323)	8352	2370	14.8^{a†}	3.5	33.4	6.9	48.3$^{a¥}$	7.6	23.7$^{a¥}$	7.6	1.3^{a‡}	3.3
30-50 (n=341)	8168	2135	15.5^{b}	3.5	34.2	6.7	45.8^{b}	7.6	21.0^{b}	7.2	2.2^{b}	4.5
BMI (kg/m^2)												
18.5-25.0 (normal, n=351)	8360	2148	14.6^{a}	3.3	33.4^{a}	6.9	47.7^{a}	7.6	23.2^{a}	7.3	1.9	4.1
25-30 (overweight, n=173)	8251	2252	15.4^{b†}	3.4	33.6^{ab}	6.6	46.9^{ab}	7.7	22.0^{ab}	8.0	1.8	4.0
>30 (obese, n=140)	8008	2495	16.2$^{b¥}$	3.9	35.2^{b†}	6.9	45.3$^{b¥}$	7.9	20.5^{b‡}	7.3	1.2	3.6
Education (highest completed)												
Low (1-3, n=183)	8300	2263	15.0	3.5	34.9^{a}	6.8	46.5	8.0	22.2	8.2	1.5	4.1
Medium (4-5, n=336)	8248	2267	15.2	3.5	33.1^{b†}	7.0	47.5	7.8	22.7	7.4	1.9	4.0
High (6-7, n=145)	8225	2222	15.3	3.6	34.1^{ab}	6.3	46.5	7.1	21.7	6.9	1.7	3.8

[1] MANCOVA, multivariate ANCOVA was performed including all tastes and subgroups. If the overall effect was significant ($p<0.05$), ANCOVA was used to compare subgroups within each taste group ($p<0.05$, Bonferroni corrected). For age and sex, independent samples t-tests were used ($p<0.05$, Bonferroni corrected).

[a,b] Superscript letters indicate significant differences, same letters indicate no significant difference between mean values.

* Indicates significant difference between men and women. † $p<0.05$, ‡ $p<0.01$, ¥ $p<0.001$.

Nutrition Questionnaires plus study

The Nutrition Questionnaires plus (NQplus) study was conducted between May 2011 and February 2013 in Wageningen and surroundings[23–27]. In total, 2,048 men and women aged between 20-70 years old participated in this study. Half of them (n=1,113) were randomly allocated to the so-called recall group. In this group, each individual completed 1-6 telephone and 3 web-based recalls. For comparison to the DNFCS we used only the first two recalls by telephone (n=968). Height was measured with a stadiometer (SECA, Germany) to the nearest 0.1 centimetre and weight was measured using a digital scale (SECA, Germany) to the nearest 0.1 kg; the average of the two measurements was included in the dataset. Weight status subgroups were categorized as in the DNFCS. Educational level was categorized into low (no education or primary or lower vocational education), middle (lower secondary or intermediate vocational) and high (higher secondary education, higher vocational education or university). Age was categorized into younger individuals (19-30 y), middle-aged (31-50 y) and older individuals (>50 y). Individuals who were pregnant (n=3), underweight (n=8) or without information on educational level (n=13) were excluded from the analyses. In total we included the food intake data from 498 men and 446 women (n_{total}=944) with a mean age of 53±12 y and BMI of 26±4 kg/m^2 (**Table 2**). All individuals gave written informed consent before participation in the study. The study was approved by the ethical committee of Wageningen University (ABR number: NL34775.081.10) and was conducted according to the declaration of Helsinki.

Table 2 Total energy intake and the contribution of macronutrients to energy intake (mean±SD) stratified by sex, age, BMI and educational level in the NQplus study1

	Total energy, kjoule/day		Total protein En%		Total fat En%		Total carbo-hydrates En%		Total mono- and disacch-arides En%		Alcohol En%	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Men (n=498)	9493[*¥]	2188	15.9	2.9	33.7	5.8	43.2[*†]	7.2	18.3[*¥]	5.8	4.7[*¥]	4.9
Age (years)												
20-30 (n=19)	11537[a§]	2380	15.2	2.8	33.2	6.1	45.7	7.4	19.0	6.4	3.5[ab]	5.3
31-50 (n=127)	9978[b]	2420	15.6	2.6	34.6	6.4	44.3	7.8	18.8	6.3	3.1[a]	3.8
51+ (n=352)	9208[c]	1998	16.0	2.9	33.4	5.6	42.6	7.0	18.1	5.6	5.4[b¥]	5.1
BMI (kg/m^2)												
18.5-25.0 (normal, n=185)	9817	2231	15.4[a¥]	2.6	33.6	6.0	44.5[a¥]	6.9	19.2[a]	5.9	4.0[a]	4.3
25-30 (overweight, n=243)	9362	2194	15.8[a¥]	2.9	33.4	5.7	43.0[a‡]	7.2	18.2[ab]	5.7	5.2[b†]	5.3
>30 (obese, n=70)	9095	1955	17.3[b]	2.8	35.2	5.7	40.1[b]	7.1	16.5[b‡]	5.9	5.0[ab]	4.8
Education (highest completed)												
Low (n=30)	9480	2433	15.4	2.3	34.6	5.3	42.8	5.9	17.6	5.2	4.9	4.7
Medium (n=134)	9397	2226	16.1	2.8	32.9	5.3	44.4	7.5	19.0	6.5	4.0	4.6
High (n=334)	9533	2155	15.8	2.9	33.9	6.0	42.7	7.2	18.1	5.6	5.0	5.1
Women (n=449)	7742[*¥]	1711	15.8	3.1	34.4	6.1	44.2[*†]	7	20.7[*¥]	5.7	2.7[*¥]	3.9
Age (years)												
20-30 (n=48)	8032	1873	14.7[a]	2.7	32.7	5.5	48.5[a§]	7.2	23.4[a]	7.0	1.5[a‡]	2.4
31-50 (n=159)	7908	1885	15.8[ab]	3.2	34.7	6.5	45.1[b]	6.9	20.9[b†]	5.5	1.7[a¥]	2.8
51+ (n=242)	7578	1540	16.1[b†]	3.0	34.6	5.9	42.9[c]	6.7	20[b¥]	5.4	3.5[b]	4.4
BMI (kg/m^2)												
18.5-25.0 (normal, n=245)	7945[a]	1647	15.0[a]	2.8	34.5	6.5	45.2[a]	7.3	21.2[a]	5.9	2.3	3.3
25-30 (overweight, n=144)	7369[b‡]	1689	16.6[b¥]	2.9	34.4	5.7	43.1[b†]	6.6	20.3[ab]	5.2	3.1	4.2
>30 (obese, n=60)	7795[ab]	1892	17.4[b¥]	3.3	34.3	5.4	42.9[ab]	6.5	19.2[b†]	5.8	2.8	4.9
Education (highest completed)												
Low (n=25)	7282[ab]	1815	17.0[a†]	3.1	32.4	5.1	45.4	7.3	19.6	5.4	2.2	3.1
Medium (n=147)	7348[a]	1631	16.4[a‡]	3.2	34.7	6.6	43.9	7.2	20.9	6.4	2.2	3.4
High (n=277)	7995[b‡]	1700	15.4[b]	2.9	34.5	5.8	44.3	6.9	20.7	5.3	2.9	4.1

[1] MANCOVA, multivariate ANCOVA was performed including all tastes and subgroups. If the overall effect was significant ($p<0.05$), ANCOVA was used to compare subgroups within each taste group ($p<0.05$, Bonferroni corrected). For sex independent samples t-tests were used ($p<0.05$, Bonferroni corrected).
[a,b] Superscript letters indicate significant differences, same letters indicate no significant difference between mean values. [*] Indicates significant difference between men and women. † $p<0.05$, ‡ $p<0.01$, ¥ $p<0.001$. [§] Age group 20-30 vs. 31-50 $p<0.05$, 31-50 vs. 51+; $p<0.01$, 20-30 vs. 51+ $p<0.001$.

Misreporting of daily energy intake

To explore the effect of misreporting of energy intake (EI) on dietary taste patterns we performed sensitivity analyses. We identified potential low energy reporters (LER) based on the ratio between energy intake (EI) and basal metabolic rate (BMR). Schofield equations were used to estimate BMR from body weight and height, taking into account age and sex(28). We used a cut-off value of EI/BMR of 1.35 to identify potential low energy reporters at group level(29). In addition, we identified low and high energy reporters at an individual level by calculating 95% confidence limits of energy intake/basal metabolic rate for the DNFCS (95% CI: 0.91-2.63) and NQplus study (95% CI: 0.98-2.46)(29).

Taste database

Panellists

Dutch adults (18-55 y) with a self-reported normal BMI (18.5-25.0 kg/m^2) were recruited from Wageningen and surroundings (the Netherlands). We selected panellists (n=15) based on their taste recognition, taste discrimination, the ability to sustain attention, and sensory profiling abilities. The panel consisted of 3 men and 12 women, with a mean age of 33±12 y and a BMI of 23±2 kg/m^2. All individuals gave written informed consent and they received financial compensation for their participation in the study. The study was approved by the ethical committee of Wageningen University (ABR number: NL47315.081.13) and was conducted according to the declaration of Helsinki. This study was registered at https://clinicaltrials.gov/ as NCT03233503. The training procedure and selection of panellists have been described in more detail elsewhere(30,31).

Training and panel performance

Panellists received intensive training to evaluate the intensity of sweet, salt, sour, bitter, umami and fat sensation using modified Spectrum™ scales (0-100mm, Table 3)(8,32). Panellists were trained for in total 63 hours over six months using Spectrum™-based reference solutions for each basic taste, followed by simple modified products and commercially available foods. Reference solutions were positioned at fixed points at the scale and contained increasing concentrations of sucrose for sweetness, sodium chloride (NaCl) for saltiness, monosodium glutamate (MSG) for umami, citric acid for sourness and caffeine for bitterness. In addition, we modified foods by adding increasing concentrations of taste compounds. For example, NaCl and MSG were added to mashed potatoes and cooked rice for saltiness and umami; caffeine and citric acid were added to agar for bitterness and sourness; sucrose was added to gelatine for sweetness; and mascarpone was added to vanilla custard for fat sensation. Subsequently, panellists were trained to evaluate the taste intensity of pre-selected commercially available foods using the taste solutions as references. At the end of training, panellists reached consensus on the basic taste and fat sensation values for 25 commercially available foods that could serve as reference products in addition to the reference solutions (**Table 3**).

Panellists were instructed to evaluate a set of 19 control products in terms of six taste attributes to assess their performance. Panel performance measures (discriminative power, agreement, and reproducibility) were regularly monitored during training and profiling sessions. Oral feedback was given by the researcher to improve the panels' performance. Panellists were able to discriminate between solutions and products, and nearly all taste values could be reproduced. Panellists profiled each of the foods in triplicate.

Food selection and preparation for profiling

After training, we selected foods for profiling based on the Dutch National Food Consumption Survey (2007-2010). Foods were selected based on pre-defined criteria, i.e. consumption frequency, and contribution to the consumption of energy and macronutrients. In addition, we selected foods that contributed most to the variation in energy intake. In total, we selected 476 foods that were reported in the DNFCS and that contributed in total to 83% of energy intake in the DNFCS and 66% of energy intake in the NQplus study for an average individual day of consumption. We used expert knowledge from research dieticians to select one of the most often consumed brands for profiling.

Foods were prepared using recipes from the product's package or were prepared according to normal household practice[33]. Cooked foods were prepared unseasoned, so without any additions of condiments, salt or spices. Foods were prepared one hour before sensory testing to control for the serving temperature. After preparation, cooked foods were kept warm using a bain-marie container (60-65 °C). Cold foods were served at room (20-25°C) or refrigerator temperature (4-9 °C) where appropriate.

Table 3 Reference solutions and products shown per taste and fat sensation

Sensation	Solution references		Food references	
	Concentration	% scale	Product name and brand	% scale
Sweet	Sucrose 20gL^{-1} (R1)	13.33[1]	Knappertjes (biscuits) Verkade®	20
	Sucrose 50gL^{-1} (R2)	33.33[1]	Vanilla vla (Vanilla custard) Friesland Campina®	33
	Sucrose 100gL^{-1} (R3)	66.67[1]	Sponge cake Albert Heijn home brand®	50
			Marshmallow Haribo®	67
			Sweetened condensed milk Friesland Campina®	88
Salt	NaCl 2.00gL^{-1} (R1)	16.67[1]	Cracotte natural (crispbread) LU®	14
	NaCl 3.50gL^{-1} (R2)	33.33[1]	Potato chips natural Pringles®	48
	NaCl 5.00gL^{-1} (R3)	56.67[1]	Old cheese 48+ Old Amsterdam®	74
			Soy sauce Kikkoman®	94
Sour	Citric acid 0.50gL^{-1} (R1)	13.33[1]	Rye bread Bolletje®	15
	Citric acid 0.80gL^{-1} (R2)	33.33[1]	Buttermilk Albert Heijn Puur en Biologisch®	38
	Citric acid 1.50gL^{-1} (R3)	66.67[1]	Biogarde (yogurt) Albert Heijn home brand®	50
			Sour pickles Albert Heijn home brand®	78
			Bottled lemon juice Albert Heijn home brand®	97
Bitter	Caffeine 0.50gL^{-1} (R1)	13.33[1]	Grapefruit juice Albert Heijn home brand®	57
	Caffeine 0.80gL^{-1} (R2)	33.33[1]	Black chocolate 85% cocoa Lindt Excellence®	70
	Caffeine 1.50gL^{-1} (R3)	66.67[1]		
Umami	MSG 1.20gL^{-1} (R1)	13.33[2]	Non-fried natural seaweed Nori®	28
	MSG 3.00gL^{-1} (R2)	33.33[2]	Crab sticks Vici®	43
	MSG 7.00gL^{-1} (R3)	66.67[2]	Parmesan Cheese Grana Padano®	69
			Soy Sauce Kikkoman®	86
Fat sensation			Melba® toast	0
			Snackcups natural round (crackers) Haust®	9
			Slagroomvla (cream custard) Friesland Campina®	55
			Cream cheese original Philadelphia®	72
			White chocolate Verkade®	73
			Unsalted butter Friesland Campina®	97

[1] Inspired by Muñoz and Civille (1992)
[2] Inspired by Martin et al. (2014)

Chapter 5

Dietary taste patterns

Foods and food groups in the taste database were grouped into 6 taste clusters using hierarchical cluster analyses. Subsequently, the taste database was combined with food intake data. For reported foods that were not in the taste database we estimated mean taste intensity values based on the corresponding food groups. For each individual we calculated the % of energy intake from each taste cluster, averaged over two 24-hour recall days.-

Classification of foods in taste clusters

Groups of products were formed within the taste database using hierarchical cluster analyses on foods' mean taste intensity values. The number of clusters was decided using Ward's method[35]. Six taste clusters were identified that accounted for 73% of the variance (R^2=0.73). We described the taste clusters as 'neutral', 'fat', 'sweet & sour', 'bitter', 'sweet & fat' and 'salt, umami & fat' based on their mean taste intensity values (Table 4). For each food in the taste database, the 'distance' to the cluster centre is shown in Table D3, Appendix D. The distance gives an indication of how similar a food product is relative to the other foods in that cluster; the larger its value, the more dissimilar. To describe the type of foods that are in each taste cluster we used the 23 NEVO food groups in the Dutch Food Composition table[34]. A relatively large number of foods were classified in the 'neutral' tasting cluster that was low in all 6 taste modalities. NEVO food groups in the 'neutral' taste cluster included 94% of all 'bread' products within the taste database, 89% of all 'vegetables', 43% of all 'potatoes', 36% of all 'fish' products, 28% of all 'nuts, seeds and savoury snacks' and 15% of all 'meat, meat products and poultry'. The 'fat' taste cluster included 80% of all 'fat and oils' and 31% of all 'cheese' products. Food groups in the 'sweet & sour' taste cluster included 59% of all '(non-) alcoholic beverages', 63% of all 'fruits', 33% of all 'milk and milk products'. The 'sweet & fat' taste cluster included 92% of all 'sugar, sweets, sweet spreads and sweet sauces', 85% of all 'pastry, cakes and biscuits', and 57% of all 'milk and milk products'. The 'bitter' taste cluster consisted of 28% of all '(non-) alcoholic beverages'. Food groups in the 'salt, umami & fat' taste cluster were 83% of all 'meat, meat products and poultry', 67% of all 'nuts, seeds and savoury snacks', 63% of all 'cheese' products, 57% of all 'potatoes' and 100% of all 'soups'.

Table 4 Mean taste intensity values of all taste modalities and nutrient content stratified by taste clusters

	Taste clusters											
	Fat (n = 37 8%)		Sweet/sour (n =66 14%)		Neutral (n = 128 27%)		Sweet/fat (n = 111 23%)		Bitter (n = 17 4%)		Salt/umami/ fat (n = 117 24%)	
Taste modality	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sweet	7	6	31	15	10	8	51	11	11	8	8	6
Sour	13	16	36	15	4	3	5	7	12	11	9	7
Bitter	2	3	3	5	3	4	3	5	47	11	1	2
Salt	20	14	5	7	10	9	8	5	2	1	42	9
Umami	6	6	1	4	4	5	1	1	1	1	23	9
Fat sensation	80	11	11	12	13	9	37	16	5	4	45	14
Nutrient content												
Energy (kjoule/100g)	2287	955	298	307	847	735 6	1455	61998	159	241	1091	602
Protein (g/100g)	3	6	1	3	8	7	5	3	0	0	13	8
Fat (g/100g)	59	28	1	3	6	12	14	12	0	0	17	12
Carbohydrates (g/100g)	3	5	13	16	27	27	50	23	3	3	14	20
Mono- and disaccharides (g/100g)	2	3	12	13	5	9	37	20	2	3	2	6
Dietary fiber (g/100g)	0	1	1	1	3	3	2	2	0	1	1	1
Alcohol (g/100g)	0	0	0	2	0	0	0	0	6	11	0	0
Sodium (mg/100g)	257	250	65	171	246	332	132	120	5	12	779	691

Estimating sensory profiles of untested foods

For reported foods in the food intake data that were not in the taste database we estimated taste values based on the corresponding food groups. Currently, no food classification system exists that groups foods based on taste. Therefore, we used the Dutch NEVO food groups that were based on similarities in nutritional values. For each NEVO food group we calculated average taste intensity values based on the 476 profiled foods. For example, we calculated average taste intensity values of profiled foods in the food group 'bread' and assigned these taste values to all untested foods in this food group.

However, not all NEVO food groups were appropriate for estimating taste values. For example, the NEVO food group 'milk and milk products' consists of foods such as 'neutral' tasting milk, 'sweet & sour' tasting yoghurt and 'sweet & fat' tasting desserts. Therefore, for this food group it is more accurate to estimate taste values of untested foods using the smaller (sub-) subfood groups within the GloboDiet food group classification: 'milk', 'milk beverages', 'yoghurt', 'fromage blanc, petits suisses', 'cream desserts, puddings' and 'dairy and non-dairy creams'. The GloboDiet food group classification comprises 19 main groups and 86 subgroups, and 15 of these subgroups are further detailed into 62 sub-subfood groups based on similarities in nutritional values[22]. We used the GloboDiet (sub-) subfood groups for 5 NEVO food groups that were too diverse in taste. Three NEVO food groups ('(non-)alcoholic beverages', 'milk & milk products' and 'fat, oils & savoury sauces') were fully replaced and 2 NEVO food groups ('nuts, seeds & savoury snacks' and 'meat & meat products') were partially replaced by the GloboDiet food groups (**Figure D1, Tables D1 and D2, Appendix D**).

The NEVO food groups 'mixed dishes' and 'potatoes' did not consist of GloboDiet (sub-) subfood groups, and were too diverse in taste to calculate mean taste intensity values. Therefore we matched untested foods within the food groups 'mixed dishes' and 'potatoes' with a tested food item that was similar in macronutrient and sodium content. Similarly, 4 NEVO food groups were too diverse in taste, not consumed in isolation, or were not frequently consumed by the Dutch population: 'miscellaneous', 'herbs and spices', 'soy products and vegetarian foods' and 'preparations'. These 4 food groups were not matched with the average taste intensity values and were treated as missing values (only 1% of total energy intake).

This systematic approach resulted in mean taste intensity values for a combination of 14 NEVO and 20 GloboDiet food groups. We combined the mean taste intensity values of these 35 food groups with the 476 foods in the taste database. Subsequently we repeated hierarchical cluster analyses on the taste intensity values of foods and food groups combined. We obtained 6 taste clusters that were similar to the taste clusters described in section 2.3.1. In total, foods responsible for 99% of energy intake in both study populations were classified into one of the 6 taste clusters.

Recoding of coffee and tea

In 24-hour recall data, foods are mainly reported as single foods, even when consumed in combination with other foods. In the Netherlands, coffee and tea are consumed on a daily basis and often in combination with sugar and/or milk, therefore these added ingredients can contribute to dietary taste patterns. We identified how coffee or tea was consumed using the following rules. If coffee as well as sugar were reported in equal frequencies in an eating occasion, coffee was consumed with sugar (and similarly for tea). Exceptions were if both coffee and tea were reported in equal frequencies in an eating occasion. We assumed that coffee milk was always consumed in combination with coffee. All tested coffee products (with or without milk and/or sugar) were classified in the 'bitter' taste group in our cluster analyses (Table D3, Appendix D). Therefore we assigned coffee milk and sugar that was consumed in combination with coffee to the 'bitter' taste group. Tea with and without sugar was classified in the 'neutral' taste group. Thus, sugar that was consumed in combination with tea was assigned to the 'neutral' taste group.

Statistical analyses

Data was analysed using SAS version 9.3. (SAS Institute, Inc., Cary, NC, USA). MANCOVA was used to test differences in the percentage of energy intake from the taste clusters by sex, age, weight status (BMI) and educational level, taking into account all taste clusters simultaneously. ANCOVA was used to compare specific subgroups within each taste cluster if the MANCOVA results were significant ($p<0.05$). For age (DNFCS only) and sex, independent samples t-tests were used. Models for sex were adjusted for age, BMI and education; models for age were adjusted for BMI and education; models for BMI were adjusted for age and education; models for education were adjusted for age and BMI. We performed sensitivity analyses by excluding the percentage of energy intake from foods not profiled by our panellists, and by excluding potential low energy reporters at group level and under- and overreporters at an individual level (see section 2.1.3.). Repeated-measures ANOVA was used to compare differences in the percentage of energy between eating occasions. P-values <0.05 were considered significant (Bonferroni's correction). The between- and within-person variation and intra-class correlation coefficients were calculated for the percentage of total energy intake from each of the taste clusters between the two recall days.

Results

Major contributions to daily energy intakes in the entire diet were from 'neutral' tasting foods (36% in the DNFCS & 39% in the NQplus study), 'salt, umami & fat' tasting foods (23% & 22%, respectively) and 'sweet & fat' tasting foods (both studies 14%). The remaining daily energy intake was obtained from 'fat' tasting foods (11% & 8%, respectively), 'sweet & sour' tasting foods (both studies 11%) and 'bitter' tasting foods (both studies 5%). The intra-class correlation coefficient, a measure of day-to-day variation of energy intake, ranged from 0.12 for 'fat' tasting foods to 0.44 for 'bitter' tasting foods in the DNFCS. This was similar in the NQplus study, the intra-class correlation coefficient ranged from 0.14 for 'neutral' tasting foods to 0.48 for 'bitter' tasting foods.

Dietary taste patterns stratified by eating occasions

During main meals, individuals consumed significantly more % energy from foods tasting 'neutral' (40-49%) or 'fat' (9-14%) than during snacking occasions (11-20%, 1-2%, respectively; Figure 2, DNFCS). This was in line with the NQplus study (Figure D2, Appendix D) - 'neutral' and 'fat' tasting foods contributed relatively more energy to main meals (40-53%, 8-10%) than to snacking occasions (16-24%, 1-2%, p<0.001). During snacking occasions however, individuals consumed significantly more % energy from foods tasting 'bitter' (17-32%) and 'sweet & fat' (25-27%) than during main meals (1-5%, 15%, p<0.001) in the DNFCS. Similarly, individuals in the NQplus study consumed significantly more % energy from foods tasting 'bitter' (18-30%) and 'sweet & fat' (28-30%) than during main meals (1-3%, 6-13%, p<0.001).

Day-to-day variation in dietary taste patterns were lowest during breakfast in both the DNFCS as well as the NQplus study, as indicated by higher intra-class correlation coefficients (ICC). During breakfast the ICC ranged from 0.38 for ‘fat’ tasting foods to 0.51 for ‘bitter’ tasting foods, whereas this was 0.03 for ‘fat’ tasting foods to 0.34 for ‘bitter’ tasting foods during the other eating occasions in the DNFCS. Similarly, in the NQplus study the ICC ranged from 0.36 for ‘neutral’ tasting foods to 0.51 for ‘sweet & sour’ tasting foods during breakfast, whereas this was 0.0 for ‘salt, umami & fat’ tasting foods to 0.34 for ‘bitter’ tasting foods during the other eating occasions.

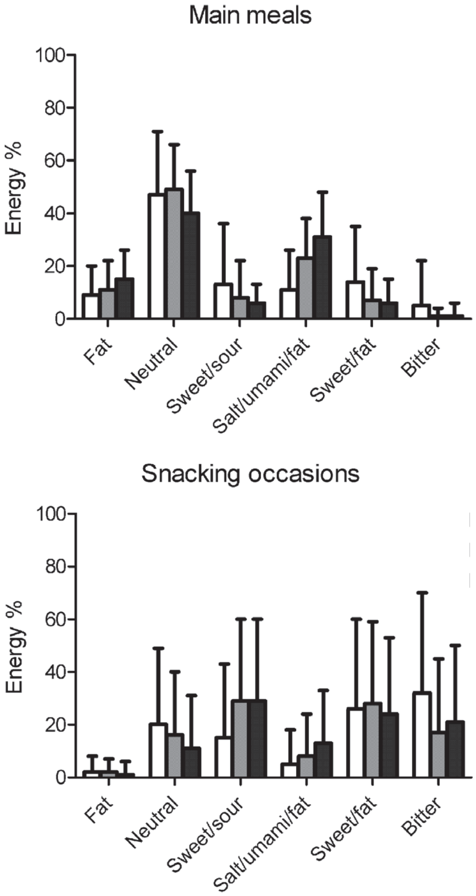

Figure 2 Mean (and SD) percentage of energy from each taste group for main meals[1] and snacking occasions[2] separately, shown for the Dutch National Food Consumption Survey (N_{total}=1351)

[1]Breakfast ( ), n=1282; lunch ( ), n=1304; dinner( ), n=1348. [2]During the morning ( ), n=1190; during the afternoon ( ), n=1301; during the evening ( ), n=1320.

Dietary taste patterns stratified by individual characteristics

Contributions to daily energy intake from each of the 6 taste clusters were assessed for different sociodemographic and weight status subgroups of the population. Dietary taste patterns were assessed for the entire diet (Tables 5-6) as well as for tested foods only for each subgroup of the population (Tables D4 and D5, Appendix D). In both study populations we found similar differences in dietary taste patterns by sex, weight status and age. We did not find any significant differences in dietary taste patterns by educational level.

Sex

Dietary taste patterns differed between men and women (Figure 3), both in the DNFCS (Table 5) as well as in the NQplus study (Table 6). Men consumed a significantly larger percentage of energy from foods tasting 'salt, umami & fat' (DNFCS, 24% & NQplus, 23%) and 'bitter' (7%) than women (DNFCS; 21%, p<0.001 & NQplus; 22%, p=0.005 and 3%, p<0.001 & 4%, p<0.001, respectively Tables 5-6). Women consumed a significantly larger percentage of energy from 'sweet & fat' (both studies 15%) and 'sweet & sour' tasting foods (13% & 12%, respectively) than men (12%, p<0.001 & 13%, p=0.001, respectively and both studies 10%, p<0.001).

Weight status

Obese women (BMI >30.0) consumed a significantly larger percentage of energy from foods tasting 'salt, umami & fat' (DNFCS; 23% & NQplus; 24%) and, although not significant, less from 'sweet & fat' (14%, 15%) than normal-weight women (BMI 18.5-25.0; 'salt, umami & fat' 20% in both studies, DNFCS; p=0.004, NQplus; p=0.011, 'sweet & fat', 16% in both studies, p=0.12, p=0.99, respectively, Figure 3). Similarly, obese men consumed a significantly larger percentage of energy from foods tasting 'salt, umami & fat' (26% in both studies) and less from 'sweet & fat' (11%, 10%) than normal-weight men ('salt, umami & fat', DNFCS; 23%, p=0.037 & NQplus; 22%, p=0.001, 'sweet & fat, 13%, p<0.05, 14%, p<0.01, respectively).

Table 5 Percentage of total energy intake (mean±SD) from each taste cluster based on cluster analyses stratified by sex, age, BMI and educational level, and averaged over 2 days of 24h recalls in the Dutch National Food Consumption Survey[1]

	Percentage of energy from taste clusters											
	Fat		Sweet/ sour		Neutral		Sweet/ fat		Bitter		Salt/ umami/fat	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Men (n=687)	$11^{*‡}$	6	$10^{*¥}$	7	$35^{*¥}$	10	$12^{*¥}$	9	$7^{*¥}$	9	$24^{*¥}$	10
Age (years)												
19-30 (n=343)	11	6	$11^{a¥}$	8	34	11	$12^{a‡}$	9	$7^{a†}$	10	$25^{a†}$	10
30-50 (n=344)	11	6	9^{b}	6	35	10	13^{b}	8	8^{b}	8	23^{b}	9
BMI (kg/m²)												
18.5-25.0 (normal, n=363)	11	6	10	7	35	10	13^{a}	9	8	9	23^{a}	10
25-30 (overweight, n=244)	11	6	10	7	34	10	12^{ab}	8	8	8	$25^{b†}$	10
>30 (obese, n=80)	11	6	10	7	37	11	$11^{b†}$	8	6	8	$26^{b†}$	10
Education (highest completed)												
Low (1-3, n=186)	11	7	10	8	34	11	12	9	7	8	25	12
Medium (4-5, n=351)	11	6	10	7	34	10	13	9	8	10	24	9
High (6-7, n=150)	11	5	11	6	37	10	12	8	6	7	23	10
Women (n=664)	$10^{*‡}$	6	$13^{*¥}$	8	$37^{*¥}$	11	$15^{*¥}$	10	$3^{*¥}$	5	$21^{*¥}$	10
Age (years)												
19-30 (n=323)	10	6	$14^{a¥}$	9	37	12	15	10	$3^{a‡}$	5	21	10
30-50 (n=341)	10	6	11^{b}	8	38	11	15	10	4^{b}	6	21	9
BMI (kg/m²)												
18.5-25.0 (normal, n=351)	10	6	13^{ab}	8	37	12	16	10	4	5	$20^{a‡}$	2510
25-30 (overweight, n=173)	10	5	$13^{a†}$	9	37	11	15	9	3	5	22^{ab}	10
>30 (obese, n=140)	10	6	11^{b}	8	39	12	14	10	3	6	23^{b}	10
Education (highest completed)												
Low (1-3, n=183)	10	6	12	9	36	12	15	10	4	5	22	10
Medium (4-5, n=336)	10	6	13	8	38	11	15	10	3	5	21	10
High (6-7, n=145)	10	6	12	8	39	11	16	10	3	5	20	9

[1] MANCOVA, multivariate ANCOVA was performed including all tastes and subgroups. If the overall effect was significant ($p<0.05$), ANCOVA was used to compare subgroups within each taste group ($p<0.05$, Bonferroni corrected). For age and sex, independent samples t-tests were used ($p<0.05$, Bonferroni corrected). Models for sex were adjusted for age, BMI and education; models for age were adjusted for BMI and education; models for BMI were adjusted for age and education; models for education were adjusted for age and BMI. [a,b] Superscript letters indicate significant differences, same letters indicate no significant difference between mean values. * Indicates significant difference between men and women. † $p<0.05$, ‡ $p<0.01$, ¥ $p<0.001$.

Chapter 5

Table 6 Percentage of total energy intake (mean±SD) from each taste group based on cluster analyses stratified by sex, age, BMI and educational level , and averaged over 2 days of 24h recalls in the NQplus study[1]

	Percentage of energy from taste clusters											
	Fat		Sweet/ sour		Neutral		Sweet/ fat		Bitter		Salt/ umami/ fat	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Men (n=498)	8	4	10[*¥]	6	39	9	13[*‡]	8	7[*¥]	6	23[*‡]	9
Age (years)												
20-30 (n=19)	8	6	11	6	37	7	11	7	6[ab]	8	26	11
31-50 (n=127)	8	5	10	6	39	9	13	8	6[a]	5	25	9
51+ (n=352)	8	4	10	6	39	10	13	8	8[b‡]	7	23	9
BMI (kg/m²)												
18.5-25.0 (normal, n=185)	8	4	10	6	40	9	14[a‡]	8	7	6	22[a‡]	9
25-30 (overweight, n=243)	8	5	10	6	38	10	13[a†]	8	8	7	24[ab]	10
>30 (obese, n=70)	9	5	10	6	38	10	10[b]	6	7	6	26[b]	8
Education (highest completed)												
Low (n=30)	7	4	7	5	38	9	14	7	8	7	25	9
Medium (n=134)	8	4	11	6	39	9	13	8	6	6	24	9
High (n=334)	8	4	10	6	39	10	13	8	7	6	23	9
Women (n=446)	8	5	12[*¥]	7	39	10	15[*‡]	9	4[*¥]	4	22[*‡]	10
Age (years)												
20-30 (n=46)	6	5	12	6	41	10	17[ab]	11	2[a‡]	3	22	10
31-50 (n=158)	8	5	11	7	40	10	16[a†]	10	3[a‡]	4	21	10
51+ (n=242)	9	5	13	6	39	10	14[b]	8	4[b]	4	21	9
BMI (kg/m²)												
18.5-25.0 (normal, n=244)	9[a†]	5	12	6	40	10	16	9	3	4	20[a]	10
25-30 (overweight, n=142)	7[b]	4	13	7	38	10	15	9	4	4	23[b†]	9
>30 (obese, n=60)	8	4	11	7	38	9	15	8	3	4	24[b†]	10
Education (highest completed)												
Low (n=25)	8	5	11	6	43	10	14	9	3	4	21	10
Medium (n=147)	8	5	13	7	39	11	16	9	3	3	22	10
High (n=274)	8	5	12	6	39	9	15	9	4	4	21	9

[1] MANCOVA, multivariate ANCOVA was performed including all tastes and subgroups. If the overall effect was significant (p<0.05), ANCOVA was used to compare subgroups within each taste group (p<0.05, Bonferroni corrected). For sex independent samples t-tests were used (p<0.05, Bonferroni corrected). Models for sex were adjusted for age, BMI and education; models for age were adjusted for BMI and education; models for BMI were adjusted for age and education; models for education were adjusted for age and BMI. [a,b] Superscript letters indicate significant differences, same letters indicate no significant difference between mean values. [*] Indicates significant difference between men and women. † p<0.05, ‡ p<0.01, ¥ p<0.001.

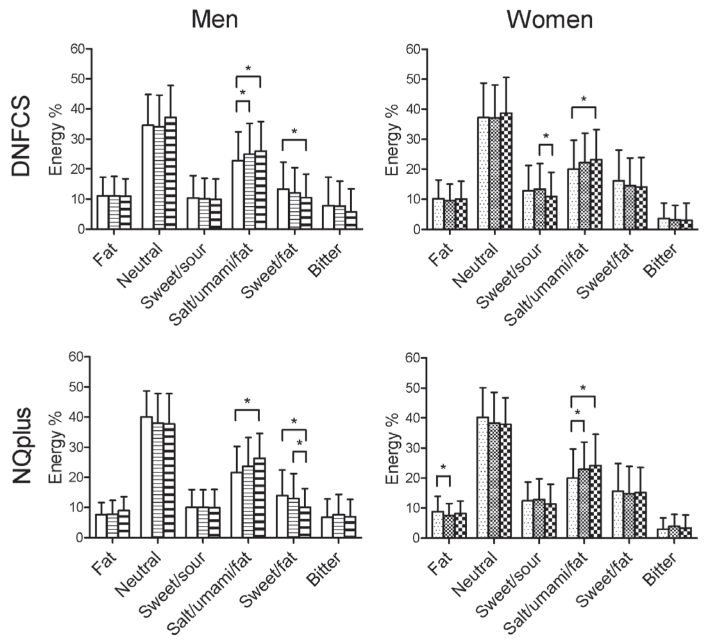

Figure 3 Percentage of total energy intake† (mean±SD) from each taste cluster based on cluster analyses stratified by sex and BMI, and averaged over 2 days of 24h recalls in the Dutch National Food Consumption Survey[1] and in the NQplus study[2]

† MANCOVA, multivariate ANCOVA was performed including all tastes and subgroups. If the overall effect was significant (p<0.05), ANCOVA was used to compare subgroups within each taste group (p<0.05, Bonferroni corrected). Models for sex were adjusted for age, BMI and education; models for BMI were adjusted for age and education* Indicates significant difference between weight status subgroups.

[1] Normal-weight men (); n=363, overweight men (); n=244, obese men (); n=80. Normal-weight women (); n=351, overweight women (); n=173, obese women (); n=140.

[2] Normal-weight men (); n=185, overweight men (); n=243, obese men (); n=70. Normal-weight women (); n=244, overweight women (); n=142, obese women (); n=60.

Age

In both study populations, we found that younger or middle-aged individuals consumed a significantly smaller percentage of energy from 'bitter' tasting foods than older individuals. In the DNCFS, younger men and women (aged 19-30 years) consumed a significantly smaller percentage of energy from 'bitter' (7% & 3%, respectively) tasting foods than middle-aged men and women (aged 31-50 years; 8%, p=0.034 & 4%, p=0.006, respectively). Similarly in the NQplus study, middle-aged men and women (aged 31-50 years) consumed a significantly smaller percentage of energy from 'bitter' (6% & 3%, respectively) tasting foods than older men and women (aged 51 and older; 8%, p=0.001 & 4%, p=0.004 respectively). In addition, we found that younger men and women (aged 19-30 years) consumed a significantly larger percentage of energy from 'sweet & sour' tasting foods (11% & 14%, respectively) than middle-aged men and women (aged 31-50 years; 9% & 11%, respectively, both p<0.001) in the DNFCS, but not in the NQplus study.

Education

No significant differences in dietary taste patterns were found between groups of low, medium or high educational level (all p-values >0.05).

Misreporting of daily energy intake

We excluded potential low energy reporters at group level (LER, n=661, 49% in the DNFCS and n=520, 53% in the NQplus study) from our analyses to explore the effect of under-reporting on dietary taste patterns. Accurate (AR) and high energy reporting (HER) overweight and obese men (25% of the energy in the DNFCS & 24% in the NQplus study) and women (24% & 23%, respectively) consumed more % energy from 'salt, umami & fat' tasting foods than AR and HER normal-weight men (23% & 22%) and women (both 20%) (**Tables D6 and D7, Appendix D**). These findings were significant for AR and HER men (p=0.018) and women (p<0.001) in the DNFCS, and for women (p=0.034) but not for men (p=0.126) in the NQplus study. In addition, we excluded potential low energy reporters (DNFCS, n=154, 11% & NQplus, n=121, 13%) and potential high energy reporters (DNFCS, n=10, 1% & NQplus, n=1, 0.1%) at an individual level from our analyses (**Tables D8 and D9, Appendix D**). Similarly, normal-reporting obese men (26% in the DNFCS, p=0.03 & 27% in the NQplus study, p<0.001) consumed more % energy from 'salt, umami & fat' tasting foods than normal-reporting normal-weight men (23% & 21%, respectively). Obese women (23%, p=0.0588 & 24%, p=0.0777, respectively) also consumed more % energy from 'salt, umami & fat' tasting foods than normal-reporting normal-weight women (both 20%), though this was not significant.

Discussion

This study is the first that aimed to assess dietary taste patterns in the Netherlands by sex, weight status, age and educational level. This is the first study to observe that dietary taste patterns differ by sex and weight status. We found similar results concerning dietary taste patterns in two different study populations. Men consumed a significantly larger percentage of energy from foods tasting 'bitter' and 'salt, umami & fat' and a smaller percentage of energy from foods tasting 'sweet & fat' and 'sweet & sour' than women. Obese men and women consumed a significantly larger percentage of energy from foods tasting 'salt, umami & fat' and less, although only significant in men, from foods tasting 'sweet & fat' than normal-weight men and women.

A key strength of our study is that we used a large database with taste values of foods - obtained by a trained panel - in combination with food intake data from two study populations. Trained panels are commonly used as an objective measure to quantify sensory properties of foods[36]. Training increases the panel's internal consensus, reproducibility and discriminative power[19–21]. Importantly, foods for profiling were selected using objective criteria – i.e. consumption frequency and contribution to energy and macronutrient intake in the DNFCS. However, it remained of interest whether dietary taste patterns could be reproduced in an observational study that was independent of our food selection process. Therefore we assessed dietary taste patterns in the DNFCS (2007-2010) as well as in an independent observational study that used a similar dietary assessment method– i.e. the NQplus study (2011-2013). In addition, we performed sensitivity analyses by excluding energy intake from foods that were not profiled by our panellists. The NQplus study population was somewhat older but also higher educated than the DNFCS study population. Despite these study population differences, similar results were found concerning dietary taste patterns in the entire diet and in the selected profiled foods for both study populations. This suggests that our findings are valid for the diet of the general population of healthy Dutch adults.

Across eating occasions, we found dietary taste patterns in line with reported macronutrient intake in the DNFCS (2007-2010)[18]. For individual foods, studies have found positive associations between sweetness and mono- and disaccharides, umami and protein, and fat sensation and fat content[2,3,37]. In the current study, individuals consumed relatively more energy from foods tasting 'salt, umami and fat' during lunch and dinner than during breakfast, in line with reported protein (24 % and 45%) and fat (22% and 42%) intake during lunch and dinner compared to breakfast (14% and 13%, respectively)[18]. In addition, energy intake from 'sweet & sour' and 'sweet & fat' tasting foods was relatively higher during snacking occasions compared to main meals, in line with reported mono-and disaccharides intake during snacking occasions (on average 48% of the total intake of mono- and disaccharides versus 30% energy from snacks[18]). Thus, taste can be related to macronutrients both at the level of individual foods as well as dietary intake.

Since the 1970s it is debated whether overweight and/or obese individuals have a preference for sweet or savoury tasting foods, and this issue is still discussed. Some studies have found a positive association between liking for sweet[9,10] or savoury foods and BMI[9]. In contrast, other studies have reported lower liking ratings for sweet and savoury foods in obese versus lean individuals[16] or no difference in liking across BMI categories[17]. An explanation for this lack of consensus on obese people's taste preferences might be that liking of food is dependent on the consumption context, for example where and with whom people are eating[38]. Therefore, laboratory measures of liking may not accurately predict dietary intake; taste preferences are not the same as dietary taste patterns. However, it may be assumed that a higher preference of certain foods is reflected in a higher intake of these foods, depending also on other factors such as costs and health[1]. To our knowledge, the current study provides the first indications for a higher percentage of energy intake from 'salt, umami and fat' and potentially less from 'sweet & fat' tasting foods in obese individuals compared to normal-weight individuals. These findings suggest that obese individuals may partly substitute consumed amounts of 'sweet & fat' tasting foods for 'salt, umami & fat' tasting foods. Another possibility could be that obese individuals consume more energy dense 'salt, umami & fat' and less energy dense 'sweet & fat' tasting foods than normal-weight individuals. Our findings are based on dietary intake in a large representative sample of 1,351 adults and an additional sample of 944 adults in the Netherlands. In contrast to our expectations, total energy intake was not significantly different between obese and normal-weight individuals. However, our conclusions seemed unaffected by underreporting of energy intake. Nevertheless, underreporting may still be an issue as we did not take the level of physical activity into account. In particular high-fat sweet foods may be sensitive to under-reporting, and under-reporting of energy intake increases with BMI[39]. Future studies on dietary taste patterns are needed to confirm our findings in other Western and non-Western study populations to fully resolve this issue globally.

In both study populations, we found similar differences in dietary taste patterns between men and women. Women consumed a significantly larger percentage of energy from foods tasting 'sweet & fat' and 'sweet & sour' than did men, in line with mono- and disaccharides intake in both studies (DNFCS; 22% total energy (TE) in women, 20% TE in men, NQplus study; 21% TE in women, 18% TE in men). Men consumed a significantly larger percentage of energy from foods tasting 'bitter', in line with a relatively higher energy intake from alcohol in men (DNFCS; 4% TE, NQplus study; 5% TE) than in women in both studies (2% TE, 3% TE, respectively). In addition, we found a significantly higher energy intake from 'salt, umami and fat' tasting foods in men than in women. In contrast, the percentage of energy from protein (DNFCS; both 15% TE, NQplus study; both 16% TE) and fat (DNFCS; both 34% TE, NQplus study; both 34% TE) did not differ between men and women in the DNFCS. However, our findings are in line with studies showing that men liked salt and/or fatty foods more than women[(9–15)]. Similarly, evidence exists for a higher liking for sweetness in women than in men[(9,10,14,15)], although one study found no sex differences in sweet food liking[(11)]. To our knowledge, only one study reported significantly higher frequency of consumption of salty-and-fatty foods in men than in women, but no sex differences in the frequency of consumption of sweet-and-fatty foods[(11)]. An explanation for our consistent differences in dietary taste patterns by sex might be that we studied the role of taste in dietary intake, including the consumption context[(38)].

Dietary taste patterns varied between the two recall days - intra-class correlation coefficients ranged from 0.12 to 0.44 in the DNFCS and from 0.14 to 0.48 in the NQplus study. This is due to the chosen dietary assessment method as such; 24-hour recalls are prone to natural day-to-day variation in intake. Therefore it is not possible to accurately estimate dietary taste patterns at the individual level in the current study. However, the within-person variation tends to cancel out at group level if the group is large enough and the recalls are repeated within individuals[(40)]. In the current study, we compared dietary taste patterns only at group level and not at an individual level, which is appropriate given our large sample size (n= 1,351 and n=944) and use of 2-day 24-hour recalls.

In conclusion, our findings demonstrate that our taste database can be used to study the role of taste in dietary intake in the Netherlands by sex, weight status, age and educational level. In addition, dietary taste patterns can be reproduced using our taste database in an independent study population. We have found that men consumed relatively more energy from foods tasting ‘bitter’ and ‘salt, umami & fat’ and less energy from foods tasting ‘sweet & fat’ and ‘sweet & sour’ than women. Moreover, our findings suggest that in particular the % of energy intake from ‘salt, umami and fat’ may be higher and from ‘sweet & fat’ may be lower in obese individuals than in normal-weight individuals. Future follow-up studies are needed to clarify a potential causal relationship between dietary taste patterns and weight gain, in adults but also in other study populations such as children and in both Western and non-Western study populations. Future prospective studies could also investigate whether dietary taste patterns can explain differences between subgroups at risk of chronic diseases such as cardiovascular disease and type 2 diabetes. Studying dietary patterns from a taste perspective - and not only a nutritional perspective - can provide us with a deeper understanding of the role of taste in dietary intake.

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Chapter 6

Dietary taste patterns of diets based on Dutch dietary guidelines, a Mediterranean diet, a Paleo diet and diet quality compared with current Dutch dietary taste patterns in women

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Abstract

Worldwide there is an enormous societal pressure to lower dietary salt, sugar and fat. Diets lower in these nutrients may be lower in taste intensity and this could be a key contributing factor for poor adherence to dietary guidelines and a consumer's demand for alternative diets. This study aimed to compare dietary taste patterns of healthy and popular diets and diet quality with the current Dutch diet of women. A taste database, containing 476 foods' taste values, was combined with different dietary scenarios, the Dutch Healthy Diet-15 (DHD-15) index and the Dutch National Food Consumption Survey (DNFCS 2007-2010). The percentage of energy from six taste clusters was assessed using 2-day 24-hour recalls in the DNFCS (n=664 women; 34±9 y, BMI 26±6 kg/m^2) and 10 daily menu's for three diets: a diet based on Dutch food-based dietary guidelines, a Mediterranean diet and a Paleo diet. The energy from 'neutral' tasting foods was relatively high in a diet based on Dutch dietary guidelines (64% energy) and a Mediterranean diet (53%), but not a Paleo diet (38%), compared with the current diet (38%). The DHD-15 index was associated with relatively more energy from 'neutral' (r 0.27, p<0.001) tasting foods and less energy from 'salt, umami & fat' (r -0.30, p<0.001) and 'bitter' (-0.24, p<0.001) tasting foods. In conclusion, healthy diets, but not a popular diet, may be lower in taste intensity compared with the current Dutch diet in women and this may be a key contributing factor for poor adherence to dietary guidelines.

Introduction

Worldwide, there is an enormous societal pressure to lower dietary salt, sugar and fat intake to prevent chronic diseases[1]. Some countries report dietary reductions of these nutrients, yet these reductions have been minimal and do not reach dietary recommendations[2–5]. Numerous studies have investigated barriers for adherence to dietary guidelines[6–9]. One of these barriers is that consumers intuitively believe the unhealthier the food, the tastier it is[10]. In support of this intuition, it is well known that sugar, salt and fat provide taste and palatability to food[11–14]. For example, highly palatable products such as chocolate and French fries are high in sugar & fat and salt & fat, respectively, and thus high in fat sensation and sweetness or saltiness. Therefore, diets lower in sugar, salt, and fat content may be lower in taste intensity and this could be a key contributing factor for poor adherence to dietary guidelines[11,12].

If dietary guidelines are indeed relatively bland in taste, this could also explain why consumers are seeking alternative diets that may better satisfy their sensory needs. Nowadays, many popular diets exist such as the Atkins diet and the Paleo diet[15]. The popularity of alternative diets might be in part attributable to their higher taste intensity values.

To study the taste profile of diets it is essential to objectively quantify the taste intensity values of foods. Food composition tables are globally available, however only three studies compiled a taste database[11,12,16]. To our knowledge, only one of these databases[12] were used to investigate associations between adherence to dietary guidelines and taste intensity of the diet[17]. Therefore, this study aimed to compare dietary taste patterns of dietary scenarios and diet quality with the current Dutch diet of women. We hypothesized that healthy dietary scenarios, but not a popular dietary scenario, would consist of relatively more energy and consumed amount from 'neutral' tasting foods compared with the current Dutch diet. Similarly, we expected associations between the energy and consumed amount from 'neutral' tasting foods and the extent of adherence to dietary guidelines.

Methods

A taste database was used to assign taste intensity values to food in healthy and popular dietary scenarios and the current Dutch diet. Subsequently, we evaluated dietary scenarios against the current diet by comparing the percentage of consumed energy and amount (gram) from six taste groups. Additionally, we studied associations between the extent of adherence to dietary guidelines and dietary taste patterns.

Food consumption data

Current diet

We used the most recent Dutch National Food Consumption Survey (DNFCS 2007-2010)[18]. The DNFCS is representative of the Dutch population regarding age, sex, region, degree of urbanization and educational level. Diet was assessed for in total 3,819 Dutch individuals aged 7-69 years. Trained dieticians used the computer directed interview program for standardization of 2-day 24-hour recalls, GloboDiet[19]. In the present analyses, we included the food intake data from women aged 19-50 years (DNFCS 2007-2010, n=698). We selected women, because energy intake in women was more similar to energy intake in the dietary scenarios. Individuals who were breastfeeding, seriously underweight, underweight or without information on weight status were excluded from the analyses (n=33). One participant was excluded because of missing food intake data at one measurement day. In total, we included the food intake data from 664 women with a mean age of 34±9 y (range 19-50 y) and BMI of 26±6 kg/m^2 (range 18.5-56.7 kg/m^2).

Dietary scenarios

For the present study, we used the average of 10 diet plans of a consumption day for each of the three dietary scenarios described below: a diet based on Dutch food-based dietary guidelines, a Mediterranean diet and a Paleo diet. Each dietary scenario included food to be consumed during the main meals and the snacking occasions (Figure 1).

Figure 1 Visual representation of 1 consumption day in the Dutch National Food Consumption Survey (top left; DNFCS, 2007-2010; n=664 women, mean age 34±9 years, mean BMI 26±6 kg/m2); Dutch food-based dietary guidelines (top right); a Mediterranean diet (bottom left); a Paleo diet (bottom right)

Dutch food-based dietary guidelines

To improve adherence to the Dutch food-based dietary guidelines, the Netherlands Nutrition Centre developed a healthy diet based on these guidelines in the form of a 'Wheel of Five'[20]. The 'Wheel of Five' is specifically tailored for the Netherlands and corresponds to the current Dutch diet as close as possible (**Table 1**). The Wheel of Five includes plenty of fruit and vegetables, sufficient amounts of whole meal bread and grain products, limited amounts of meat, fish and pulses on a weekly basis, daily consumption of unsalted nuts, milk and milk products, use of oil and liquid fats, water, tea and filtered coffee. The Wheel of Five contains the recommended consumption in grams per day for men and women of all ages. For the present study, the Netherlands Nutrition Centre designed diet plans based on the ‘Wheel of Five’ for women aged 19-50 years.

Mediterranean diet

The Mediterranean diet is based on dietary patterns in Greece and southern Italy in the early 1960s[21]. The Mediterranean diet is characterized by abundant plant foods, olive oil as a source of fat, dairy products, eggs, low to moderate amounts of fish and poultry, low amounts of red meat and low to moderate amounts of wine[21]. For a Mediterranean diet we used scenarios that were based on legumes, vegetables, fruit, (fatty) fish, chicken, meat, eggs, unsweetened dairy products, whole-grain cereals and fats rich in unsaturated fatty acids[22]. We used the first ten diet plans from four weeks of seven diets plans that were available, to keep the results comparable to the other dietary scenarios[22].

Paleo diet

An example of a popular diet is the Paleo diet, which is based on a reconstructed diet from the Paleolithic era. A Paleo diet has similarities to low-carbohydrate diets, in that processed starches and sugars are often avoided[23]. Many Paleo diets are high in protein and low in carbohydrates. Foods from a Paleo diet include lean meat, fish, eggs, fruit, vegetables, and nuts and limited or no dairy[24–26]. For a Paleo diet we used scenarios that were based on fatty fish, meat, eggs, dairy in limited amounts, vegetables, fruit, nuts and seeds and fats rich in unsaturated fatty acids[26]. Grains were not included in the Paleo diet, except for unprocessed (spelt) grains.

Taste database

Panellists

Dutch adults (18-55 y) with a self-reported normal BMI (18.5-25.0 kg/m^2) were recruited from Wageningen and surroundings (Taste, Fat and Texture study)[27]. We selected panellists based on their taste recognition, taste discrimination, the ability to sustain attention and sensory profiling abilities. Panellists were trained to evaluate the intensity of sweet, salt, sour, bitter, umami and fat sensation using a modified Spectrum™ method and received this intensive training for in total 63 hours over six months.

Table 1 Average energy, macronutrient, dietary fibre and sodium intake of 10 diet plans for each of the three dietary scenarios: the current diet (DNFCS), a diet according to Dutch food-based dietary guidelines, a Mediterranean diet and a Paleo diet, expressed in % energy and % amount (gram)*

	DNFCS† (reference)	Dutch dietary guidelines‡	Mediterranean	Paleo
	% energy (% amount)	*% energy (% amount)*	*% energy (% amount)*	*% energy (% amount)*
Energy in kcal (kjoule)	1972 (8251)	2033 (8506)	1712 (7163)	1875 (7845)
Total fat	34 (19)	30 (12)	45 (24)	46 (25)
Protein	15 (18)	20 (17)	25 (30)	19 (24)
Carbohydrates	47 (57)	46 (43)	27 (33)	30 (37)
Mono- and disaccharides	22 (27)	18 (17)	15 (18)	23 (29)
Dietary fibre	2 (5)	4 (8)	4 (9)	3 (8)
Alcohol	2 (1)	0	0 (0)	1.5 (1)
Sodium in mg	2413	1699	2107	2243

*Amount in % of total consumed amount in gram, excluding water. †DNFCS; Dutch National Food Consumption Survey 2007-2010; n=664 women aged 19-50 years. ‡Dutch food-based dietary guidelines for women aged 19-50 years.

Food selection and preparation

Foods for profiling (n=467) were selected based on the most recent Dutch National Food Consumption Survey (DNFCS 2007-2010)[18]. For the selection of foods, we used dietary intake data of 1402 adults between 19-50 years old (704 men, 698 women). Foods were selected based on several criteria, i.e. high consumption frequency, and largest contribution to the consumption of energy and macronutrients. In addition, we selected foods that contributed most to the variation in energy intake. The selected foods contributed in total to 83% of energy intake in the DNFCS. We used expert knowledge from research dieticians to select one of the most often consumed brands. Foods were prepared using recipes from the product's package or were prepared according to normal household practice[28]. Cooked foods were prepared unseasoned, so without any additions of condiments, salt or spices. Foods were prepared one hour before sensory testing to control for the serving temperature. After preparation, cooked foods were kept warm using a bain-marie container (60-65 °C). Cold foods were served at room (20-25°C) or refrigerator temperature (4-9 °C) where appropriate.

Classification of foods in taste groups

Groups of foods were formed within the taste database using hierarchical cluster analyses on foods' and food groups' mean taste intensity values. The number of clusters was decided using Ward's method[29]. Six taste groups were identified that accounted for 73% of the total variance in taste (R^2=0.73). The taste groups were labelled as 'neutral', 'fat', 'sweet & sour', 'bitter', 'sweet & fat' and 'salt, umami & fat' based on their mean taste intensity values.

Dietary taste patterns

Foods reported in the current diet (24hR) and dietary scenarios were coded according to the Dutch food composition table[30] and were matched with foods in the taste database. For estimating taste values to untested foods, we used NEVO food groups in the Dutch food composition table[30] in combination with the GloboDiet classification system[19] as described previously[31]. For example, we calculated average taste intensity values of profiled foods in the NEVO food group 'bread' and assigned these values and the corresponding cluster to all untested foods in this food group. Subsequently, we assessed dietary taste patterns: the percentage of daily energy intake and consumed amount (gram) contributed by each of the six taste food groups. For the current diet, we calculated the percentage of energy intake and consumed amount from each taste cluster, averaged over two 24-hour recall days for each individual. For the three dietary scenarios we calculated the average percentage of energy intake and consumed amount from each taste cluster of 10 scenarios.

Dutch Healthy Diet index

For the current diet, we calculated a score for the extent of adherence to the Dutch food-based dietary guidelines of 2015 for each individual consumption day using the Dutch Healthy Diet 2015 index (DHD15-index)[32]. The DHD-15 index consists of fifteen components representing the fifteen Dutch food-based dietary guidelines of 2015[33]. A score for each component ranges from 0 to 10, resulting in a total score between 0 (no adherence) and 150 (complete adherence). The fifteen components include recommendations for vegetables, fruit, wholegrain products, legumes, nuts, dairy, fish, red meat, processed meat, sweetened beverages and fruit juices, alcohol, tea, coffee, fats and oils, and salt. More details on the development and evaluation of the DHD-15 are described elsewhere[32].

Statistical analyses

Data was analysed using SAS version 9.3. (SAS Institute, Inc., Cary, NC, USA). We assessed the percentage of consumed energy and amount (gram) from each taste group for the three dietary scenarios and the current diet. In the current diet, the percentage of consumed energy and amount from each taste group was correlated with the DHD-15 index using Spearman correlation coefficients. P-values <0.05 were considered significant. The 95% CI of the correlation coefficients were calculated by Fisher's Z-transformation.

Results

Dietary taste patterns

Percentage of consumed energy

Dutch food-based dietary guidelines (64% of energy) and a Mediterranean diet (53%), but not a Paleo diet (38%), were relatively high in energy from 'neutral' tasting foods compared with the current diet (38%, Figure 2, Table E1, Appendix A). All three dietary scenarios were relatively low in energy from 'sweet & fat' tasting foods (Dutch food-based dietary guidelines; 3%, Mediterranean; 3%, Paleo; 8%, vs. current diet; 15%). In addition, Dutch food-based dietary guidelines were relatively low in energy from 'salt, umami & fat' tasting foods (7%) compared with the current diet (21%). Excluding beverages from the analyses, resulted in a relative high % of energy from 'sweet & sour' tasting foods in all dietary scenarios (Dutch food-based dietary guidelines; 11%, Mediterranean; 15%, Paleo; 13%) compared to the current diet (5%).

Percentage of consumed amount

Findings for the percentage of % consumed amount were similar. Dutch food-based dietary guidelines (64% of energy) and a Mediterranean diet (57%) were relatively high in energy from 'neutral' tasting foods compared with the current diet (53%). A Paleo diet (50%) was more similar to the current diet (53%) concerning the consumed amount from 'neutral' tasting foods. In addition, a Mediterranean diet (17%) and a Paleo diet (13%) were relatively high in % consumed amount, but not % energy, from 'salt, umami & fat' tasting foods compared to the current diet (7%). The consumed amount from 'bitter' tasting foods was relatively low in a Mediterranean diet (3%) and a Paleo diet (6%) compared to the current diet (12%). In addition, the % of consumed amount from 'bitter' tasting foods was relatively high in the Dutch food-based dietary guidelines (4%) and Mediterranean diet (4%) compared with the current diet (0%), but only when beverages were excluded.

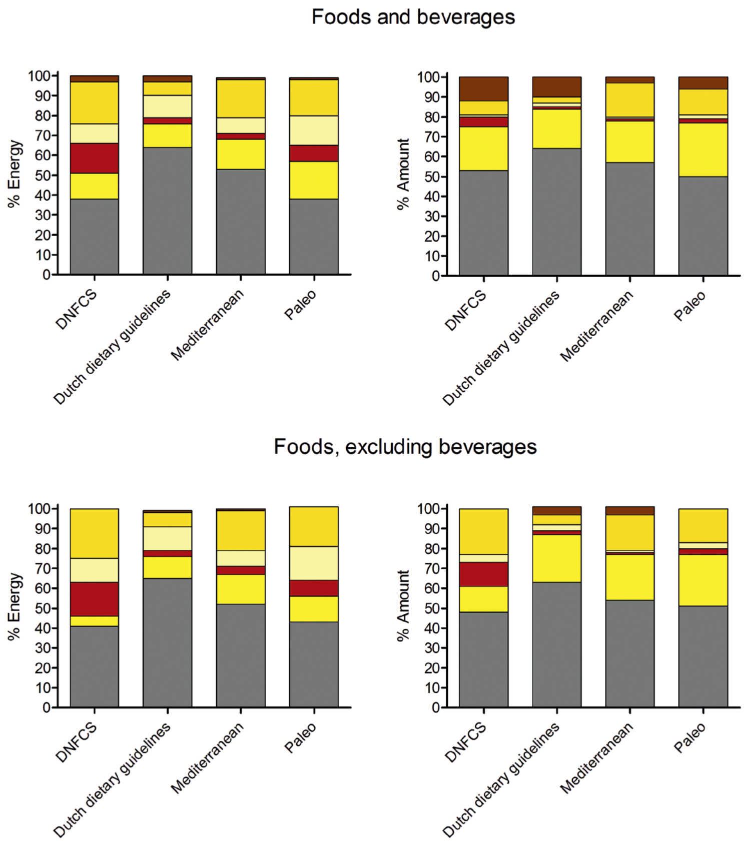

Figure 2 Dietary intake from six taste groups, expressed in % energy (left) and % amount (gram, right), including (top) and excluding (bottom) beverages*.

*Neutral ( ), 'sweet & sour' ( ), 'sweet & fat' ( ), 'fat' ( ), 'salt, umami & fat' ( ), 'bitter' ( ) tasting foods.

Associations between dietary taste patterns and adherence to dietary guidelines

The extent of adherence to Dutch food-based dietary guidelines, assessed using the DHD-15 index, was on average 48.4±14.2 for women in the DNFCS (0; no adherence, 150; complete adherence). The extent of adherence to Dutch food-based dietary guidelines was positively associated with % consumed energy and amount from 'neutral' (r 0.27, r 0.43, respectively, both p<0.001, Table 2) and negatively associated with % consumed energy and amount from 'salt, umami & fat' (r -0.30, r -0.33, respectively, both p<0.001) and 'bitter' (r -0.24, r -0.25, respectively, both p<0.001) tasting foods. In addition, the extent of adherence to Dutch food-based dietary guidelines was positively associated with % consumed energy, but not % consumed amount, from 'sweet & fat' (r 0.12, $p<0.01$, r 0.02, $p>0.05$) tasting foods. The extent of adherence to Dutch food-based dietary guidelines was negatively associated with % consumed amount, but not % consumed energy, from 'sweet & sour' (r -0.17, $p<0.001$, r 0.02, $p>0.05$, respectively) tasting foods.

Table 2 Spearman correlation coefficients between the extent of adherence to Dutch food-based dietary guidelines (DHD-15 index) and % consumed energy and amount from six taste groups in the Dutch National Food Consumption Survey (2007-2010; n=664 women, 34±9 y, BMI 26±6 kg/m^2)

	% Energy		% Amount (gram)	
Taste groups	r	CI	r	CI
Neutral	0.27*	(0.20, 0.34)	0.43*	(0.36, 0.49)
Sweet/sour	0.02†	(-0.06, 0.09)	-0.17*	(-0.25, -0.10)
Sweet/fat	0.12	(0.05, 0.20)	0.02	(-0.06, 0.09)
Fat	-0.06	(-0.14, -0.01)	-0.16*	(-0.23, -0.08)
Salt/umami/fat	-0.30*	(-0.37, -0.23)	-0.33*	(-0.39, -0.26)
Bitter	-0.24*	(-0.31, -0.17)	-0.25*	(-0.32, -0.18)

† $p<0.01$, * $p<0.001$

Discussion

This study aimed to compare dietary taste patterns of dietary scenarios and diet quality with the current Dutch diet of women. As hypothesized, 'neutral' tasting foods contributed relatively more to the consumed energy and amount in a diet according to the Dutch food-based dietary guidelines and a Mediterranean diet compared with the current diet. A Paleo diet was more similar to the current diet concerning the consumed energy and amount from 'neutral' tasting foods. Moreover, adherence to Dutch food-based dietary guidelines was associated with relatively more energy and amount from 'neutral' tasting foods and less from 'salt, umami & fat' and 'bitter' tasting foods. These findings suggest that a lower taste intensity of healthy diets, but not a popular diet, may be a key contributing factor for poor adherence to dietary guidelines.

Numerous studies have investigated barriers for adherence to dietary guidelines[(6–9)]. One of these barriers is that consumers intuitively believe the unhealthier the food, the tastier it is[(10)]. In line with this intuition, previous studies have found associations between sweet taste intensity, salt taste intensity and fat sensation values of individual foods and its mono- and disaccharide, sodium, and fat content, respectively[11–14]. Moreover, it is clear that the unhealthy taste intuition is also confirmed by our current findings of less intense tasting dietary guidelines compared with current dietary taste patterns. Our findings may also explain why consumers are seeking alternative diets that may better satisfy their sensory needs. For example, a Paleo diet only includes limited amounts of grains and dairy, which are 'neutral' in taste and relatively large amounts of 'salt, umami & fat' tasting meat and fish. Here we showed that the popularity of alternative diets, such as a Paleo diet, might be in part attributable to their higher taste intensity values.

To date, it is unknown whether consumers can get used to less taste in their diet. Previous research on saltiness suggest that gradual reductions of saltiness in foods such as bread, crackers and soup is feasible without altering the perceived intensity, pleasantness and intake[34–37]. However, adherence to recommendations for sodium intake is low and it remains unknown whether consumers can get used to reductions in whole diet saltiness[2]. In addition, it is unclear what the effects are of sweet taste exposure on later preference, food choice and intake[38]. Sweet taste is innately pleasant, unlike salt taste for which infants develop a preference in the first year of life[39]. In a long-term study by Wise et al.[40], subjects were put on either a reduced simple sugar diet or their regular diet. In the intervention group compared to the control group, they found effects on perceived taste intensity, but not on perceived pleasantness of vanilla puddings and raspberry beverages that varied in sucrose concentration. Similarly, other studies provide limited evidence for an effect of a reduced sweet taste exposure on the perceived sweetness and intake of other sweet foods[41–44]. There is a need for studies on whole diet sweetness and saltiness, rather than the effects of sweet and salty taste exposure on intake of a selection of sweet and salty foods.

Understanding poor adherence to dietary guidelines is important because of its higher prevalence among overweight or obese individuals[45,46]. Previously, we found that obese men and women consumed relatively more energy from 'salt, umami & fat' tasting foods and relatively less from 'sweet & fat' tasting foods than normal-weight men and women[31]. Similarly, we found associations between BMI z-scores in early childhood and the contribution to energy intake from 'salt, umami & fat' tasting foods in a large population-based cohort[47]. In the current study, a relatively higher consumed energy and amount from 'salt, umami & fat' tasting foods was associated with lower adherence to dietary guidelines. In line with these findings, Cox et al.[17] found a tendency for higher energy-adjusted salt taste exposure with lower adherence to dietary guidelines. In addition, they found that higher sweet taste exposure was associated with higher adherence to dietary guidelines[17]. Similarly, we found that the consumed energy and amount from 'sweet & sour' tasting foods, but not from 'sweet & fat' tasting foods, was relatively higher in Dutch food-based dietary guidelines compared with the current diet, but only when we excluded beverages from our analyses. In line with a recent report, our findings suggest that sweetness per se may not be an issue for diet quality and that 'salt, umami & fat' tasting foods are potentially of greater concern for diet quality and the current obesity epidemic[48].

In the current study we selected healthy dietary scenarios based on Dutch food-based dietary guidelines and a Mediterranean diet. However, for examples of healthy dietary scenarios we could also have studied the Dietary Approaches to Stop Hypertension (DASH) diet. Similar to our healthy dietary scenarios, the DASH diet includes plenty of fruits, vegetables, and low-fat dairy products, while being lower in fat, sweets, sugar-containing beverages and red meat[49]. Therefore, we expect that the DASH diet would also be relatively low in taste intensity compared with the current Dutch diet. It should be mentioned that our current Dutch diet was based on the same population from which we selected our foods for sensory profiling. However, in a previous study we showed that dietary taste patterns were similar in the current Dutch diet compared with a study population that was independent of our food selection process[31]. Moreover, our dietary scenarios were examples of a Mediterranean and a Paleo diet and that results may differ somewhat depending on definitions of these diets. For example, diet plans that were available for a Mediterranean diet did not include red wine, while this is often included in definitions of the Mediterranean diet [50]. Including red wine in a Mediterranean diet would increase the consumed energy and amount from bitter tasting foods. Nevertheless, the majority of the consumed energy and amount in healthy dietary scenarios remain low in taste intensity.

One of the strategies that may be used to make healthy diets more appealing could be the enhancement of flavour. In contrast to taste intensity, flavour intensity has been found to increase with increased adherence to dietary guidelines[17].

Flavour enhancement by using for example herbs and spices is indeed one of the strategies used by the Netherlands Nutrition Centre for the development of diet plans based on Dutch food-based dietary guidelines[20]. However, healthy flavour enhancement may not be that easy and convenient for the consumer.

Another promising but challenging strategy is the reduction of sugar, salt and fat content in foods, while maintaining taste and palatability. From recent studies it is clear that foods can vary substantially in salt, sugar and fat content at similar levels of sweet and salt taste intensity, and fat sensation values[13,14]. These findings suggest that it is possible to develop foods that are healthier while maintaining taste. Food technology clearly has a role to play in the development of taste enhancement techniques. For example, taste enhancement can be achieved by the addition of aromas, inhomogeneous spatial distribution of tastants and textural modifications to enhance the release of tastants from the food matrix during oral processing[51]. However, successful application of these techniques requires substantial research and development for each product individually.

In conclusion, healthy diets, but not a popular diet, may be lower in taste intensity compared with current Dutch dietary taste patterns in women and this may be a key contributing factor for poor adherence to dietary guidelines. Randomized controlled trials are needed to investigate whether an exposure period to lower or higher whole diet sweetness and saltiness affects dietary taste patterns. Given the current dietary guidelines to reduce dietary salt, sugar and saturated fat intake, further research on the feasibility of these guidelines, from a taste perspective, is clearly needed.

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Chapter 7

General discussion

The overall aim of this thesis was to assess the role of taste in energy intake in young children and adults, and to investigate how taste relates to nutrients and the extent of adherence to dietary recommendations. To this aim, five research questions were defined:

1. How is taste intensity related to nutrient content in single foods, and is this relationship modified by food form (**Chapter 2**)?

2. To what extent can different dietary assessment methods assess dietary taste patterns (**Chapter 3**)?

3. How do dietary taste patterns develop during early childhood (**Chapter 4**)?

4. Do dietary taste patterns differ by individual characteristics in adults (**Chapter 5**)?

5. How is taste related to the extent of adherence to dietary guidelines and how do healthy and popular dietary scenarios differ from the current diet concerning dietary taste patterns (**Chapter 6**)?

This final chapter will start with an overview of the main findings, followed by a discussion of the methodological issues. The main findings will be interpreted and discussed, and implications and suggestions for future research will be proposed.

Main findings

Table 1 provides an overview of the main findings of this thesis. In **Chapter 2** we studied the relationship between taste intensity, energy and nutrient content in individual foods. We found that sweet taste intensity was associated with mono- and disaccharides, but not with energy content. Salt taste intensity was associated with sodium, protein, fat and energy content. Food form, i.e. liquids, semi-solids and solids, did not modify relationships between taste intensity, energy and nutrient content.

In **Chapters 3-6** we combined our taste database with dietary intake data to investigate dietary taste patterns. First, we investigated to what extent different dietary assessment method can be used to assess dietary taste patterns (**Chapter 3**). We evaluated dietary taste patterns based on FFQ against 3-d 24hR and biomarkers of exposure in an adult study population. We found that the FFQ's reliability for ranking adults' dietary taste pattern was acceptable to good compared to 24hR. Moreover, similar associations for FFQ and 24hR were found between dietary taste patterns and biomarkers for sodium and protein intake, that is urinary Na and N. These findings suggest that food intake data assessed with FFQ as well as 24hR can be used to investigate dietary taste patterns.

In **Chapter 4** we investigated the development of dietary taste patterns during early childhood in a large population-based cohort. In children aged one year the majority of energy intake was obtained from 'neutral' (64%) tasting foods, which was substantially higher than in children aged two years (42%). Energy intake from 'sweet & fat', 'fat' and 'salt, umami & fat' tasting foods was higher in two year olds than in one year olds. Higher child BMI z-scores were associated with relatively more energy from 'salt, umami & fat' tasting foods. Furthermore, higher maternal educational level was associated with relatively more energy from 'neutral' tasting foods and less from 'sweet & fat', ' fat' and ' salt, umami & fat' tasting foods.

Subsequently, dietary taste patterns were investigated in adults in two independent study populations (**Chapter 5**). In both study populations we found that men consumed relatively more energy from 'salt, umami & fat' and 'bitter' tasting foods, whereas women consumed relatively more energy from 'sweet & fat' and 'sweet & sour' tasting foods. In addition, we found that obese individuals (BMI>30.0 kg/m^2) consumed relatively more energy from 'salt, umami & fat' tasting foods and relatively less from 'sweet & fat' tasting foods than lean individuals.

In our last study, we compared dietary taste patterns of healthy and popular dietary scenarios with Dutch dietary taste patterns in women from the DNFCS 2007-2010 (**Chapter 6**). In addition, we investigated associations between the extent of adherence to dietary guidelines, as a measure of diet quality, and dietary taste patterns in these women. We found that a diet according to the Dutch food-based dietary guidelines and a Mediterranean diet was relatively high in neutral tasting foods compared with the current diet. The Paleo diet that we calculated was more similar in the consumed energy and amount from 'neutral' tasting foods compared to the current diet. The individual extent of adherence to Dutch dietary guidelines – as measured with the Dutch Healthy Diet Index - was associated with a relatively high intake – in energy as well amount - from 'neutral' tasting foods and lower intake of energy and amount from 'salt, umami & fat' and 'bitter' tasting foods. These findings suggest that healthy diets, but not a popular diet, may be lower in taste intensity compared with current Dutch dietary taste patterns in women.

Table 1 Overview of the main findings of this thesis*

Chapter	Aim	Method(s)	Main findings
2	The relationship between taste, energy and nutrients and the modifying effect of food form (liquids, semi-solids, solids).	Taste and nutrient database for processed foods	Sweetness ↑ with mono- and disaccharides (r=0.70), but not energy content. Saltiness ↑ with sodium (r=0.72), protein (r=0.39), fat (r=0.37) and energy content (r=0.43). No modifying effect of food form on these associations.
3	Dietary taste patterns based on FFQ against 24hR and biomarkers of exposure in adults.	Taste database, FFQ, 3-d 24hR and biomarkers from the NQplus study	The FFQ's reliability against 24hR was acceptable to good for ranking of adults' dietary taste patterns. Associations between dietary taste patterns and urinary Na and N were similar for FFQ and 24hR (Na; FFQ, r=0.24, 24hR, r=0.23, p<0.001, N; FFQ, r=0.08, n.s., 24hR, r=0.05, n.s.).
4	Dietary taste patterns in children aged one and two years and associations with parental feeding behaviour, maternal and child characteristics.	Taste database and FFQ data from the Generation R study	Dietary taste patterns were more intense in taste in two year olds than in one year olds. Child BMI at 1 year ↑ % energy 'salt, umami & fat' tasting foods (r=0.23). The intensity of dietary taste patterns ↓ with maternal educational level.
5	Dietary taste patterns in adults by sex, age, BMI and education.	Taste database and 2-d 24hR data from DNFCS and NQplus study	Men ↑ % energy 'salt, umami & fat' and 'bitter' tasting foods, women ↑ % energy 'sweet & fat' and 'sweet & sour' tasting foods. Obese individuals ↑ % energy 'salt, umami & fat' and ↓ 'sweet & fat' tasting foods than lean individuals.
6	Comparing dietary taste patterns of healthy and popular dietary scenarios with current Dutch dietary taste patterns in adult women	Taste database, 2-d 24hR from the DNFCS, 10 daily menu's for each dietary scenario: the Dutch dietary guidelines, a Mediterranean diet and a Paleo diet	Diets according to dietary guidelines and a Mediterranean diet, but not a Paleo diet, ↓ in taste intensity compared with current Dutch dietary taste patterns in women.

***** FFQ; food frequency questionnaire, 24hR; 24h recalls, DNFCS; Dutch National Food Consumption Survey 2007-2010, NQplus study; Nutrition Questionnaires plus study

Methodological considerations

Assessment of dietary taste patterns

Estimating taste values of untested foods

For the assessment of dietary taste patterns, a taste database is needed that includes taste values of all foods that are consumed by the general population. Although we selected the most frequently consumed foods in the Netherlands (n=476), it was impractical to include all foods (n=1,446) that were reported in the Dutch National Food Consumption Survey (2007-2010). Selected foods contributed in total to 83% of energy intake[1]. We estimated taste values for the remainder of foods that were reported but not profiled on taste. Estimations of taste intensity values were based on the corresponding food groups. Currently, no food classification system exists that groups foods based on taste. Therefore, we used the Dutch NEVO food groups that were based on similarities in nutritional values[2]. For each food group we calculated mean taste intensity values based on the tested foods in that food group. Mean taste intensity values of these food groups were used to estimate taste intensity values of untested foods.

However, not all NEVO food groups were appropriate for estimating taste values. For example, the NEVO food group 'milk and milk products' consists of foods such as 'neutral' tasting milk, 'sweet & sour' tasting yoghurt and 'sweet & fat' tasting desserts. Therefore, for this food group we estimated taste values of untested foods using the smaller (sub-) subfood groups within the GloboDiet food group classification: 'milk', 'milk beverages', 'yoghurt', 'fromage blanc, petits suisses', 'cream desserts, puddings' and 'dairy and non-dairy creams'[3]. Thus, we used a combination of NEVO and GloboDiet food groups to increase the accuracy of estimated taste values. However, it may have been more accurate to estimate taste values based on individual tested foods that were most similar in macronutrient and sodium content. Nevertheless, dietary taste patterns by sex and weight status based on tested foods were similar to dietary taste patterns based on the entire diet. Therefore, for the studies described in this thesis, it was sufficient to estimate taste values based on food groups.

Clustering of foods in taste groups

Unlike with nutrients, it is not possible to calculate with taste values. For example, three bites of an apple do not result in three times the perceived taste intensity values of one bite of an apple. Therefore, we grouped foods based on taste to investigate the contribution to energy intake and consumed amount of food from food taste groups. Food taste groups included foods that were most similar in taste intensity values within groups. Foods were classified in groups based on taste using hierarchical cluster analyses[4]. However, cluster analysis has some drawbacks. First, cluster analyses can be sensitive to outliers[5]. For example, foods such as marmite, that are high in salt and umami taste intensity, may appear as single members in a cluster. Therefore, we excluded marmite from our data analyses. However, excluding marmite did not affect our dietary taste patterns, because marmite is not an important contributor to energy intake in the Netherlands.

Second, the number and type of food items in food frequency questionnaires can also influence grouping of foods by cluster analyses. Food frequency questionnaires are developed based on the nutrient(s) of interest[6]. For example, FFQ developed for studying cardiovascular disease may include more items on the use of fats and oils, including also the use of dressings[7]. Such dressings can be high in sour taste intensity and fat sensation and may appear in a separate 'sour and fat' tasting cluster. Performing cluster analyses on such a FFQ can thus result in different taste clusters compared with a more general FFQ that inquires about the consumption of fats and oils on a more aggregated level. However, the different FFQ used for the studies in this thesis were more general and were thus more suitable for the comparison of dietary taste patterns across study populations.

Third, some foods fit better than other foods considering the label of the taste clusters. This is however inherent to cluster analyses; the clustering algorithm searches for foods that are more similar in taste than foods in other clusters. To indicate the 'fit' of foods within clusters, the 'distance' to the cluster centres can be determined. Large numbers for the 'distance' means that foods fit less well within the particular cluster, but still fit better than in any of the other taste clusters[8]. For example, banana, pear, fruit biscuit, and baked beans in tomato sauce fit best in a 'neutral' tasting cluster as compared to other taste clusters. However, the distance to the cluster centre varies for these foods; for 'banana' it is 24.2, for 'beans bakes tomato sauce' 22.9, while for 'Baguette white' it is 9.3 and for 'beans French boiled' it is 8.0. Thus 'Baguette white' and 'beans French boiled' fit bitter within the 'neutral' tasting cluster than the other foods mentioned. Nevertheless, all foods fit best in the taste cluster to which they are assigned, as compared with the other taste clusters. Taken together, clustering foods on taste intensity values is an appropriate method to study dietary taste patterns.

Contribution of taste groups to energy intake

In this thesis, we predominantly investigated the role of taste in energy intake (**Chapters 3-5**), as the role of taste in energy intake may be of particular importance from a nutritional perspective. In our first study, we found associations between sweet taste intensity and mono- and disaccharides, and between salt taste intensity and sodium, protein, fat and energy content in individual foods, respectively (**Chapter 2**). Thus, the basic tastes and fat sensation are associated with macronutrients and thus indirectly with energy content.

To our knowledge, we are the first to investigate dietary taste patterns, based on energy intake in the entire diet. Previous studies on the entire diet have investigated taste exposure, based on the frequency of consumption, instead of energy intake[9–11]. For example, Cox et al.[9] defined taste exposure by the reported intake in serves multiplied by taste intensity values. This fundamental difference in methodology between our studies, i.e. dietary taste patterns based on frequency of consumption vs. energy intake, challenges comparison of our dietary taste patterns. For example, higher intakes of vegetables, despite being low in bitterness, resulted in higher bitterness scores in their study[9]. In our study however, vegetables are classified as 'neutral' tasting foods as they are low in taste intensity compared to other foods in our diet. Moreover, vegetables do not contribute much energy and were thus not well represented in our dietary taste patterns based on energy intake. It can be argued what the most appropriate method is for studying dietary taste patterns, and this may differ depending on the research question. Studying the role of taste in energy intake is highly relevant in the context of obesity (**Chapters 4-5**) and the development of dietary taste patterns in early childhood (**Chapter 4**), because energy content is an important reinforcer of food intake[12]. However, for studies on healthy diets it is important to also include the consumed amount, to take into account the contribution of low-energy foods, such as vegetables, to dietary taste patterns.

In contrast to Cox et al.[9], we did not include flavour intensity in our taste database. We made this decision because basic tastes and fat sensation are associated with macronutrients and thus indirectly with energy content. Because flavour is not associated with macronutrient and thus energy content, we believe that flavour may be less relevant from a nutritional perspective. Nevertheless, we do acknowledge that flavour, as well as odour and texture, are important factors in enhancing the appeal of healthy diets[9].

Individual foods

In our taste database, we predominantly included individual foods or ingredients, and not how these foods are consumed in combination. We included individual foods in our taste database, because Dutch food consumption surveys report foods on an individual basis and do not report how foods were consumed in combination. However, people eat meals which contain a variety of foods with complex combinations of ingredients, tastes and textures. It is well known that tastes may interact, and may be competing in mixtures of tastes[13,14]. One way to overcome this discrepancy between food consumption data and actual consumption of foods, is the development of an in-home profiling method[15]. This method entails that trained panellists are asked to assess the taste intensity values of foods that they typically consume at home. However, a pitfall of this method is that in-home profiling is less well controlled and that it can be questioned whether foods consumed by trained panellists are representative for the general population. More ideal would be if food consumption surveys report how foods are consumed in combination, in order to include these combinations of foods in a taste database. This would also raise the opportunity to include important taste enhancers and seasonings in a taste database, such as gravy consumed in combination with cooked potatoes. Studying the whole diet, including taste enhancers, seasonings and combinations of foods, may increase the intensity of dietary taste patterns described in this thesis.

Dietary assessment methods

In this thesis, we investigated dietary taste patterns using existing food frequency questionnaires (FFQ; **Chapters 3, 4**) and 24h recalls (24hR; **Chapters 3, 5, 6**). FFQ data contains less detailed information on food preparation and less data on single foods as 24hR data do[6]. Previous studies have evaluated FFQ to 24hR[16–18], but this was done for the assessment of food, energy and nutrient intake and not for dietary taste patterns. Because of correlated errors between FFQ and 24hR it is generally preferred to also validate these methods against biomarkers of exposure[6]. FFQ and 24hR both rely on memory, are prone to socially desirable answers and use the same food composition table[6]. Therefore, we not only studied the reliability of FFQ against 3-d 24hR, but also against urinary biomarkers for sodium (Na) and protein (N) intake in **Chapter 3** of this thesis.

We investigated the reliability of FFQ in the NQplus study population, which included mostly highly educated and committed participants, who might have been more accurate in reporting dietary intake and collecting urine samples than the general population. Therefore, the observed level of agreement between the FFQ and 24hR concerning dietary taste patterns, and correlations with the recovery biomarkers might have been higher than one would expect in other study populations. However, our results were of similar magnitude as in previous studies in adults[17]. Therefore, these findings suggests that both FFQ and 24hR can be used in combination with our taste database, to investigate dietary taste patterns.

Misreporting of energy intake

One of the largest challenges in dietary assessment studies is to provide reliable and accurate estimates of dietary intake. In dietary assessment, misreporting of energy intake is a well-known phenomenon[6]. In particular high-fat sweet foods may be sensitive to under-reporting, and more importantly under-reporting of energy intake increases with BMI[19]. However, we found similar dietary taste patterns by weight status when we performed our analyses with and without potential misreporters of energy intake. Thus, in this thesis, dietary taste patterns were not affected by excluding misreporters of energy intake (**Chapter 5**).

Study populations

It can be questioned whether the dietary taste patterns in this thesis can be extrapolated to other study populations. For example, our findings of relatively more energy from 'salt, umami and fat' tasting foods and less from 'sweet and fat' tasting foods in obese individuals compared with normal-weight individuals are supported by findings from other Western study populations[9,20–22], but not by findings in non-Western study populations[23]. This could be explained by differences in dietary taste patterns across cultures. For example in Malaysia, the majority of energy intake is obtained from 'salt, umami & fat' tasting foods, while in the Netherlands this is only one quarter of energy intake[23]. Therefore, our findings only apply to Western study populations.

Moreover, in this thesis we studied dietary taste patterns in early childhood and in adults, but not in older children, adolescents and elderly. In **Chapter 4** we found that dietary taste patterns of children aged 2 years were already quite similar to that of adults (**Chapter 5**). At this age however, children have little food choice autonomy[24]. Previous studies have found that the optimal preferred sweetness levels are higher in children than in adolescents, and higher in adolescents than in adults[25,26]. Therefore, it may be expected that sweetness may play a larger role in dietary taste patterns during later childhood than in early childhood, and that whole diet sweetness may again decline during adolescence[25,26]. In elderly, based on a decline in taste and smell after the age of 55 years, more intense dietary taste patterns may be expected[27]. Taken together, our dietary taste patterns can not be generalized to older children, adolescents and elderly. However, we studied dietary taste patterns in adults using food intake data from the Dutch National Food Consumption Survey, a nationally representative sample of the population[1]. Therefore, our dietary taste patterns in adults are representative for the general adult population in the Netherlands.

Discussion and interpretation of the main findings

Dietary taste patterns throughout the life course

In this thesis, we studied dietary taste patterns during early childhood (**Chapter 4**) and in adults (**Chapter 3, 5, 6**). In one year old children, we found that the majority of energy intake was obtained from 'neutral' tasting foods, whereas this was substantially lower in two year old children. Dietary taste patterns of two year old children were more intense and varied in taste and more similar to that of adults, than that of one year old children. This could potentially have important consequences for the development of taste preferences and food choices later in life.

At this moment, it is unclear whether exposure to sweet tasting foods in early-life affects later taste preferences and food choice. Sweet taste is innately rewarding, as indicated by a universal preference for this taste in newborns[28]. It is an important question whether this strong innate preference for sweetness can be modified by sweet taste exposure. In a longer-term study, infants with a lower compared with a higher exposure to sweet foods, showed no differences in preferences or intakes of sweet foods after an exposure period of 3 months[29]. In shorter-term studies, children exposed to a sweet food for 1-3 weeks showed increased[30] but also decreased[31,32] preferences for the same sweet food and not for other sweet foods. Thus, it remains unclear whether higher exposure to whole diet sweetness during childhood results in an enhanced preference for sweetness later in life[33]. Given the current recommendations to lower dietary sugar intake, it is important to know whether high exposure to sweetness in childhood could make it challenging to adhere to these recommendations later in life. Currently, there is insufficient evidence to suggest that sweet taste exposure affects sweetness preference, food choice and intake.

Unlike for sweetness, a preference for salt taste is usually developed during the first year of life. Findings for salt responses suggest that newborns are relatively insensitive to salt and that salt sensitivity develops gradually over the first two years of life[34]. The absence of salt sensitivity in newborns might be explained from an evolutionary viewpoint. The first food that a newborn encounters is breastmilk, which is dominant in sweetness and fattiness and contains sufficient amounts of sodium for the newborn. Therefore, it may not be necessary to have an innate preference for saltiness[35]. Theoretically thus, exposure to saltiness may have an effect on later preferences. Indeed, previous studies have found associations between infants exposure to sodium-containing foods and later preference for saltiness[36,37]. However, these studies did not investigate the exposure to whole diet saltiness. It might be that a preference for salty tasting foods is part of a preference for more intense tasting foods in general[35].

In this thesis, we observed significant positive associations between dietary taste patterns at the age of one year and dietary taste patterns at the age of two years for all taste clusters (**Chapter 4**). These findings suggest that early exposure to certain tastes may indeed be important for later taste preferences and food intake. However, two year olds still have little food choice autonomy, and therefore these findings may also reflect stability in parenting practices[24].

At this stage it is unknown whether the increase in intensity and variety of dietary taste patterns with child's age continues into later childhood. Based on previous literature we may expect an increase in whole diet sweetness during childhood, which decreases again through adolescence and adulthood[25,26]. In line with this, in adults we observed lower intakes of 'sweet & sour' tasting foods in men and women aged 31-50 y compared with adults aged 19-30 y (**Chapter 5**). These findings suggest that whole diet sweetness may even further decrease during adulthood.

In general however, dietary taste patterns in adults seemed relatively stable when we compared adults aged 19-50 from the DNFCS with adults aged 19-70 in the NQplus study (**Chapter 5**). After the age of 55 years, a decline in the sense of taste and smell is more prevalent[(27)]. This decline in chemosensory function could be caused by delayed renewal of taste buds, oral infections or other factors related to oral health and ageing[(27,38)]. Therefore, more intense dietary taste patterns might be expected in older adults. Although the NQplus study population was somewhat older, they were also higher educated compared to the DNFCS study population. Higher education is often associated with better health[(39)]. It might be that less healthy older adults have a greater decline in chemosensory function, possibly resulting in more intense dietary taste patterns. However, the older adults population is highly heterogeneous in terms of their food preferences[(40)]. Moreover, other factors such as food neophobia may also affect the extent to which they change their eating behaviour and thus dietary taste patterns[(41)].

Dietary taste patterns by weight status

Since the 1970s it is debated whether overweight and/or obese individuals have a preference for sweet or savoury tasting foods, and this issue is still discussed. Several studies have investigated taste preferences or liking of sweet or savoury elements of the diet[(22,42–44)]. However, only few studies assessed the taste of the whole diet, but none of them focused on differences in dietary taste patterns by weight status[(15,45)]. Previous hedonic studies have found a positive association between liking for sweet[(43,42)] or savoury foods and BMI[(43)]. In contrast, other studies have reported lower liking ratings for sweet and savoury foods in obese versus lean individuals[(44)] or no difference in liking across BMI categories[(22)].

In the present thesis, we found evidence for a potential link between savoury food intake and obesity. That is, obese men and women consumed relatively more energy from 'salt, umami & fat' tasting foods and relatively less from 'sweet & fat' tasting food than normal-weight men and women (**Chapter 5**). These findings were consistent across two different study populations. In a recent study by Cox et al.[9], overweight and obese subjects tended to report lower exposure to whole diet sweetness than underweight subjects. No differences were found for saltiness by weight status. In previous studies on individual foods, positive associations were found between saltiness, but not sweetness, and energy content[45–47]. Many processed foods high in salt are also high in fat content (processed meat, cheese, crisps, pizza), and less foods exist, that are consumed in isolation, that are high in salt but low in fat content (besides soup). Although many sweet foods exist that are high in fat content, various sweet foods exist that are low in fat content (sugar-sweetened beverages, fruit and fruit juice, candy, sweetened low-fat dairy products). Since fat is the most energy-dense nutrient, energy content may indeed be more related to salty and umami taste than to the sweet taste. This may suggest that 'salt, umami & fat' tasting foods may be more often high in energy density, and the consumption of energy dense foods has been associated with BMI[48,49]. Taken together, energy-dense savoury food intake, and not per se sweet food intake, is potentially of concern for the development of obesity.

In line with these findings in adults, we found associations between increasing child BMI z-score at the age of 1 year and relatively more energy from 'salt, umami & fat' tasting foods in a large population-based cohort (**Chapter 4**). In our studies, 'salt, umami & fat' tasting foods were on average higher in protein content than foods from other taste groups. Previous observational studies have found that a higher protein intake during the complementary feeding period is associated with a higher BMI[50–53] and a higher fat mass index[54] in later childhood. In addition, a large randomized trial found that children aged one year receiving high-protein infant formulas had a higher BMI and higher risk of becoming obese in later childhood than children receiving low-protein infant formulas[55]. Although effect estimates were relatively small, higher energy intake from 'salt, umami & fat' tasting foods in early-life could potentially be related to higher risk of obesity at a population level.

Dietary taste patterns and adherence to dietary guidelines

Worldwide, there is an enormous societal pressure to lower dietary salt, sugar and saturated fat intake to prevent chronic diseases[56]. Some countries report dietary reductions of these nutrients, yet these reductions have been minimal and do not reach dietary recommendations[57–60]. However, it is well known that these nutrients provide taste and palatability to foods[45–47,61]. In our study on individual foods, we found positive associations between sweet taste intensity and mono- and disaccharide content, and salt taste intensity and sodium content (**Chapter 2**). In line with this, others studies have found associations between sweet, salt, umami taste intensity and fat sensation values and mono- and disaccharide, sodium, protein, and fat content, respectively[45,47,61]. Diets lower in sugar, salt and saturated fat may be lower in taste intensity and this could be a key contributing factor for poor adherence to dietary guidelines. Although fat sensation can be derived from both saturated and unsaturated fat, saturated fat is often combined with sugar or salt in processed foods[62]. Moreover, bland tasting healthy diets could also explain why consumers are seeking alternative diets, which may better satisfy their sensory needs. The popularity of alternative diets, such as the Atkins diet and the Paleo diet might be in part attributable to their higher taste intensity values.

Therefore, we compared dietary taste patterns of healthy and popular dietary scenarios with Dutch dietary patterns in women from the DNFCS 2007-2010[1] (**Chapter 6**). In addition, dietary taste patterns in women were correlated with the Dutch Healthy Diet (DHD) index[63], i.e. the extent of adherence to dietary guidelines. The consumed energy and amount from 'neutral' tasting foods was relatively high in a diet according to the Dutch food-based dietary guidelines and a Mediterranean diet compared with the current diet. A Paleo diet was more similar to the current diet concerning the consumed energy and amount from 'neutral' tasting foods. The extent of adherence to Dutch dietary guidelines was associated with a relatively higher consumption of energy and amount from 'neutral' tasting foods and lower consumption of energy and amount from 'salt, umami & fat' and 'bitter' tasting foods. Taken together, these findings confirm that a lower taste intensity of healthy diets may be a key contributing factor for poor adherence to dietary guidelines. We also showed that the popularity of alternative diets, such as a Paleo diet, might be in part attributable to their higher taste intensity values.

Understanding poor adherence to dietary guidelines is important because of its higher prevalence among overweight or obese individuals[64,65]. In this thesis, we found evidence for a potential link between savoury food intake and BMI, and between savoury food intake and lower adherence to dietary guidelines. In contrast, associations between sweet food intake and diet quality was less clear. Relatively more energy from foods tasting 'sweet & fat', but not 'sweet & sour', was positively associated with diet quality. In contrast, relatively larger amounts from foods tasting 'sweet & sour', but not 'sweet & fat', was negatively associated with diet quality. These findings suggest that the type of food from which sweetness is derived may be more important for diet quality. For example, 'sweet & sour' foods included many types of fruit, but also sweetened beverages. It is well known that energy consumed from sugar-sweetened beverages is not fully compensated for in subsequent energy intake, and energy-containing beverages are not included in dietary recommendations(66,67). These findings are in line with recent findings by Cox et al.(9) and suggest that savouriness, and not per se sweetness(68), may be an issue for diet quality and the current obesity epidemic.

Practical implications and directions for future research

According to recent policy documents of the WHO, the general population can get used to less sweetened and salted food in the diet, but these statements were not supported by scientific evidence(69,70). For saltiness, it seems that long-term reduction in dietary sodium can alter the perceived salt taste intensity and pleasantness in crackers and soup(71). Similarly, research by Bolhuis et al.(72) showed that a gradual salt reduction of 50% in bread did not affect bread consumption or choice of sandwich fillings. These findings are in line with other studies(73,74), suggesting that consumers can adjust to gradual reductions of salt in foods such as bread, crackers and soup. However, worldwide adherence to recommendations for salt intake remains low and it remains unknown whether consumers can get used to reductions in whole diet saltiness(57).

Similarly, it is unclear whether consumers can get used to reduced sweet taste in their diet. Sweet taste is innately pleasant, unlike salt taste for which infants develop a preference in the first year of life(34). Hypothetically, exposure to sweet taste may enhance a sweetness preference. At the same time, exposure to a particular taste was shown to result in a decreased desire for that taste in the short term, i.e. sensory specific satiety. In the long term, it is less clear what the effects are of sweet taste exposure on later preference, food choice and intake(33). In a long-term study by Wise et al.(75), subjects were put on either a reduced simple sugar diet or their regular diet. In the intervention group compared to the control group, they found effects on perceived taste intensity, but not on perceived pleasantness of vanilla puddings and raspberry beverages that varied in sucrose concentration. Similarly, other studies provide limited evidence for an effect of a reduced sweet taste exposure on the perceived sweetness and intake of other sweet foods[76–79]. There is a need for studies on whole diet sweetness, rather than the effects of sweet taste exposure on intake of a selection of sweet foods.

Our comparison of diet plans based on Dutch dietary guidelines with current Dutch dietary patterns suggests substantive changes in dietary taste patterns are needed to adhere to dietary guidelines. This raises the question whether we should limit the consumption of intense tasting foods already early in life. From a nutritional perspective, this could be beneficial for adherence to dietary guidelines already in early-life. However, studies have also shown that dietary restriction of foods may enhance the desire for these foods in children[30]. In the absence of parental monitoring this could lead to higher consumption of these previously restricted foods. Taken together, it is important to reduce sugar, salt and saturated fat intake but entire restriction of foods high in these nutrients may be detrimental.

Future studies are needed to investigate tracking of dietary taste patterns from early-life into later childhood and adulthood. Moreover, studies are needed to investigate associations between dietary taste patterns during infancy and child BMI and body composition in later childhood. In adults, prospective studies could investigate a potential causal relationship between dietary taste patterns and BMI. In these studies, underreporting of energy intake should be assessed, taking into account the level of physical activity.

To investigate dietary taste patterns throughout the life course, it may be worthwhile to develop FFQ for the assessment of dietary taste patterns. In adults, ‘fat’ tasting foods might be excluded from such an FFQ, as we observed little variation in the % energy from these foods by sex, age, weight status and educational level. Additionally, foods from different taste groups should be included as separate food items in FFQ. For example, existing FFQs were found to combine ‘neutral’ and ‘sweet & fat’ tasting cookies in one food item, which is appropriate for nutrients but not for dietary taste patterns.

Conclusions

The role of taste in dietary intake in young children differed from adults. During the first two years of life, dietary taste patterns become more intense and varied in taste, and more similar to dietary taste patterns of adults. This transition in dietary taste patterns could potentially have important consequences for the development of taste preferences and food choice later in life. In individual foods, associations were found between sweet taste intensity and mono- and disaccharides, and between salt taste intensity and sodium content. Healthy diets were lower in taste intensity, because of lower levels of sugar, salt and saturated fat. Besides factors such as costs, convenience, and other sensory characteristics such as flavour and texture, taste may be a key contributing factor for poor adherence to dietary guidelines (80,81). However, healthy diets can be made more appealing by adding flavour, such as from herbs & spices(9).

Studying dietary intake from a taste perspective has provided new insights that may give new input for the development of randomized controlled trials. These trials are needed to investigate whether an exposure period to lower or higher whole diet sweetness and saltiness affects dietary taste patterns in a natural setting. To this aim, our taste database may be used to compare the contribution to energy intake from foods with different tastes before and after the exposure period. Given the current dietary guidelines to reduce dietary salt, sugar and fat intake, further research on the feasibility of these guidelines, from a taste perspective, is clearly needed.

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Summary

The prevalence of overweight and obesity has increased dramatically worldwide over the last decades, regardless of geographical boundaries and cultural differences. Making the desirable and appropriate food choices is important in preventing weight gain and obesity. Food choices are to a great extent guided by the taste of food.

The overall aim of this thesis was to assess the role of taste in energy intake in young children and adults, and to investigate how taste relates to nutrients and adherence to dietary recommendations.

In **Chapter 2** we studied the relationship between taste intensity, energy and nutrient content in individual foods. We found associations between sweetness and mono- and disaccharide content, and between saltiness and sodium, protein, and fat content. Saltiness, but not sweetness, was associated with energy content. We found no modifying effect of food form, i.e. liquids, semi-solids and solids, on the relationship between taste intensity and nutrient content.

In **Chapters 3-6** we combined our taste database with dietary intake data to investigate dietary taste patterns. First, we evaluated dietary taste patterns based on FFQ against 3-d 24hR and biomarkers of exposure in an adult study population (**Chapter 3**). We found that the FFQ's reliability against 24hR was acceptable to good for ranking of adults' dietary taste patterns. Moreover, associations between dietary taste patterns and urinary Na and N were similar for FFQ and 24hR. These findings suggest that both FFQ and 24hR can be used to investigate dietary taste patterns.

In **Chapter 4** we investigated the development of dietary taste patterns during early childhood in a large population-based cohort. In children aged one year the majority of energy intake was obtained from 'neutral' (64%) tasting foods, which was substantially higher than in children aged two years (42%). Energy intake from 'sweet & fat', 'fat' and 'salt, umami & fat' tasting foods was higher in two year olds than in one year olds. Higher child BMI Z-scores were associated with relatively more energy from 'salt, umami & fat' tasting foods. Furthermore, higher maternal educational level was associated with relatively more energy from 'neutral' tasting foods and less from 'sweet & fat', ' fat' and ' salt, umami & fat' tasting foods.

Subsequently, dietary taste patterns were investigated in adults in two study populations (**Chapter 5**). In both study populations we found that men consumed relatively more energy from 'salt, umami & fat' and 'bitter' tasting foods, whereas women consumed relatively more energy from 'sweet & fat' and 'sweet & sour' tasting foods. In addition, we found that obese individuals consumed relatively more energy from 'salt, umami & fat' tasting foods and relatively less from 'sweet & fat' tasting foods than lean individuals.

In our last study, we compared dietary taste patterns of healthy and popular dietary scenarios with Dutch dietary taste patterns in women from the DNFCS 2007-2010 (**Chapter 6**). In addition, we investigated associations between the extent of adherence to food-based dietary guidelines, as a measure of diet quality, and dietary taste patterns in these women. We found that healthy diets may be lower in taste intensity compared with current Dutch dietary taste patterns in women. Popular diets, such as a Paleo diet, were more similar in taste intensity to the current diet.

Diets lower in sugar, salt, and saturated fat content may be lower in taste intensity and this could be a key explanatory factor for poor adherence to dietary guidelines. However, healthy diets can be made more appealing by adding flavour, such as herbs & spices. One of the strategies that may be used to lower dietary salt, sugar and saturated fat intake is the gradual reduction of these nutrients in food. Another promising but challenging strategy could be that foods are reformulated to reduce levels of salt, sugar and saturated fat without affecting taste and palatability. However, successful application of these techniques requires substantial research and development for each product individually.

Studying dietary intake from a taste perspective has provided new insights that may give new input for the development of randomized controlled trials. These trials are needed to investigate whether high or low sweet and salty taste exposure affects long-term perceived intensity and preferences for sweetness and saltiness and dietary taste patterns. Given the current dietary guidelines to reduce dietary salt, sugar and saturated fat intake, further research on the feasibility of these guidelines, from a taste perspective, is clearly needed.

Appendix A

Supplementary tables

Chapter 2: The relationship between taste and nutrient content in commercially available foods from the United States

Table A1 Product names with missing values for taste (product 1) or nutrients (2-25)

	Product name
1	Breakfast cereals chocolate flavor in milk
2	Butternut squash chicken sausage
3	Sausage
4	Maple Brown Sugar Instant Oatmeal
5	Vanilla frother
6	Mocha latte
7	Mocha cappuccino
8	Mocha latte
9	Donuts mocha
10	Mocha (coffee)
11	Black unsweetened iced tea
12	Hot apple cider
13	Long island ice tea (alcoholic)
14	Sunspiced garlic powder
15	Sunspiced onion powder
16	Roasted red pepper puree - soft frozen puree
17	Roasted red pepper puree - hard frozen puree
18	Shelf stable refrigerated puree roasted red pepper
19	Soft frozen puree - garlic
20	Shelf-stable puree with vinegar - garlic
21	Hard frozen puree (100% frozen garlic)
22	Shelf stable refrigerated puree - garlic
23	Frozen puree - garlic
24	Onion sauce
25	Cream of corn soup

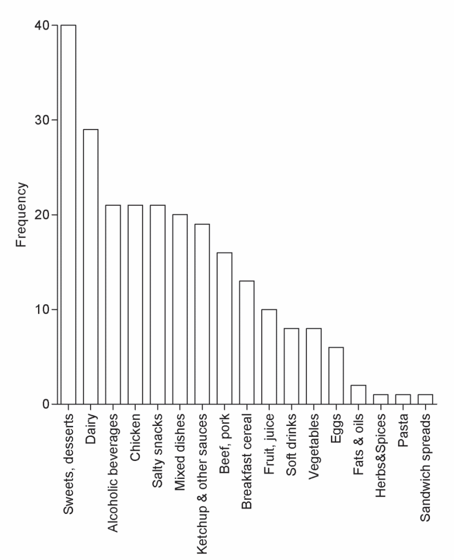

Figure A1 Frequency (number of food products) from each food group for the 237 US foods

Appendix A

Table A2 Products and the food form groups (1= liquid, 2=semi-solid, 3=solid), known and/or positive values for mono- and disaccharide and sodium content (1= included, 0= excluded from regression analyses) and clusters (1= neutral, 2=sweet, 3=salty)

	Productname	Texture group	Mono- and disac-charides	Sodium	Cluster
1	Chicken broth with vegetables, contains milk, soy and wheat	1	1	1	3†
2	Tomato soup	1	1	1	3†
3	Chicken broth 100% fat free-no msg 33% less sodium	1	1	1	3†
4	100% Orange juice	1	1	1	2
5	100% Grape juice	1	1	1	2
6	100% Orange juice, no pulp, from concentrate	1	1	1	2
7	Grape juice	1	1	1	2
8	Grape juice from concentrate, 120% vitamin c	1	1	1	2
9	100% Orange juice, pasteurized	1	1	1	2
10	100% Grape juice from concentrate with added ingredients	1	1	1	2
11	Soft drink	1	1	1	2
12	Diet soft drink	1	0	1	2
13	Soft drink	1	1	1	2
14	Nutritional shake, chocolate	1	1	1	2
15	Nutrition shake chocolate	1	1	1	2
16	Soft drink	1	1	1	2
17	Chocolate drink	1	1	1	2
18	Soft drink	1	1	1	2
19	Soft drink	1	1	1	2
20	Soft drink	1	1	1	2
21	Soft drink	1	1	1	2
22	Chocolate milk 2% reduced fat	1	1	1	2
23	Chocolate nutritional beverage low fat milk with 32mg DHA omega-3, vitamins A&D	1	1	1	2
24	Nutritional drink, rich milk chocolate	1	1	1	2
25	Chocolate low fat milk	1	1	1	2
26	Chocolate drink	1	1	1	2
27	100% orange juice, no pulp, pasteurized, not from concentrate	1	1	0	2
28	100% Orange juice, no pulp, not from concentrate	1	1	0	2
29	Apple juice	1	1	0	2
30	Hard cider	1	0	0	2
31	Fat free milk, vitamins A&D	1	1	1	1
32	Fat free milk	1	1	1	1
33	Skim milk, vitamins A & D	1	1	1	1
34	Vitamin D milk, pasteurized, homogenized	1	1	1	1
35	Vitamin D homogenized milk	1	1	1	1
36	Whole milk, vitamin D	1	1	1	1
37	2% Reduced fat milk, 30% less fat than whole milk, fat reduced from 8g to 5g, 2% milkfat, pasteurized, homogenized	1	1	1	1
38	Reduced fat milk (2%)	1	1	1	1
39	2% Milkfat reduced fat milk, vitamins A& D, 37% less fat than whole milk	1	0	1	1
40	2% reduced fat milk, vitamins A&D	1	0	1	1
41	Tequila	1	0	1	1
42	Butter milk	1	1	1	1
43	Butter milk	1	1	1	1
44	Butter milk	1	1	1	1
45	Butter milk	1	1	1	1
46	Beer	1	0	0	1
47	Hard cider	1	0	0	1
48	Hard cider	1	0	0	1
49	Hard cider	1	0	0	1
50	Hard cider	1	0	0	1
51	Hard cider	1	0	0	1
52	Hard cider	1	0	0	1

Table A2 continued

	Productname	Texture group	Mono- and disac-charides	Sodium	Cluster
53	Hard cider	1	0	0	1
54	Hard cider	1	0	0	1
55	Hard cider	1	0	0	1
56	Hard cider	1	0	0	1
57	Hard cider	1	0	0	1
58	Hard cider	1	0	0	1
59	Hard cider	1	0	0	1
60	Hard cider	1	0	0	1
61	Hard cider	1	0	0	1
62	Hard cider	1	0	0	1
63	Hard cider	1	0	0	1
64	Hard cider	1	0	0	1
65	Cooked- dehydrated mashed potatoes	2	1	1	3
66	Sweet pepper sauce	2	1	1	3
67	Three cheese sauce	2	1	1	3
68	Tomato basil sauce	2	1	1	3
69	Tomato basil sauce	2	1	1	3
70	Roasted garlic sauce	2	1	1	3
71	Mushroom sauce	2	1	1	3
72	Buffalo wild wing parmesan garlic sauce	2	1	1	3
73	Honey mustard dressing	2	1	1	3
74	Light mayonnaise	2	1	1	3
75	Mayonnaise	2	1	1	3
76	Mayonnaise	2	1	1	3
77	Blue cheese sauce	2	1	1	3
78	Margarine	2	0	1	3
79	Margarine	2	0	1	3
80	Ranch dressing	2	1	1	3
81	Ketchup	2	1	1	3
82	Ketchup	2	1	1	3
83	Barbeque sauce	2	1	1	3
84	Buffalo wing sauce	2	0	1	3
85	Roasted red pepper puree	2	1	1	3
86	Sauteed garlic base	2	1	1	3
87	Japan teriyaki sauce	2	1	1	3
88	Chicken gravy, dried	2	0	1	3
89	Frozen yogurt, cherry flavor	2	1	1	2
90	White chocolate mocha flavored syrup	2	1	1	2
91	Ice-cream	2	1	1	2
92	Greek frozen yogurt, blueberry vanilla	2	1	1	2
93	Diced canned tomatoes	2	1	1	2
94	Creamy peanut butter	2	1	1	2
95	Whipped cream	2	1	0	2
96	Whipped cream fat free	2	1	0	2
97	Strawberry greek style yogurt	2	1	1	1
98	Strawberry greek style yogurt	2	1	1	1
99	Strawberry greek style yogurt	2	1	1	1
100	Chicken pot pie	3	1	1	3
101	Eggs	3	1	1	3
102	Potato chips	3	1	1	3
103	French fries	3	1	1	3
104	French fries	3	0	1	3
105	Popcorn	3	0	1	3
106	Corn chips	3	0	1	3
107	Chicken breast nuggets, made with white meat	3	0	1	3
108	Chicken breast nuggets	3	1	1	3
109	Corn chips	3	0	1	3

Table A2 continued

	Productname	Texture group	Mono- and disac-charides	Sodium	Cluster
110	Spicy chicken patties	3	0	1	3
111	Sausage egg and cheese croissant	3	1	1	3
112	Potato chips	3	1	1	3
113	Fully cooked chicken breast strips	3	0	1	3
114	Microwave turkey/pork	3	1	1	3
115	Oven cooked turkey/pork	3	1	1	3
116	Mini corn dogs	3	1	1	3
117	Chicken sausage patties	3	1	1	3
118	Microwave beef	3	1	1	3
119	Oven cooked beef	3	1	1	3
120	Gluten free chicken strips	3	1	1	3
121	Oven roasted turkey shortcuts	3	1	1	3
122	Breaded chicken nuggets	3	0	1	3
123	French fries	3	0	1	3
124	Baked chicken breast strips, whole grain	3	1	1	3
125	Grilled chicken breast fillets	3	0	1	3
126	Potato chips	3	1	1	3
127	Pizza pepperoni	3	1	1	3
128	Pizza pepperoni	3	1	1	3
129	Steak	3	0	1	3
130	Pizza pepperoni	3	1	1	3
131	Corn chips	3	1	1	3
132	Potato chips	3	1	1	3
133	Pizza pepperoni	3	1	1	3
134	Chicken strips	3	1	1	3
135	Fully-cooked turkey breakfast sausage patties	3	1	1	3
136	Corn dogs	3	1	1	3
137	Fully-cooked turkey breakfast sausage links	3	1	1	3
138	Sausage egg and cheese biscuit	3	1	1	3
139	Crackers	3	1	1	3
140	Pizza pepperoni	3	1	1	3
141	Hot dog lean pork sausage (bun)	3	1	1	3
142	Pizza pepperoni	3	1	1	3
143	Pizza pepperoni	3	1	1	3
144	Sausage egg and cheese biscuit snack size	3	1	1	3
145	Popcorn chicken	3	0	1	3
146	Hot dog chicken and pork sausage (bun)	3	1	1	3
147	Fully-cooked pork breakfast sausage	3	1	1	3
148	Corn chips	3	1	1	3
149	Corn chips	3	0	1	3
150	Hot dog beef sausage (no bun)	3	1	1	3
151	Hot dog beef sausage (bun)	3	1	1	3
152	Bratwurst	3	1	1	3
153	Bratwurst	3	1	1	3
154	Pita chips	3	1	1	3
155	Popcorn	3	0	1	3
156	Corn chips	3	1	1	3
157	Honey ham	3	0	1	3
158	Hot dog chicken and pork sausage (no bun)	3	0	1	3
159	Chicken nuggets	3	1	1	3
160	Popcorn	3	0	1	3
161	Cheddarwurst . smoked sausage with cheese	3	1	1	3
162	Pita chips	3	1	1	3
163	Hot dog beef sausage (no bun)	3	1	1	3
164	Hot dog lean pork sausage (no bun)	3	1	1	3
165	Turkey bacon	3	0	1	3
166	Corn chips	3	1	1	3

Table A2 continued

	Productname	Texture group	Mono- and disac-charides	Sodium	Cluster
167	Pizza pepperoni	3	1	1	3
168	Smoked turkey breast, boneless and fully cooked	3	1	1	3
169	Turkey bacon	3	0	1	3
170	Saltine crackers	3	0	1	3
171	Buffalo chicken strips	3	0	1	3
172	Pretzels	3	1	1	3
173	Parmesan cheese	3	1	1	3
174	Parmesan cheese	3	1	1	3
175	Strawberry candy	3	1	1	2
176	Orange candy	3	1	1	2
177	Cooked sweet potatoes	3	1	1	2
178	Candy	3	1	1	2
179	Candy	3	1	1	2
180	Peanuts with chocolate	3	1	1	2
181	Peanut butter snack cakes	3	1	1	2
182	Crunchy breakfast cereals in milk	3	1	1	2
183	Breakfast cereals in milk	3	1	1	2
184	Crunchy breakfast cereals	3	1	1	2
185	Whole grain cereal in milk	3	1	1	2
186	Breakfast cereals chocolate flavor in milk	3	1	1	2
187	Sweet potato fries	3	1	1	2
188	Baked apple pie	3	1	1	2
189	Rich frosted mini donuts	3	1	1	2
190	Lemon mousse cake	3	1	1	2
191	Lime pie, cookie crust	3	1	1	2
192	Crumb topped coffee cakes	3	1	1	2
193	Chocolate chip cookie	3	1	1	2
194	Strawberry fruit & yogurt bar	3	1	1	2
195	Mascarpone cake, with nuts	3	1	1	2
196	Pumpkin pie	3	1	1	2
197	All butter pound cake	3	1	1	2
198	Chocolate raspberry duet cake	3	1	1	2
199	Chocolate chip cookies	3	1	1	2
200	Breakfast cereals	3	1	1	2
201	Cream filled chocolate cupcakes, chocolate iced, chocolate filling	3	1	1	2
202	Cream filled chocolate cup cakes, buttercreme filling	3	1	1	2
203	Light pound cake	3	1	1	2
204	Chocolate cupcakes	3	1	1	2
205	Pound cake	3	1	1	2
206	Lemon pie	3	0	1	2
207	Pound cake	3	1	1	2
208	Pound cake	3	1	1	2
209	Pound ring cake	3	1	1	2
210	Vanilla wafers	3	1	1	2
211	Vanilla wafers	3	1	1	2
212	Powdered sugar mini donuts	3	0	1	2
213	All butter loaf cake	3	1	1	2
214	Caramel apple cake	3	1	1	2
215	Butterscotch krimpets, baked fresh	3	1	1	2
216	Breakfast cereals chocolate flavor	3	1	1	2
217	Pound cake	3	1	1	2
218	Chocolate sandwhich cremes	3	1	1	2
219	Wheat thins snacks, reduced fat, 30% less fat than original wheat thins with 11g whole grain per serving	3	1	1	2
220	Cherry candy	3	1	0	2
221	Orange candy	3	1	0	2
222	Strawberry candy	3	1	0	2

Table A2 continued

	Productname	Texture group	Mono- and disac-charides	Sodium	Cluster
223	Ground pork. 90% lean. 10% fat	3	0	1	1
224	Ground chicken with natural flavorings	3	0	1	1
225	Shelled eggs	3	0	1	1
226	Egg white	3	1	1	1
227	Egg beaters	3	1	1	1
228	Breakfast cereals in milk	3	1	1	1
229	Breakfast cereals in milk	3	1	1	1
230	Egg beaters	3	0	1	1
231	Egg white	3	0	1	1
232	Ground pork	3	0	1	1
233	Whole grain cereal	3	1	1	1
234	Breakfast cereals	3	1	1	1
235	Breakfast cereals	3	1	1	1
236	Popcorn	3	0	1	1
237	100% Whole grain spaghetti	3	1	0	1

† Exlcuded from liquid regression analysis for the relationship between salt taste intensity and sodium content

Appendix B

Supplementary tables

Chapter 3: Evaluation of dietary taste patterns as assessed by FFQ against 24-h recalls and biomarkers of exposure

Table B1 Total energy intake and the contribution of macronutrients to energy intake (mean±SD) stratified by gender, age, BMI and educational level assessed by the FFQ and 24-h recalls (24hR)

	Total energy, kcal/day		Total protein En%		Total fat En%		Total carbohydrates En%		Total mono- and disaccharides En%		Alcohol En%	
	FFQ	24hR	FFQ	24hR	FFQ	24hR	FFQ	24hR	FFQ	24hR	FFQ	24hR
Men (n=449)	2253±606$^{*¥}$	2248±473$^{*¥}$	14±2	16±2	35±5	33±5*†	42±6	43±7	18±5$^{*¥}$	18±6$^{*¥}$	5±4$^{*¥}$	5±5$^{*¥}$
Age (years)												
20-49 (N=125)	2478±744^{a}	2399±538^{a}	14±2^{a}	16±2	36±5^{a}	34±5	43±5	45±7^{a}	17±5^{a}	19±6	3±3^{a}	3±3^{a}
50-70 (N=324)	2166±520$^{b¥}$	2190±432$^{b¥}$	15±2^{b†}	16±3	34±5^{b†}	33±5	42±6	43±6^{b‡}	18±5^{b‡}	18±5	5±5$^{b¥}$	5±5$^{b¥}$
BMI (kg/m^2)												
18.5-25.0 (normal, N=160)	2316±633^{a}	2310±484	14±2^{a}	15±2^{a}	35±5	33±5	43±6^{a}	45±6^{a}	19±5^{a}	20±6^{a}	4±4^{a}	4±4^{a}
>25.0 (overweight and obese, N=289)	2218±589^{b†}	2214±463	15±2$^{b¥}$	16±3$^{b¥}$	35±5	34±5	42±6^{b‡}	43±7$^{b¥}$	18±5^{b†}	18±5^{b‡}	5±5^{b†}	5±5^{b†}
Education (highest)												
Low or medium (1-5, N=147)	2283±694	2217±482	14±3	16±3	35±5	33±4	43±5	44±6	18±5	19±6	4±4	4±4
High (6-7, N=302)	2238±560	2263±468	14±2	16±2	35±5	34±5	42±6	43±7	18±5	18±5	5±5	5±5
Women (n=397)	1859±498$^{*¥}$	1847±380$^{*¥}$	15±3	16±3	34±6	34±5*†	43±6	44±6	20±5$^{*¥}$	21±5$^{*¥}$	3±4$^{*¥}$	3±4$^{*¥}$
Age (years)												
20-49 (N=170)	1896±529	1875±430	14±3	16±3	35±6	34±5	44±6^{a}	46±6^{a}	20±5	22±5^{a}	2±3^{a}	2±2^{a}
50-70 (N=227)	1830±473	1827±337	15±2	16±3	34±6	35±5	42±5^{b‡}	43±6$^{b¥}$	20±5	20±5$^{b¥}$	3±4$^{b¥}$	4±4$^{b¥}$
BMI (kg/m^2)												
18.5-25.0 (normal, N=216)	1909±468^{a}	1893±380^{a}	14±2^{a}	15±3^{a}	34±6	34±6	44±6^{a}	45±6^{a}	20±5	21±5^{a}	2±3^{a}	2±3
>25.0 (overweight/ obese, N=181)	1798±528^{b†}	1793±373^{b‡}	15±3$^{b¥}$	17±3$^{b¥}$	35±6	34±5	42±6^{b‡}	43±6$^{b¥}$	19±5	20±5^{b‡}	3±4^{b†}	3±4
Education (highest)												
Low or medium (1-5, N=152)	1737±477^{a}	1742±373^{a}	15±3^{a}	17±3^{a}	34±6	34±6	43±6	44±7	20±5	21±5	2±3^{a}	2±3^{a}
High (6-7, N=245)	1934±497$^{b¥}$	1913±370$^{b¥}$	14±2$^{b¥}$	16±3$^{b¥}$	35±6	34±5	43±6	44±6	19±5	21±5	3±4^{b†}	3±4^{b†}

[1] MANOVA, multivariate ANOVA was performed including all macronutrients and subgroups. If the overall effect was significant (p<0.05), ANOVA was used to compare subgroups within each macronutrient (p<0.05, Bonferroni corrected). ^{a,b} Superscript letters indicate significant differences, same letters indicate no significant difference between mean values. * Indicates significant difference between men and women. † p<0.05, ‡ p<0.01, ¥ p<0.001.

Table B2 Mean taste intensity values of all taste modalities and nutrient content stratified by taste clusters in the taste database (n=467)

	Taste clusters											
	Fat (7%)		Sweet/sour (14%)		Neutral (28%)		Sweet/fat (22%)		Bitter (4%)		Salt/umami/ fat (25%)	
Taste modality	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sweet	6	6	32	15	11	9	51	10	11	8	8	6
Sour	9	13	35	14	4	3	5	7	12	11	11	11
Bitter	2	3	3	5	3	4	3	5	47	11	2	3
Salt	17	13	4	6	10	9	8	5	2	1	42	9
Umami	6	6	1	3	4	5	1	1	1	1	22	9
Fat sensation	82	10	11	11	13	9	38	15	5	4	46	14
Nutrient content												
Energy (kcal/100g)	583	233	71	73	201	176	351	148	38	58	268	149
Protein (g/100g)	3	6	1	2	8	7	5	3	0	0	12	8
Fat (g/100g)	62	27	1	3	6	12	14	12	0	0	18	13
Carbohydrates (g/100g)	3	5	14	16	27	28	50	22	3	3	14	20
Mono- and disaccharides (g/100g)	2	3	13	14	6	13	37	19	2	3	2	6
Dietary fiber (g/100g)	0	1	1	1	3	3	2	2	0	1	1	1
Alcohol (g/100g)	0	0	0	2	0	0	0	0	6	11	0	0
Sodium (mg/100g)	222	231	52	142	244	330	137	122	5	12	798	689

Table B3 Mean taste intensity values of all taste modalities and nutrient content stratified by taste clusters for the food items in the FFQ

	Taste clusters											
	Fat (11%)		Sweet/sour (11%)		Neutral (32.5%)		Sweet/fat (9.5%)		Bitter (6%)		Salt/umami/fat (30%)	
Taste modality	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sweet	4	5	23	12	11	7	49	10	8	7	9	6
Sour	2	1	38	12	4	4	6	5	14	14	15	11
Bitter	2	3	3	4	3	5	4	4	53	9	1	1
Salt	12	5	2	1	9	7	7	3	2	1	37	7
Umami	3	2	1	1	4	5	1	0	1	1	19	7
Fat sensation	87	7	18	13	16	11	40	12	4	3	51	14
Nutrient content												
Energy (kcal/100g)	677	212	54	20	190	176	321	165	144	164	270	168
Protein (g/100g)	1	5	2	2	6	6	4	2	3	3	13	9
Fat (g/100g)	74	24	1	1	7	13	13	12	5	9	21	20
Carbohydrates (g/100g)	1	3	8	4	24	24	47	25	19	30	7	10
Mono- and disaccharides (g/100g)	0	1	8	4	6	14	38	23	14	27	3	5
Dietary fiber (g/100g)	0	1	1	1	4	5	2	2	0	0	1	1
Alcohol (g/100g)	0	0	0	2	0	3	0	0	1	3	0	0
Sodium (mg/100g)	132	148	25	20	156	187	90	79	68	87	593	317

Table B4 Daily nutrient intake assessed by FFQ and 24hR (n=846) according to taste clusters

			Taste clusters											
	Total		Sweet/Sour		Neutral		Fat		Bitter		Salt/umami/fat		Sweet/fat	
	FFQ	24hR	FFQ	24hR	FFQ	24hR	FFQ	24hR	FFQ	24hR	FFQ	24hR	FFQ	24hR
Protein (en%)	15±2	16±3	1±1	1±1	6±2	7±2	-	-	1±1	-	6±2	6±3	1±0	1±1
Fat (en%)	35±5	34±5	1±1	1±1	8±3	7±3	9±4	7±4	1±1	0±1	13±5	14±5	4±2	4±3
Carbohydrates (en%)	43±6	44±7	7±4	7±4	23±5	23±6	-	-	2±2	2±2	4±3	3±3	7±4	8±5
Mono- and disaccharides (en%)	19±5	20±5	6±4	7±4	5±2	5±2	-	-	2±2	1±2	-	1±1	5±3	6±3
Alcohol (en%)	4±4	4±4	1±1	1±2	0±1	-	-	-	3±3	3±4	-	-	-	-
Sodium (mg)	2130±714	2494±757	71±54	88±81	893±337	961±369	48±37	50±51	33±36	30±49	997±507	1247±572	88±68	118±88

Table B5 Spearman correlation coefficients between urinary recovery biomarkers for sodium (Na) and protein (N) intake and the contribution to sodium and protein intake assessed by FFQ and 24hR (n=846) according to taste clusters

	Urinary Na (n=726)				Urinary N (n=355)			
	FFQ		24hR		FFQ		24hR	
Taste group	Correlation	95% CI	Correlation	95% CI	Correlation	95% CI	Correlation	95% CI
Total	0.25¥	0.18, 0.31	0.25¥	0.18, 0.31	0.44¥	0.32, 0.50	0.50¥	0.38, 0.54
Sweet/sour	-0.07	-0.14, 0.00	-0.04	-0.11, 0.03	0.11†	0.01, 0.21	0.13†	0.03, 0.23
Neutral*	0.12¥	0.05, 0.19	0.17¥	0.10, 0.24	0.32¥	0.21, 0.40	0.38¥	0.27, 0.45
Fat	0.11‡	0.04, 0.18	0.09†	0.02, 0.16	0.09	-0.01, 0.19	0.11†	0.01, 0.21
Bitter	0.03	-0.04, 0.10	0.10†	0.03, 0.17	0.26¥	0.15, 0.35	0.26¥	0.15, 0.35
Salt, umami & fat*	0.33¥	0.25, 0.38	0.25¥	0.18, 0.31	0.29¥	0.18, 0.38	0.32¥	0.21, 0.40
Sweet & fat	0.02	-0.05, 0.09	-0.03	-0.10, 0.04	-0.04	-0.14, 0.06	-0.07	-0.17, 0.03

†p<0.05, ‡p<0.01, ¥p<0.001

*Pearson's correlation coefficient

Appendix B

Table B6 Percentage of energy intake from each taste group assessed by the FFQ and 24-h recalls (24hR) stratified by gender, age, body weight status and education

	Taste groups											
	Sweet/ sour		Neutral		Fat		Bitter		Salt/ umami/fat		Sweet/fat	
	FFQ	24hR	FFQ	24hR	FFQ	24hR	FFQ	24hR	FFQ	24hR	FFQ	24hR
Men (n=449)	9±5$^{*¥}$	10±6$^{*¥}$	38±8*‡	39±8	9±5	7±4	7±6$^{*¥}$	7±6$^{*¥}$	24±8*‡	24±8*†	11±6	13±7$^{*¥}$
Age (years)												
20-49 (N=125)	8±5	10±6	38±9	40±8	9±5	7±4	6±5^{a}	6±5^{a}	27±10^{a}	25±8	11±6	12±6
50-70 (N=324)	10±5	10±5	38±8	39±9	9±5	7±3	8±6$^{b¥}$	8±6$^{b¥}$	23±8$^{b¥}$	24±8	11±6	13±7
BMI (kg/m^2)												
18.5-25.0 (normal, N=160)	9±4	10±6	39±8	40±8^{a}	10±5	7±3	7±6	7±5	22±9^{a}	22±8^{a}	12±7	13±7
>25.0 (overweight and obese, N=289)	10±5	10±5	38±8	38±8^{b†}	9±5	7±4	7±6	7±6	25±8^{b‡}	25±8$^{b¥}$	11±6	12±7
Education (highest)												
Low or medium (1-5, N=147)	9±5	10±6	39±8	39±7	9±5	7±3	7±6	7±6	25±9	25±8	12±6	13±7
High (6-7, N=302)	10±5	10±5	38±8	39±9	10±5	7±4	7±6	7±6	24±8	24±8	11±6	13±7
Women (n=397)	12±6$^{*¥}$	12±6$^{*¥}$	40±8*‡	39±9	9±5	7±4	5±4$^{*¥}$	4±3$^{*¥}$	22±8*‡	23±8*†	12±6	15±8$^{*¥}$
Age (years)												
20-49 (N=170)	10±5^{a}	12±6	40±9	40±9	8±4^{a}	7±4	4±4^{a}	2±3^{a}	24±9^{a}	22±8	14±7^{a}	17±9^{a}
50-70 (N=227)	13±6$^{b¥}$	13±5	40±7	39±9	10±5^{b†}	8±4	5±5$^{b¥}$	4±4$^{b¥}$	22±8^{b‡}	23±9	11±6$^{b¥}$	14±7^{b‡}
BMI (kg/m^2)												
18.5-25.0 (normal, N=216)	12±6	12±5	41±9	41±9	10±5^{a}	8±4^{a}	4±4	3±3	21±9^{a}	21±8^{a}	12±6	15±8
>25.0 (overweight/obese, N=181)	12±6	12±6	39±7	39±9	8±4^{b‡}	7±4^{b†}	5±5	4±4	24±7$^{b¥}$	24±8$^{b¥}$	12±7	15±8
Education (highest)												
Low or medium (1-5, N=152)	12±6	12±6	40±8	40±9	9±5	8±4	4±4	3±3^{a}	22±9	22±9	12±6	16±8
High (6-7, N=245)	11±5	12±5	40±8	40±9	9±4	7±4	5±5	4±4$^{b¥}$	23±8	22±8	12±6	15±8

[1] MANCOVA, multivariate ANCOVA was performed including all tastes and subgroups. If the overall effect was significant ($p<0.05$), ANCOVA was used to compare subgroups within each taste group ($p<0.05$, Bonferroni corrected). Models for gender were adjusted for age, BMI and education; models for age were adjusted for BMI and education; models for BMI were adjusted for age and education; models for education were adjusted for age and BMI. a,b Superscript letters indicate significant differences, same letters indicate no significant difference between mean values. * Indicates significant difference between men and women. † $p<0.05$, ‡ $p<0.01$, ¥ $p<0.001$.

Appendix C

Supplementary tables

Chapter 4: Development of dietary taste patterns in early childhood and its associations with maternal and child characteristics

Table C1 Mean taste intensity values of all taste modalities and nutrient content stratified by taste clusters for the food items in the FFQ's at the child's age of 1 year and 2 years

	Taste clusters									
	Fat (n=147; 29%)		Sweet/sour (n=28; 5%)		Neutral (n=178; 35%)		Sweet/fat (n=50; 10%)		Salt/umami/ fat (n=107; 21%)	
Taste modality	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sweet	4	4	25	12	12	7	48	10	8	6
Sour	5	9	38	11	4	3	7	7	9	7
Bitter	2	2	2	1	2	5	4	3	1	1
Salt	17	10	8	11	7	4	6	3	36	8
Umami	5	5	5	8	4	3	1	0	20	6
Fat sensation	87	6	21	13	16	7	39	16	46	11
Nutrient content										
Energy (kcal/100g)	677	203	77	53	134	138	285	164	242	113
Carbohydrates (g/100g)	1	3	13	7	20	24	41	25	9	11
Mono- and disaccharides (g/100g)	1	1	12	7	6	12	34	22	2	3
Protein (g/100g)	1	3	2	2	4	4	4	2	14	8
Fat (g/100g)	74	23	2	5	4	9	12	12	17	11
Sodium (mg/100g)	178	159	185	320	124	181	87	76	514	324

Table C2 The percentage of daily energy intake from each taste group in one year and two year old children (n=777)

	Total population				Sub population (n=777)			
	1 year (n=3629)		2 years (n=844)		1 year		2 years	
	Energy %				Energy %			
Taste group	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Neutral	63.6	13.2	42.3	8.4	63.3	12.8	42.2	8.4
Sweet/sour	13.3	8.0	10.4	6.7	14.3	7.6	10.4	6.7
Sweet/fat	6.8	5.5	18.3	7.4	6.7	5.2	18.3	7.5
Fat	5.5	4.2	11.4	4.4	5.1	3.9	11.5	4.4
Salt/umami/fat	10.8	6.2	17.6	5.6	10.6	5.9	17.6	5.6

Table C3 Associations of maternal characteristics (β (95%CI)) with contribution to % energy from each taste cluster at the age of one year in Dutch participants only (n=2,358)

	Neutral	Sweet/sour	Sweet/fat	Fat	Salt/umami/fat
Maternal age					
Model 1	**0.4 (0.3, 0.6)**	**-0.2 (-0.3, -0.1)**	**-0.1 (-0.1, -0.0)**	**-0.1 (-0.1, -0.0)**	**-0.1 (-0.2, -0.0)**
Model 2	**0.3 (0.2, 0.5)**	**-0.2 (-0.2, -0.1)**	-0.1 (-0.1, 0.0)	**-0.0 (-0.1, 0.0)**	**-0.1 (-0.1, -0.0)**
Educational level					
Low	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
High					
Model 1	**2.9 (1.6, 4.2)**	-0.6 (-1.3, 0.2)	**-1.1 (-1.6, -0.6)**	**-0.6 (-1.0, -0.2)**	**-0.6 (-1.1, -0.1)**
Model 2	**1.5 (0.2, 2.8)**	0.1 (-0.7, 0.9)	**-0.7 (-1.2, -0.2)**	**-0.5 (-0.9, -0.2)**	-0.3 (-0.9, 0.2)
Maternal BMI					
Model 1	**-0.3 (-0.4, -0.1)**	**0.1 (0.0, 0.2)**	**0.1 (0.1, 0.2)**	0.0 (-0.0, 0.1)	0.0 (-0.0, 0.1)
Model 2	**-0.2 (-0.3, -0.0)**	0.1 (-0.0, 0.2)	**0.1 (0.0, 0.1)**	0.0 (-0.0, 0.1)	-0.0 (-0.1, 0.1)

Model 1 is unadjusted. Model 2 is adjusted for all other maternal and child characteristics. **Bold** values indicate statistically significant effect estimates.

Table C4 Associations of child characteristics (β (95%CI)) with contribution to % energy from each taste cluster at the age of one year in Dutch participants only (n=2,358)

	Neutral	Sweet/sour	Sweet/fat	Fat	Salt/umami/fat
Sex					
Boy	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Girl					
Model 1	**1.1 (0.1, 2.2)**	0.2 (-0.5, 0.8)	**-0.4 (-0.8, -0.0)**	**-0.6 (-0.9, -0.2)**	-0.3 (-0.8, 0.1)
Model 2	0.9 (-0.1, 1.8)	0.2 (-0.4, 0.8)	**-0.3 (-0.7, 0.1)**	**-0.5 (-0.8, -0.2)**	-0.2 (-0.7, 0.2)
Child age at FFQ					
Model 1	**-2.0 (-2.2, -1.7)**	**0.4 (0.2, 0.6)**	**0.6 (0.5, 0.7)**	**0.3 (0.3, 0.4)**	**0.7 (0.5, 0.8)**
Model 2	**-2.0 (-2.2, -1.7)**	**0.4 (0.2, 0.5)**	**0.6 (0.5, 0.7)**	**0.3 (0.3, 0.4)**	**0.6 (0.5, 0.8)**
Child BMI Z-score					
Model 1	-0.4 (-0.8, 0.1)	**0.3 (0.1, 0.6)**	-0.1 (-0.3, 0.1)	0.0 (-0.1, 0.1)	0.1 (-0.1, 0.3)
Model 2	-0.3 (-0.7, 0.1)	**0.3 (0.0, 0.5)**	-0.1 (-0.3, 0.0)	0.0 (-0.1, 0.2)	0.1 (-0.1, 0.3)
Breastfeeding duration					
Model 1	**0.4 (0.3, 0.6)**	**-0.2 (-0.3, -0.1)**	**-0.1 (-0.2, -0.1)**	0.0 (-0.0, 0.1)	**-0.1 (-0.2, -0.1)**
Model 2	**0.3 (0.1, 0.4)**	**-0.2 (-0.3, -0.1)**	**-0.1 (-0.1, -0.0)**	0.0 (-0.0, 0.1)	**-0.1 (-0.2, -0.0)**
Introduction of complementary feeding					
After 6 months	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
3-6 months					
Model 1	**-1.6 (-2.6, -0.5)**	0.4 (-0.3, 1.0)	**0.8 (0.3, 1.2)**	-0.1 (-0.4, 0.3)	**0.5 (0.0, 1.0)**
Model 2	**-1.0 (-2.1, 0.0)**	0.1 (-0.6, 0.7)	**0.6 (0.2, 1.1)**	-0.1 (-0.4, 0.3)	0.4 (-0.1, 0.8)
0-3 months					
Model 1	**-3.1 (-5.6, -0.5)**	-1.2 (-2.8, 0.3)	**2.1 (1.0, 3.1)**	**1.1 (0.3, 1.9)**	**1.2 (0.1, 2.3)**
Model 2	-1.9 (-4.4, 0.5)	**-1.7 (-3.2, -0.1)**	**1.8 (0.7, 2.8)**	**0.9 (0.2, 1.7)**	0.9 (-0.2, 2.0)

Model 1 is unadjusted. Model 2 is adjusted for all other maternal and child characteristics. **Bold** values indicate statistically significant effect estimates.
* Child age- and sex- specific BMI Z-scores

Table C5 Associations of maternal characteristics (β (95%CI)) with contribution to % energy from each taste cluster at the age of two years (n=844)

	Neutral	Sweet/sour	Sweet/fat	Fat	Salt/umami/fat
Maternal age					
Model 1	**0.2 (0.0, 0.3)**	**-0.2 (-0.2, -0.1)**	0.1 (-0.0, 0.2)	0.0 (-0.1, 0.1)	**-0.1 (-0.2, -0.1)**
Model 2	0.1 (-0.0, 0.3)	**-0.2 (-0.3, -0.1)**	**0.2 (0.0, 0.3)**	-0.0 (-0.1, 0.1)	-0.1 (-0.2, 0.0)
Educational level					
Low	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
High					
Model 1	**2.0 (0.4, 3.5)**	-0.1 (-1.2, 1.1)	-1.1 (-2.4, 0.3)	0.0 (-0.7, 0.7)	**-0.9 (-1.8, 0.0)**
Model 2	1.2 (-0.3, 2.7)	0.3 (-0.9, 1.5)	-0.9 (-2.2, 0.5)	-0.2 (-1.0, 0.6)	-0.5 (-1.4, 0.5)
Maternal BMI					
Model 1	**-0.3 (-0.4, -0.1)**	0.1 (-0.1, 0.2)	0.1 (-0.0, 0.2)	0.0 (-0.1, 0.1)	**0.1 (0.0, 0.2)**
Model 2	**-0.3 (-0.4, -0.1)**	0.1 (-0.1, 0.2)	0.1 (-0.1, 0.2)	0.0 (-0.1, 0.1)	**0.1 (0.0, 0.2)**

Model 1 is unadjusted. Model 2 is adjusted for all other maternal and child characteristics. **Bold** values indicate statistically significant effect estimates.

Table C6 Associations of child characteristics (β (95%CI)) with contribution to % energy from each taste cluster at the age of 2 year (n=844)

	Neutral	Sweet/sour	Sweet/fat	Fat	Salt/umami/fat
Sex					
Boy	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Girl					
Model 1	-0.5 (-1.7, 0.6)	**1.2 (0.7, 1.6)**	**-1.2 (-2.2, -0.3)**	0.2 (-0.4, 0.8)	0.3 (-0.0, 0.7)
Model 2	-0.7 (-1.8, 0.5)	**1.3 (0.4, 2.2)**	**-1.2 (-2.2, -0.2)**	0.2 (-0.4, 0.8)	0.4 (-0.4, 1.2)
Child age at FFQ					
Model 1	0.1 (-0.4, 0.6)	-0.1 (-0.6, 0.3)	-0.2 (-0.6, 0.3)	0.2 (-0.1, 0.5)	-0.0 (-0.4, 0.3)
Model 2	0.1 (-0.5, 0.6)	-0.2 (-0.6, 0.3)	-0.1 (-0.6, 0.4)	0.2 (-0.1, 0.5)	-0.0 (-0.4, 0.3)
Child BMI Z-score					
Model 1	0.3 (-0.1, 0.8)	0.0 (-0.4, 0.4)	-0.4 (-0.8, 0.0)	-0.0 (-0.3, 0.2)	0.1 (-0.2, 0.4)
Model 2	0.4 (-0.1, 0.9)	-0.0 (-0.4, 0.4)	**-0.4 (-0.9, -0.0)**	-0.0 (-0.3, 0.2)	0.1 (-0.2, 0.4)
Breastfeeding duration					
Model 1	0.1 (-0.0, 0.3)	0.0 (-0.1, 0.1)	**-0.2 (-0.3, -0.1)**	**0.1 (0.1, 0.2)**	-0.1 (-0.2, 0.0)
Model 2	0.1 (-0.1, 0.2)	0.0 (-0.1, 0.1)	**-0.2 (-0.3, -0.0)**	**0.1 (0.0, 0.2)**	-0.0 (-0.2, 0.1)
Introduction of complementary feeding					
After 6 months	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
3-6 months					
Model 1	-0.4 (-1.6, 0.9)	0.2 (-0.8, 1.1)	-0.6 (-1.6, 0.6)	-0.3 (-0.9, 0.4)	**1.0 (0.2, 1.8)**
Model 2	-0.1 (-1.4, 1.1)	0.1 (-0.9, 1.1)	-0.8 (-1.9, 0.3)	-0.1 (-0.8, 0.6)	**0.9 (0.1, 1.8)**
0-3 months					
Model 1	-0.7 (-4.6, 3.3)	1.0 (-1.9, 3.9)	-2.6 (-5.8, 0.6)	0.9 (-1.5, 3.2)	1.4 (-1.0, 3.9)
Model 2	-0.8 (-4.8, 3.2)	1.2 (-1.7, 4.0)	-2.9 (-5.9, 0.1)	1.0 (-1.2, 3.2)	1.5 (-0.9, 3.9)

Model 1 is unadjusted. Model 2 is adjusted for all other maternal and child characteristics. **Bold** values indicate statistically significant effect estimates.

Table C7 Mean taste intensity values for the food items in the FFQ at 1 year and the classification into taste clusters

Item		Mean taste intensity values (0-100)						Cluster		
#	Name	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance
2	Corn or Rice waffles	3	0	1	7	1	4	1	Neutral	15.6
3	Otherwise: biscuits, crispbread, crackers, breadsticks or multigrain waffles	6	1	1	9	0	5	1	Neutral	13.6
5	Wholemeal or brown buns	4	2	2	12	0	8	1	Neutral	13.0
6	Buns with currants or raisins	6	2	1	11	0	7	1	Neutral	11.8
7	Malt or white buns	6	2	2	11	0	10	1	Neutral	10.7
8	Croissant	6	2	1	11	0	7	1	Neutral	11.8
9	Other croissants or buns	5	2	2	11	0	8	1	Neutral	12.2
11	Wholemeal or brown bread	4	2	2	12	0	8	1	Neutral	13.0
12	Bread with currants and raisins	6	2	1	11	0	7	1	Neutral	11.8
13	Malt or white bread	5	2	2	11	0	9	1	Neutral	11.4
14	Other bread	5	2	2	11	0	8	1	Neutral	12.4
43	Eggs	5	2	1	10	8	26	1	Neutral	14.3
47	Cornflakes, rice Kries piers, rice flour	14	1	1	5	1	15	1	Neutral	4.2
48	Oatmeal	6	1	2	6	1	20	1	Neutral	8.6
49	Albona, Bambix, Biovim, Brinta, Nutrigan, Muesli	15	2	2	6	1	12	1	Neutral	5.2
50	Other cereals	15	2	2	6	1	13	1	Neutral	4.8
53	Bebelac 2	19	2	0	4	3	17	1	Neutral	7.4
54	BiobimLac 2	19	2	0	4	3	17	1	Neutral	7.4
55	Bledena growth Danone milk	19	2	0	4	3	17	1	Neutral	7.4
56	Enfamil AR 2	19	2	0	4	3	17	1	Neutral	7.4
57	Friso 1 allergy care	19	2	0	4	3	17	1	Neutral	7.4

Table C7 continued

Item		Mean taste intensity values (0-100)						Cluster		
#	Name	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance
58	Friso 2 comfort	19	2	0	4	3	17	1	Neutral	7.4
59	Friso 2 extra	19	2	0	4	3	17	1	Neutral	7.4
60	Friso 2 hypoallergenic	19	2	0	4	3	17	1	Neutral	7.4
61	Friso 2 normal	19	2	0	4	3	17	1	Neutral	7.4
62	Friso 3 normal	19	2	0	4	3	17	1	Neutral	7.4
63	Neocate	19	2	0	4	3	17	1	Neutral	7.4
64	Nestle Toddler Milk BL	19	2	0	4	3	17	1	Neutral	7.4
65	Nestle Toddler Milk Vanilla	19	2	0	4	3	17	1	Neutral	7.4
66	Nestle NAN 2	19	2	0	4	3	17	1	Neutral	7.4
67	Nestlé NAN hypoallergenic 2	19	2	0	4	3	17	1	Neutral	7.4
68	Nutramigen	19	2	0	4	3	17	1	Neutral	7.4
69	Nutramigen 2 LGG	19	2	0	4	3	17	1	Neutral	7.4
70	Nutrilon 2	19	2	0	4	3	17	1	Neutral	7.4
71	Nutrilon 3	19	2	0	4	3	17	1	Neutral	7.4
72	Nutrilon AR 2	19	2	0	4	3	17	1	Neutral	7.4
73	Nutrilon Forte 2	19	2	0	4	3	17	1	Neutral	7.4
74	Nutrilon Hypoallergenic 2	19	2	0	4	3	17	1	Neutral	7.4
75	Nutrion Peptides 2	19	2	0	4	3	17	1	Neutral	7.4
76	Nutrilon Toddler Milk	19	2	0	4	3	17	1	Neutral	7.4
77	Nutrilon Soya 2	19	2	0	4	3	17	1	Neutral	7.4
78	Omneo 2	19	2	0	4	3	17	1	Neutral	7.4
79	Peptide Junior	19	2	0	4	3	17	1	Neutral	7.4
80	Pregestimil	19	2	0	4	3	17	1	Neutral	7.4
81	Similac 2	19	2	0	4	3	17	1	Neutral	7.4
82	Simical 3	19	2	0	4	3	17	1	Neutral	7.4
83	Other infant formula	19	2	0	4	3	17	1	Neutral	7.4
85	Whole milk	12	4	1	3	1	20	1	Neutral	6.5
86	Semi-skimmed milk	12	4	1	3	1	20	1	Neutral	6.5
89	Other milk	12	7	1	3	1	20	1	Neutral	7.2
101	Oat meal porridge	15	1	1	3	0	22	1	Neutral	9.1
111	Tea	4	5	20	1	1	2	1	Neutral	24.2
112	Sugar added to tea	20	4	16	1	0	2	1	Neutral	21.4
117	Infant food meal 6-8 months with pasta	9	8	3	11	9	25	1	Neutral	13.2
118	Infant food meal 6-8 months without pasta	10	9	3	12	11	28	1	Neutral	16.6
119	Infant food meal 12-15 months with pasta	7	6	2	10	7	25	1	Neutral	12.3
120	Infant food meal 12-15 months without pasta	8	7	3	12	8	27	1	Neutral	14.9
121	Infant food meal 18 months with pasta	7	6	2	10	7	25	1	Neutral	12.3
122	Infant food meal 18 months without pasta	8	7	3	12	8	27	1	Neutral	14.9
123	Other kids meal	8	7	3	11	8	26	1	Neutral	13.9
125	Crepes or pancakes	15	2	1	8	2	35	1	Neutral	20.0
126	Pasta	3	2	1	3	1	16	1	Neutral	10.4
128	Multigrain Rice, couscous, bulgur, wheat or Tarly	7	1	2	4	1	8	1	Neutral	10.7
129	Other types of rice	5	2	2	3	3	6	1	Neutral	12.1
130	Legumes	12	3	2	23	12	15	1	Neutral	18.7
132	Boiled potatoes	7	2	1	19	10	20	1	Neutral	16.3
133	Fried potatoes	8	3	1	19	10	28	1	Neutral	19.7
148	Frites baked in the oven	9	3	0	17	8	37	1	Neutral	24.5
158	Carrots	15	2	1	5	3	10	1	Neutral	6.2
159	Cauliflower, Brussels sprouts or red cabbage	7	5	5	4	4	10	1	Neutral	8.7
160	Green beans	8	3	2	7	5	10	1	Neutral	7.2
161	Spinach	7	5	6	9	5	9	1	Neutral	9.6
162	Broccoli, leeks and red peppers	7	5	4	3	5	8	1	Neutral	10.0
163	Other vegetables	3	1	7	2	2	4	1	Neutral	16.3
164	Curly kale	9	8	6	5	4	9	1	Neutral	9.5
167	Stirred carrots	15	2	1	5	3	10	1	Neutral	6.2
168	Stirred cauliflower, Brussels sprouts or red cabbage	7	5	5	4	4	10	1	Neutral	8.7
169	Stirred green beans	8	3	2	7	5	10	1	Neutral	7.2

Table C7 continued

Item		Mean taste intensity values (0-100)						Cluster		
#	Name	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance
170	Stirred spinach	7	5	6	9	5	9	1	Neutral	9.6
171	Stirred broccoli, leeks and red peppers	7	5	4	3	5	8	1	Neutral	10.0
172	Stirred other vegetables	8	8	6	5	4	8	1	Neutral	9.7
185	Raw vegetables	8	15	6	3	2	4	1	Neutral	17.2
256	Apple, banana, grapes, pear, currants, raisins or fruit compote	28	17	1	1	1	14	1	Neutral	21.7
263	Water or diet (soft) drinks	10	10	7	2	1	4	1	Neutral	15.4
265	Small cookies	30	1	1	10	0	11	1	Neutral	19.0
269	Non-wholemeal biscuit food	32	2	0	8	1	18	1	Neutral	20.3
42	Sandwich spread	19	45	1	24	13	36	2	Sweet/sour	25.1
87	Skimmed milk, buttermilk	6	37	1	5	2	24	2	Sweet/sour	19.8
93	Low fat chocolate milk, low fat yoghurt drinks	32	26	3	4	1	29	2	Sweet/sour	16.6
102	Low-fat yogurt, low fat custard, low fat curd	12	54	2	3	1	28	2	Sweet/sour	23.0
103	Half-fat yogurt, half fat custard, half fat curd	27	33	1	2	1	36	2	Sweet/sour	17.3
105	Unknown type of yogurt, custard, porridge or pudding quark	23	32	3	3	1	35	2	Sweet/sour	16.5
253	Red sauces added to diner meal	27	32	1	32	24	29	2	Sweet/sour	32.6
257	Kiwi, strawberries, orange	22	40	4	1	0	5	2	Sweet/sour	18.5
258	Other fruit	28	24	2	3	1	10	2	Sweet/sour	19.3
260	Orange juice	32	42	2	1	0	2	2	Sweet/sour	22.4
261	Other fruit juice	39	40	2	2	1	3	2	Sweet/sour	24.4
264	Regular soft drinks, juice and lemonade	45	27	7	3	1	3	2	Sweet/sour	30.1
290	Ketchup in addition to a snack	27	32	1	32	24	29	2	Sweet/sour	32.6
15	Gingerbread	42	2	4	8	1	22	3	Sweet/fat	19.1
39	Chocolate butter, chocolate confetti/flocks	62	2	7	7	1	57	3	Sweet/fat	24.3
41	Other sweet sandwich fillings	66	12	3	5	0	30	3	Sweet/fat	21.1
91	Full-fat chocolate	37	2	7	6	0	39	3	Sweet/fat	12.6
92	Half-fat chocolate milk, half- fat drinking yoghurt	36	16	4	5	1	32	3	Sweet/fat	16.3
95	Unknown type of chocolate or yoghurt drinks	35	15	5	5	1	33	3	Sweet/fat	15.9
97	1-person infant dessert (eg Danone)	42	16	1	4	0	44	3	Sweet/fat	11.9
98	Semolina pudding	41	6	5	5	2	44	3	Sweet/fat	8.6
100	Mousse, pudding, full fruit curd	37	13	7	3	1	44	3	Sweet/fat	13.6
104	Full-fat yogurt, whole custard, rice pudding, pudding	29	16	4	3	1	38	3	Sweet/fat	21.0
107	Ice cream	48	3	1	6	0	51	3	Sweet/fat	13.5
109	Added sugar or other confectionery to dairy	66	17	1	2	0	8	3	Sweet/fat	37.4
110	Whipped cream sweetened	49	2	0	2	1	51	3	Sweet/fat	14.2
266	Cake or large cakes	51	1	2	10	1	32	3	Sweet/fat	11.1
268	Wholemeal biscuit diet	36	5	1	10	1	21	3	Sweet/fat	22.7
270	Pastry	47	5	1	9	1	42	3	Sweet/fat	5.7
271	Bonbons or pralines	55	2	9	7	1	65	3	Sweet/fat	27.7
272	Chocolate bar	55	2	9	7	1	65	3	Sweet/fat	27.7
276	Candy Bars	63	3	4	9	1	52	3	Sweet/fat	21.1
279	Candies and sweets	48	17	2	3	0	15	3	Sweet/fat	26.2
40	Peanut butter, nuts and seeds paste	27	2	2	24	2	69	4	Fat	30.5
188	Dressing: oil / vinegar dressing	2	1	5	7	3	66	4	Fat	24.4
189	Halvanaise, half fat salad dressing	12	34	1	29	8	71	4	Fat	35.9
190	Mayonnaise	10	33	1	25	8	76	4	Fat	31.7
191	Other type of dressing	13	22	2	26	8	75	4	Fat	24.5
251	Mayonnaise added to diner meal	10	33	1	25	8	76	4	Fat	31.7
252	Halvanaise added to diner meal	12	34	1	29	8	71	4	Fat	35.9
288	Mayonnaise in addition to a snack	10	33	1	25	8	76	4	Fat	31.7
289	Halvanaise in addition to a snack	12	34	1	29	8	71	4	Fat	35.9
401	Butter	3	1	0	18	2	94	4	Fat	8.7
402	Butter product half fat	3	2	2	14	4	89	4	Fat	4.8
403	Margarine	3	2	1	13	3	89	4	Fat	6.1
404	Diet Margarine	3	2	2	10	3	87	4	Fat	8.0
405	Stanols Margarine	3	2	2	14	4	89	4	Fat	4.8

Table C7 continued

Item		Mean taste intensity values (0-100)						Cluster		
#	Name	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance
406	Margarine from a cup	3	3	1	12	2	84	4	Fat	7.2
407	Margarine from a packet	2	1	1	14	0	94	4	Fat	10.1
408	Diet Margarine	3	4	2	9	3	84	4	Fat	9.2
409	Stanols Margarine	3	2	2	14	4	89	4	Fat	4.8
410	Liquid margarine	3	2	1	13	2	88	4	Fat	6.1
411	Solid baking fat	4	3	2	16	10	91	4	Fat	6.7
412	Liquid baking fat	8	8	1	56	23	90	4	Fat	43.6
413	Olive oil	2	1	10	8	3	94	4	Fat	13.9
414	Other type of oil	3	2	2	11	4	90	4	Fat	7.4
415	Solid frying fat	3	2	2	14	4	89	4	Fat	4.8
416	Liquid frying fat	3	2	2	14	4	89	4	Fat	4.8
451	Butter (dinner meal)	3	1	0	18	2	93	4	Fat	8.2
452	Unknown type of fat on bread	3	2	1	13	3	89	4	Fat	5.9
453	Other type of fat on bread	4	3	3	19	7	90	4	Fat	4.8
454	Unknown type of baking fat	3	3	2	17	5	90	4	Fat	3.6
455	Other type of baking fat	3	2	2	13	4	89	4	Fat	5.4
456	Unknown type of baking fat for fish or meat	3	3	2	17	5	90	4	Fat	3.6
457	Other type of baking fat for fish or meat	3	2	2	13	4	89	4	Fat	5.8
458	Unknown type of frying fat	3	2	4	12	4	90	4	Fat	7.3
459	Other type of frying fat	3	3	1	17	5	89	4	Fat	3.3
28	20 + / 30 + cheese spread	4	14	5	41	30	70	5	Salt/umami/fat	28.0
29	20 + / 30 + cheese	7	16	2	40	18	46	5	Salt/umami/fat	8.7
30	48 + cheese spread	6	18	1	41	17	51	5	Salt/umami/fat	12.6
31	40 + or 48 + cheese	6	21	4	50	18	65	5	Salt/umami/fat	27.4
32	Other cheese (eg goat)	6	18	2	43	18	55	5	Salt/umami/fat	15.8
34	Liver products, meat sandwich filling	7	6	3	41	23	63	5	Salt/umami/fat	18.5
35	Ham, ham cured	6	6	1	47	26	40	5	Salt/umami/fat	14.7
36	Sausage sandwich filling, corned beef, roast beef	4	9	1	40	21	50	5	Salt/umami/fat	7.3
37	Bacon, pepperoni, bacon, salami	4	9	0	51	21	69	5	Salt/umami/fat	28.3
38	Other processed meat	6	7	2	43	23	58	5	Salt/umami/fat	14.7
114	Soup with legumes	6	8	2	40	22	40	5	Salt/umami/fat	8.2
115	Other soup	12	10	1	38	29	25	5	Salt/umami/fat	23.1
124	Ready to eat Italian meal	10	9	1	33	26	41	5	Salt/umami/fat	8.5
146	Stew	6	6	3	41	13	30	5	Salt/umami/fat	18.4
149	French fried potatoes not fried by yourself	9	3	0	15	7	41	5	Salt/umami/fat	24.9
150	French fried potatoes fried by yourself	9	3	0	15	7	42	5	Salt/umami/fat	25.0
193	Ready-bought fish	5	7	1	29	25	37	5	Salt/umami/fat	12.5
194	Fish sticks	5	6	1	34	23	41	5	Salt/umami/fat	7.3
195	Flounder, brill cod, saithe, haddock, tuna	4	9	2	25	22	29	5	Salt/umami/fat	20.0
196	Trout, plaice, salmon forel, swordfish	5	9	2	28	24	33	5	Salt/umami/fat	16.0
197	Seafood	5	8	1	29	25	33	5	Salt/umami/fat	16.1
198	Herring, mackerel, eel or salmon	4	8	2	28	24	33	5	Salt/umami/fat	16.3
199	Other fish	5	8	1	27	23	32	5	Salt/umami/fat	17.3
202	Piece Beer, pork steak, fried meat, skinless chicken	6	7	1	24	15	36	5	Salt/umami/fat	16.1
203	Blind finch, pork filet, chicken with skin	5	6	1	30	17	44	5	Salt/umami/fat	6.9
204	Hamburger, sausage, spare rips, shoulder	9	5	1	46	27	47	5	Salt/umami/fat	13.3
205	Sausage, pork belly	5	9	2	37	17	59	5	Salt/umami/fat	14.0
206	Roulades, chopped	5	5	1	32	17	50	5	Salt/umami/fat	7.8
208	Kipburger, chicken nuggets	7	3	1	35	21	49	5	Salt/umami/fat	7.0
209	Frikadel, croquette, bamibal	9	4	1	43	16	38	5	Salt/umami/fat	12.0
210	Other meat	5	6	1	31	17	48	5	Salt/umami/fat	6.8
245	Cheese added to dinner meal	6	18	1	41	17	51	5	Salt/umami/fat	12.3
248	Peanut sauce added to dinner meal	32	9	2	41	14	60	5	Salt/umami/fat	28.6
249	Other warm sauces added to dinner meal	22	21	2	29	21	29	5	Salt/umami/fat	25.3
254	Other sauces added to dinner meal	19	33	1	30	16	51	5	Salt/umami/fat	27.4
281	Mini snack-bar product	6	3	1	30	15	45	5	Salt/umami/fat	9.4
282	Frikadel, croquette	9	4	1	42	15	35	5	Salt/umami/fat	14.0

Table C7 continued

Item		Mean taste intensity values (0-100)						Cluster		
#	Name	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance
283	Meatball or hamburger	5	7	1	38	21	51	5	Salt/umami/fat	6.7
284	Kipburger or chicken nuggets	7	3	1	35	21	49	5	Salt/umami/fat	7.0
285	French fried potatoes	9	3	0	15	7	42	5	Salt/umami/fat	25.0
286	Sausages, or cheese sandwich	8	5	1	41	17	40	5	Salt/umami/fat	9.7
287	Other snacks like spring rolls or satay	15	5	1	36	24	47	5	Salt/umami/fat	8.7
291	Peanut sauce in addition to a snack	32	9	2	41	14	60	5	Salt/umami/fat	28.6
292	Other sauce	19	33	1	30	16	51	5	Salt/umami/fat	27.4
293	Chips	9	4	1	42	18	31	5	Salt/umami/fat	17.1
294	In-between cheese snack	6	18	1	41	17	51	5	Salt/umami/fat	12.3
295	In-between sausage snack	6	7	1	43	24	56	5	Salt/umami/fat	14.1
296	In-between toast with filling snack	6	11	3	45	23	63	5	Salt/umami/fat	20.3
88	Soy-based milk								Missing	
94	Soy-based milk								Missing	
99	Soy-based dessert								Missing	
108	Water ice								Missing	
187	Dressing: only natural vinegar dressing								Missing	
207	Kidney or liver products								Missing	
228	Vegetarian burger								Missing	
229	Other meat substitutes								Missing	
246	Cream added to dinner meal								Missing	

Table C8 Mean taste intensity values for the food items in the FFQ at 2 years and the classification into taste clusters

Item		Mean taste intensity values (0-100)						Cluster		
#	Name	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance
1	Corn or Rice waffles	3	0	1	7	1	4	4	Neutral	15.6
2	Rye bread	6	2	1	11	0	7	4	Neutral	11.8
3	Otherwise: biscuits, crispbread, crackers, breadsticks or multigrain waffles	7	2	1	9	1	5	4	Neutral	12.6
4	Wholemeal or brown buns	4	2	2	12	0	8	4	Neutral	13.0
5	Malt or white buns	6	2	2	11	0	10	4	Neutral	10.2
6	Buns with currants or raisins	6	2	1	11	0	7	4	Neutral	11.8
7	Croissant	6	2	1	11	0	7	4	Neutral	11.8
8	Other croissants or buns	5	2	2	12	0	8	4	Neutral	12.3
9	Wholemeal or brown bread	4	2	2	12	0	8	4	Neutral	13.0
10	Malt or white bread	5	2	2	11	0	10	4	Neutral	11.0
11	Bread with currants and raisins	6	2	1	11	0	7	4	Neutral	11.8
12	Other bread	4	2	2	11	0	8	4	Neutral	12.6
37	Cooked eggs	5	2	1	10	8	26	4	Neutral	14.3
38	Fried eggs	5	2	1	10	8	26	4	Neutral	14.3
39	Cornflakes, rice Kries piers, rice flour	14	1	1	6	1	14	4	Neutral	4.4
40	Oatmeal	6	1	2	6	1	20	4	Neutral	8.6
41	Albona, Bambix, Biovim, Brinta, Nutrigan, Muesli	11	1	1	5	1	20	4	Neutral	6.5
42	Other cereals	11	1	2	5	1	20	4	Neutral	6.4
43	BiobimLac 2	19	2	0	4	3	17	4	Neutral	7.4
44	BiobimLac 3	19	2	0	4	3	17	4	Neutral	7.4
45	Bledena growth Danone milk	19	2	0	4	3	17	4	Neutral	7.4
46	Flexical	19	2	0	4	3	17	4	Neutral	7.4

Table C8 continued

Item		Mean taste intensity values (0-100)						Cluster		
#	Name	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance
47	Friso 1 allergy care	19	2	0	4	3	17	4	Neutral	7.4
48	Friso 3 normal	19	2	0	4	3	17	4	Neutral	7.4
49	Neocate advance	19	2	0	4	3	17	4	Neutral	7.4
50	Nestle Toddler Milk BL	19	2	0	4	3	17	4	Neutral	7.4
51	Nestle Toddler Milk Vanilla	19	2	0	4	3	17	4	Neutral	7.4
52	Nestle NAN 2	19	2	0	4	3	17	4	Neutral	7.4
53	Nestlé NAN hypoallergenic 2	19	2	0	4	3	17	4	Neutral	7.4
54	Nutramigen	19	2	0	4	3	17	4	Neutral	7.4
55	Nutramigen 2 LGG	19	2	0	4	3	17	4	Neutral	7.4
56	Nutri-junior	19	2	0	4	3	17	4	Neutral	7.4
57	Nutrilon 2	19	2	0	4	3	17	4	Neutral	7.4
58	Nutrilon 3	19	2	0	4	3	17	4	Neutral	7.4
59	Nutrilon AR 2	19	2	0	4	3	17	4	Neutral	7.4
60	Nutrilon Forte 2	19	2	0	4	3	17	4	Neutral	7.4
61	Nutrilon Hypoallergenic 2	19	2	0	4	3	17	4	Neutral	7.4
62	Nutrilon Omneo 2	19	2	0	4	3	17	4	Neutral	7.4
63	Nutrilon Toddler Milk	19	2	0	4	3	17	4	Neutral	7.4
64	Nutrion Peptides 2	19	2	0	4	3	17	4	Neutral	7.4
65	Nutrilon Soya 2	19	2	0	4	3	17	4	Neutral	7.4
66	Peptide Junior	19	2	0	4	3	17	4	Neutral	7.4
67	Pregestimil	19	2	0	4	3	17	4	Neutral	7.4
68	Simical 3	19	2	0	4	3	17	4	Neutral	7.4
69	Other infant formula	19	2	0	4	3	17	4	Neutral	7.4
70	Missing type of infant formula	19	2	0	4	3	17	4	Neutral	7.4
71	Whole milk	12	4	1	3	1	20	4	Neutral	6.5
72	Semi-skimmed milk	12	4	1	3	1	20	4	Neutral	6.5
75	Other milk	12	4	1	3	1	20	4	Neutral	6.2
80	Unknown type of infant formula	27	2	5	3	1	24	4	Neutral	17.8
99	Coffee	2	9	63	3	1	4	4	Neutral	62.6
100	Tea	4	5	20	1	1	2	4	Neutral	24.2
101	Sugar added to tea							4	Neutral	
105	Nestle infant food meal	8	7	3	12	8	27	4	Neutral	14.9
106	Infant food meal 12 months garden vegetables	8	7	3	12	8	27	4	Neutral	14.9
107	Infant food meal 12 months stew with chees	8	7	3	12	8	27	4	Neutral	14.9
108	Infant food meal 12 months red cabbage	8	7	3	12	8	27	4	Neutral	14.9
109	Infant food meal 12 months risotto with tomato	8	7	3	12	8	27	4	Neutral	14.9
110	Infant food meal 12 months pasta with ham and cheese	8	7	3	12	8	27	4	Neutral	14.9
111	Infant food meal 12 months other type	8	7	3	12	8	27	4	Neutral	14.9
112	Infant food meal 15 months without pasta	8	7	3	12	8	27	4	Neutral	14.9
113	Infant food meal 15 months vegetable lasagna	8	7	3	12	8	27	4	Neutral	14.9
114	Infant food meal 15 months spaghetti bolognese	8	7	3	12	8	27	4	Neutral	14.9
115	Infant food meal 18 months vegetable dish	8	7	3	12	8	27	4	Neutral	14.9
116	Infant food meal 18 months spinach	8	7	3	12	8	27	4	Neutral	14.9
117	Infant food meal 18 months pasta	8	7	3	12	8	27	4	Neutral	14.9
118	Other kids meal	8	7	3	12	8	27	4	Neutral	14.9
124	Crepes or pancakes	15	2	1	8	2	35	4	Neutral	20.0
125	Pasta	3	2	1	3	1	16	4	Neutral	10.6
126	Multigrain Rice, couscous, bulgur, wheat or Tarly	7	1	2	4	1	8	4	Neutral	10.7
127	Other types of rice	3	2	2	2	4	6	4	Neutral	14.5
128	Legumes	15	5	1	26	14	16	4	Neutral	22.4
129	Boiled potatoes	5	2	1	8	7	13	4	Neutral	9.0
130	Fried potatoes	5	2	1	8	7	13	4	Neutral	9.0
134	Boiled green beans or carrots	10	3	2	8	4	10	4	Neutral	6.0

Appendix C

Table C8 continued

Item		Mean taste intensity values (0-100)						Cluster		
#	Name	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance
135	Boiled cauliflower	7	5	5	4	5	10	4	Neutral	8.9
136	Boiled curly kale	7	5	5	2	3	6	4	Neutral	12.1
137	Boiled spinach or leek	7	4	6	11	5	10	4	Neutral	9.7
138	Boiled other vegetables	9	15	5	6	5	10	4	Neutral	13.5
139	Stirred green beans or carrots	10	3	2	8	4	10	4	Neutral	6.0
140	Stirred cauliflower	7	5	5	4	5	10	4	Neutral	8.9
141	Stirred red pepper	14	11	3	2	4	9	4	Neutral	10.9
142	Stirred spinach or leek	7	4	6	11	5	10	4	Neutral	9.7
143	Stirred other vegetables	7	13	5	6	5	9	4	Neutral	12.9
144	Raw vegetables	7	9	5	4	3	5	4	Neutral	13.4
171	Walnuts in addition to warm meal	5	1	12	2	6	22	4	Neutral	14.7
172	Sunflower seeds in addition to warm meal	6	2	3	3	2	23	4	Neutral	10.7
182	Apple, banana, grapes, pear, currants, raisins or fruit compote	28	18	1	1	1	14	4	Neutral	22.4
187	Water or diet (soft) drinks	4	7	8	1	1	4	4	Neutral	16.8
190	Small cookies	33	1	1	10	1	13	4	Neutral	21.1
192	Non-wholemeal biscuit food	30	1	0	8	1	17	4	Neutral	18.5
219	Walnuts (snack)	5	1	12	2	6	22	4	Neutral	14.7
36	Sandwich spread	19	45	1	24	13	36	3	Sweet/sour	25.1
73	Skimmed milk, buttermilk	6	37	1	5	2	24	3	Sweet/sour	19.8
78	Low fat chocolate milk, low fat yoghurt drinks	32	27	1	4	1	29	3	Sweet/sour	16.3
87	Low-fat yogurt	2	66	2	3	1	26	3	Sweet/sour	37.4
89	Half-fat yogurt with fruit flavour	26	27	0	4	1	35	3	Sweet/sour	18.7
90	Half-fat yogurt	10	46	2	1	1	29	3	Sweet/sour	20.7
93	Full-fat yogurt	3	69	2	3	1	29	3	Sweet/sour	39.5
94	Unknown type of yogurt	24	32	2	3	1	34	3	Sweet/sour	15.7
180	Red sauces added to dinner meal	29	37	1	30	22	28	3	Sweet/sour	29.0
183	Kiwi, strawberries, orange	22	39	5	1	0	4	3	Sweet/sour	19.0
184	Other fruit	32	22	1	2	1	9	3	Sweet/sour	22.0
185	Apple juice	35	44	2	1	0	1	3	Sweet/sour	24.8
186	Other fruit juice	36	40	2	1	0	3	3	Sweet/sour	22.8
188	Regular soft drinks, juice and lemonade	55	26	3	3	0	4	3	Sweet/sour	37.5
216	Ketchup in addition to a snack	29	37	1	30	22	28	3	Sweet/sour	29.0
13	Gingerbread	41	2	3	9	1	22	5	Sweet/fat	19.4
33	Chocolate butter, chocolate confetti/flocks	61	3	6	7	1	54	5	Sweet/fat	20.5
35	Other sweet sandwich fillings	65	11	3	5	0	29	5	Sweet/fat	20.0
76	Full-fat chocolate milk	37	2	7	6	0	39	5	Sweet/fat	12.6
77	Half-fat chocolate milk, half- fat drinking yoghurt	42	4	7	5	1	35	5	Sweet/fat	8.6
81	1-person infant dessert (eg Danone)	42	16	1	4	0	44	5	Sweet/fat	11.9
82	Semolina pudding	41	6	5	5	2	44	5	Sweet/fat	8.6
84	Mousse, pudding, full fruit curd	39	4	6	4	1	43	5	Sweet/fat	10.9
85	Oat meal porridge	39	4	6	4	1	43	5	Sweet/fat	10.9
86	Low-fat yogurt with fruit flavour	41	23	1	2	1	34	5	Sweet/fat	18.7
88	Half-fat curd with fruit flavour	48	22	1	3	1	45	5	Sweet/fat	16.2
91	Full-fat yogurt with fruit flavour	40	28	1	4	1	42	5	Sweet/fat	22.4
92	Full-fat custard	34	3	4	3	1	40	5	Sweet/fat	14.6
95	Ice cream	48	2	1	5	0	52	5	Sweet/fat	13.7
97	Added sugar or other confectionery to dairy	65	17	1	2	0	9	5	Sweet/fat	36.3
98	Whipped cream	49	2	0	2	1	51	5	Sweet/fat	14.2
189	Concentrated fruit syrup	57	17	0	1	0	4	5	Sweet/fat	37.9
191	Wholemeal biscuit diet	38	4	1	11	1	20	5	Sweet/fat	22.3
193	Cake or large cakes	46	2	1	9	1	27	5	Sweet/fat	13.8
194	Fruit pastry	40	3	1	10	1	24	5	Sweet/fat	18.5
195	Whipped cream pastry	48	3	0	7	1	51	5	Sweet/fat	13.3
196	Other pastry	41	2	1	9	1	31	5	Sweet/fat	12.8
197	Bonbons or pralines	55	2	9	7	1	63	5	Sweet/fat	25.7

Table C8 continued

Item		Mean taste intensity values (0-100)						Cluster		
#	Name	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance
198	Small chocolate bar	54	2	9	7	1	65	5	Sweet/fat	27.7
199	Medium chocolate bar	54	2	9	7	1	65	5	Sweet/fat	27.7
200	Large chocolate bar	54	2	9	7	1	65	5	Sweet/fat	27.7
201	Mini candy bar	59	4	4	8	1	39	5	Sweet/fat	11.7
202	Medium candy bar	59	4	4	8	1	39	5	Sweet/fat	11.7
203	King size candy bar	59	4	4	8	1	39	5	Sweet/fat	11.7
204	Candies and sweets	48	16	2	4	0	16	5	Sweet/fat	24.5
14	Butter	3	1	0	18	2	94	2	Fat	8.7
15	Margarine	3	2	2	10	3	87	2	Fat	8.0
16	Diet Margarine	3	2	1	13	3	89	2	Fat	6.1
17	Stanols Margarine	3	2	2	14	4	89	2	Fat	4.8
18	Margarine from a packet	2	1	1	14	0	94	2	Fat	10.1
19	Diet Margarine	3	4	2	9	3	84	2	Fat	9.2
20	Stanols Margarine	3	2	2	14	4	89	2	Fat	4.8
21	Margarine from a cup	3	3	1	12	2	84	2	Fat	7.2
22	Other type of fat on bread	4	3	3	19	7	90	2	Fat	4.8
23	Unknown type of fat on bread	3	2	1	13	3	89	2	Fat	5.9
34	Peanut butter, nuts and seeds paste	27	2	2	24	2	69	2	Fat	30.5
146	Dressing: oil / vinegar dressing	2	1	5	7	3	66	2	Fat	24.4
147	Halvanaise, half fat salad dressing	12	34	2	30	8	70	2	Fat	36.4
148	Mayonnaise	10	33	1	25	8	76	2	Fat	31.7
149	Other type of dressing	9	27	2	23	7	71	2	Fat	28.3
178	Mayonnaise added to dinner meal	10	33	1	25	8	76	2	Fat	31.7
179	Halvanaise added to dinner meal	12	34	2	30	8	70	2	Fat	36.4
214	Mayonnaise in addition to a snack	10	33	1	25	8	76	2	Fat	31.7
215	Halvanaise in addition to a snack	12	34	2	30	8	70	2	Fat	36.4
226	Butter (eggs)	3	1	0	18	2	93	2	Fat	8.2
227	Margarine (eggs)	3	3	1	12	2	84	2	Fat	7.2
228	Diet Margarine (eggs)	3	4	2	9	3	84	2	Fat	9.2
229	Margarine from a packet (eggs)	2	1	1	14	0	94	2	Fat	10.1
230	Stanols Margarine (eggs)	3	2	2	14	4	89	2	Fat	4.8
231	Liquid margarine (eggs)	3	2	1	13	2	88	2	Fat	6.1
232	Solid baking fat (eggs)	4	3	2	16	10	91	2	Fat	6.7
233	Liquid baking fat (eggs)	8	8	1	56	23	90	2	Fat	43.6
234	Olive oil (eggs)	2	1	10	8	3	94	2	Fat	13.9
235	Sunflower oil (eggs)	3	2	2	11	4	90	2	Fat	7.4
236	Other type of baking fat or oil (eggs)	3	2	2	13	4	89	2	Fat	5.4
237	Unknown type of baking fat or oil (eggs)	3	3	2	17	5	90	2	Fat	3.6
238	Butter (potatoes)	3	1	0	18	2	93	2	Fat	8.2
239	Margarine (potatoes)	3	3	1	12	2	84	2	Fat	7.2
240	Diet Margarine (potatoes)	3	4	2	9	3	84	2	Fat	9.2
241	Margarine from a packet (potatoes)	2	1	1	14	0	94	2	Fat	10.1
242	Stanols Margarine (potatoes)	3	2	2	14	4	89	2	Fat	4.8
243	Liquid margarine (potatoes)	3	2	1	13	2	88	2	Fat	6.1
244	Solid baking fat (potatoes)	4	3	2	16	10	91	2	Fat	6.7
245	Liquid baking fat (potatoes)	8	8	1	56	23	90	2	Fat	43.6
246	Olive oil (potatoes)	2	1	10	8	3	94	2	Fat	13.9
247	Sunflower oil (potatoes)	3	2	2	11	4	90	2	Fat	7.4
248	Other type of baking fat or oil (potatoes)	3	2	2	13	4	89	2	Fat	5.4
249	Missing type of baking fat or oil (potatoes)	3	3	2	17	5	90	2	Fat	3.6
250	Unknown type of baking fat or oil (potatoes)	3	3	2	17	5	90	2	Fat	3.6
251	Olive oil (fried potatoes)	2	1	10	8	3	94	2	Fat	13.9
252	Sunflower oil (fried potatoes)	3	2	2	11	4	90	2	Fat	7.4
253	Solid frying fat (fried potatoes)	3	2	2	14	4	89	2	Fat	4.8
254	Liquid frying fat (fried potatoes)	3	2	2	14	4	89	2	Fat	4.8
255	Other type of frying fat (fried potatoes)	3	2	2	14	4	89	2	Fat	4.8
256	Unknown type of frying fat (fried potatoes)	3	2	4	12	4	90	2	Fat	7.3

Table C8 continued

Item		Mean taste intensity values (0-100)						Cluster		
#	Name	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance
257	Missing type of frying fat (fried potatoes)	3	2	4	12	4	90	2	Fat	7.3
258	Fat in addition to boiled vegetables	3	3	2	17	5	90	2	Fat	3.6
259	Butter (vegetables)	3	1	0	18	2	93	2	Fat	8.2
260	Margarine (vegetables)	3	3	1	12	2	84	2	Fat	7.2
261	Diet Margarine (vegetables)	3	4	2	9	3	84	2	Fat	9.2
262	Margarine from a packet (vegetables)	2	1	1	14	0	94	2	Fat	10.1
263	Stanols Margarine (vegetables)	3	2	2	14	4	89	2	Fat	4.8
264	Liquid margarine (vegetables)	3	2	1	13	2	88	2	Fat	6.1
265	Solid baking fat (vegetables)	4	3	2	16	10	91	2	Fat	6.7
266	Liquid baking fat (vegetables)	8	8	1	56	23	90	2	Fat	43.6
267	Olive oil (vegetables)	2	1	10	8	3	94	2	Fat	13.9
268	Sunflower oil (vegetables)	3	2	2	11	4	90	2	Fat	7.4
269	Other type of baking fat or oil (vegetables)	3	2	2	13	4	89	2	Fat	5.4
270	Unknown type of baking fat or oil (vegetables)	3	3	2	17	5	90	2	Fat	3.6
271	Baking fat for fish	3	2	2	13	4	89	2	Fat	5.4
272	Butter (meat)	3	1	0	18	2	93	2	Fat	8.2
273	Margarine (meat)	3	3	1	12	2	84	2	Fat	7.2
274	Diet Margarine (meat)	3	4	2	9	3	84	2	Fat	9.2
275	Margarine from a packet (meat)	2	1	1	14	0	94	2	Fat	10.1
276	Stanols Margarine (meat)	3	2	2	14	4	89	2	Fat	4.8
277	Liquid margarine (meat)	3	2	1	13	2	88	2	Fat	6.1
278	Solid baking fat (meat)	4	3	2	16	10	91	2	Fat	6.7
279	Liquid baking fat (meat)	8	8	1	56	23	90	2	Fat	43.6
280	Olive oil (meat)	2	1	10	8	3	94	2	Fat	13.9
281	Sunflower oil (meat)	3	2	2	11	4	90	2	Fat	7.4
282	Other type of baking fat or oil (meat)	3	2	2	13	4	89	2	Fat	5.8
283	Missing type of baking fat or oil (meat)	3	3	2	17	5	90	2	Fat	3.6
285	Solid frying fat (meat)	3	2	2	14	4	89	2	Fat	4.8
286	Liquid frying fat (meat)	3	2	2	14	4	89	2	Fat	4.8
287	Unknown type of baking fat or oil (meat)	3	3	2	17	5	90	2	Fat	3.6
288	Butter (meat replacers)	3	1	0	18	2	93	2	Fat	8.2
289	Margarine (meat replacers)	3	3	1	12	2	84	2	Fat	7.2
290	Diet Margarine (meat replacers)	3	4	2	9	3	84	2	Fat	9.2
291	Margarine from a packet (meat replacers)	2	1	1	14	0	94	2	Fat	10.1
292	Stanols Margarine (meat replacers)	3	2	2	14	4	89	2	Fat	4.8
293	Liquid margarine (meat replacers)	3	2	1	13	2	88	2	Fat	6.1
294	Solid baking fat (meat replacers)	4	3	2	16	10	91	2	Fat	6.7
295	Liquid baking fat (meat replacers)	8	8	1	56	23	90	2	Fat	43.6
296	Olive oil (meat replacers)	2	1	10	8	3	94	2	Fat	13.9
297	Sunflower oil (meat replacers)	3	2	2	11	4	90	2	Fat	7.4
298	Other type of baking fat or oil (meat replacers)	3	2	2	13	4	89	2	Fat	5.8
299	Missing type of baking fat or oil (meat replacers)	3	3	2	17	5	90	2	Fat	3.6
301	Solid frying fat (meat replacers)	3	2	2	14	4	89	2	Fat	4.8
302	Liquid frying fat (meat replacers)	3	2	2	14	4	89	2	Fat	4.8
303	Unknown type of baking fat or oil (meat replacers)	3	3	2	17	5	90	2	Fat	3.6
304	Butter (gravy)	3	1	0	18	2	93	2	Fat	8.2
305	Margarine (gravy)	3	3	1	12	2	84	2	Fat	7.2
306	Diet Margarine (gravy)	3	4	2	9	3	84	2	Fat	9.2
307	Margarine from a packet (gravy)	2	1	1	14	0	94	2	Fat	10.1
308	Stanols Margarine (gravy)	3	2	2	14	4	89	2	Fat	4.8
309	Liquid margarine (gravy)	3	2	1	13	2	88	2	Fat	6.1
310	Solid baking fat (gravy)	4	3	2	16	10	91	2	Fat	6.7
311	Liquid baking fat (gravy)	8	8	1	56	23	90	2	Fat	43.6
312	Olive oil (gravy)	2	1	10	8	3	94	2	Fat	13.9
313	Sunflower oil (gravy)	3	2	2	11	4	90	2	Fat	7.4

Table C8 continued

Item		Mean taste intensity values (0-100)						Cluster		
#	Name	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance
314	Other type of baking fat or oil (gravy)	3	2	2	14	4	89	2	Fat	4.8
315	Missing type of baking fat or oil (gravy)	3	2	2	14	4	89	2	Fat	4.8
317	Solid frying fat (gravy)	3	2	2	14	4	89	2	Fat	4.8
318	Liquid frying fat (gravy)	3	2	2	14	4	89	2	Fat	4.8
319	Unknown type of baking fat or oil (gravy)	3	2	2	14	4	89	2	Fat	4.8
24	48 + cheese spread	6	18	1	41	17	51	1	Salt/umami/fat	12.5
25	40 + or 48 + cheese	6	20	4	49	18	64	1	Salt/umami/fat	25.7
26	Luxury cheese	6	17	2	36	14	65	1	Salt/umami/fat	21.7
27	Other cheese (eg goat)	4	14	5	41	30	70	1	Salt/umami/fat	28.0
28	Liver Products meat sandwich filling	7	6	3	41	24	62	1	Salt/umami/fat	18.1
29	Ham, ham, cured	7	6	1	45	25	41	1	Salt/umami/fat	12.4
30	Sausage sandwich filling, corned beef, roast beef	5	9	1	42	23	51	1	Salt/umami/fat	9.3
31	Bacon, pepperoni, bacon, salami	3	13	1	48	20	60	1	Salt/umami/fat	20.1
32	Other processed meat	6	7	2	43	23	56	1	Salt/umami/fat	13.0
102	Soup with legumes	7	8	2	40	24	37	1	Salt/umami/fat	11.0
103	Soup with pasta and meat	12	10	1	38	28	26	1	Salt/umami/fat	22.3
104	Other soup	13	10	1	38	28	25	1	Salt/umami/fat	22.9
119	Spring roll	11	6	1	36	26	51	1	Salt/umami/fat	9.2
120	Rice dishes	6	2	1	39	27	38	1	Salt/umami/fat	13.5
121	Bami dishes	6	2	1	39	27	38	1	Salt/umami/fat	13.5
122	Other Chinese dishes	6	2	1	39	27	38	1	Salt/umami/fat	13.5
123	Ready to eat Italian meal	9	11	0	29	25	37	1	Salt/umami/fat	12.5
131	Stew	6	6	3	41	13	30	1	Salt/umami/fat	18.4
132	Potato croquettes	9	3	0	15	7	41	1	Salt/umami/fat	24.9
133	Other fried potatoes	9	3	0	16	8	38	1	Salt/umami/fat	24.6
150	Ready-bought fish	5	4	1	32	27	48	1	Salt/umami/fat	10.4
151	Fish sticks	6	5	1	39	23	47	1	Salt/umami/fat	7.0
152	Flounder, brill cod, saithe, haddock, tuna	4	9	2	25	22	29	1	Salt/umami/fat	20.0
153	Trout, plaice, salmon forel, swordfish	5	9	2	28	24	33	1	Salt/umami/fat	16.0
154	Seafood	5	7	1	29	26	32	1	Salt/umami/fat	16.3
155	Herring, mackerel, eel or salmon	4	8	2	28	24	33	1	Salt/umami/fat	16.3
156	Other fish	6	5	1	37	24	47	1	Salt/umami/fat	7.1
157	Piece Beer, pork steak, fried meat, skinless chicken	5	7	1	25	16	37	1	Salt/umami/fat	14.6
158	Blind finch, pork filet, chicken with skin	6	7	1	30	18	43	1	Salt/umami/fat	7.0
159	Hamburger, sausage, spare rips, shoulder	6	12	1	48	28	55	1	Salt/umami/fat	18.2
160	Sausage, pork belly	5	4	1	29	15	47	1	Salt/umami/fat	10.4
161	Smoked sausage	5	11	2	38	17	60	1	Salt/umami/fat	14.9
162	Kromesky	5	7	1	40	19	52	1	Salt/umami/fat	8.9
163	Hamburger	6	5	1	36	20	49	1	Salt/umami/fat	5.6
165	Kipburger, chicken nuggets	7	3	1	35	21	49	1	Salt/umami/fat	7.0
166	Frikadel, croquette, bamibal	9	4	1	42	15	35	1	Salt/umami/fat	14.0
167	Other meat	5	7	1	32	17	49	1	Salt/umami/fat	6.2
173	Other types of nuts to dinner meal	13	2	4	19	8	37	1	Salt/umami/fat	23.5
174	Cheese added to dinner meal	6	18	1	41	17	51	1	Salt/umami/fat	12.3
176	Peanut sauce added to dinner meal	32	9	2	41	14	60	1	Salt/umami/fat	28.6
177	Other warm sauces added to dinner meal	24	20	2	31	20	34	1	Salt/umami/fat	22.7
181	Other sauces added to dinner meal	16	34	1	29	12	61	1	Salt/umami/fat	32.0
205	Mini snack-bar product	6	3	1	30	15	45	1	Salt/umami/fat	9.4
206	Frikadel, croquette	9	4	1	42	15	35	1	Salt/umami/fat	14.0
207	Meatball or hamburger	5	7	1	38	21	51	1	Salt/umami/fat	6.7
208	Kipburger or chicken nuggets	7	3	1	35	21	49	1	Salt/umami/fat	7.0
209	French fried potatoes	9	3	0	15	7	42	1	Salt/umami/fat	25.0
210	Sausages, or cheese sandwich	9	6	1	38	19	31	1	Salt/umami/fat	15.3
211	Other small snacks like spring rolls or satay	11	6	1	36	26	51	1	Salt/umami/fat	9.2
212	Other large snacks like spring rolls or satay	11	6	1	36	26	51	1	Salt/umami/fat	9.2

Table C8 continued

Item		Mean taste intensity values (0-100)						Cluster		
#	Name	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance
213	Other type of snack	9	4	1	42	15	35	1	Salt/umami/fat	14.0
217	Peanut sauce in addition to a snack	32	9	2	41	14	60	1	Salt/umami/fat	28.6
218	Other sauce	16	34	1	29	12	61	1	Salt/umami/fat	32.0
220	Other types of nuts in between	13	2	4	19	8	37	1	Salt/umami/fat	23.5
221	Chips	10	4	1	42	19	32	1	Salt/umami/fat	16.4
222	In-between cheese snack	6	18	1	41	17	51	1	Salt/umami/fat	12.3
223	In-between sausage snack	7	7	2	42	28	59	1	Salt/umami/fat	17.2
224	Other types of meat in between	5	7	1	42	23	45	1	Salt/umami/fat	8.5
225	In-between toast with filling snack	7	7	3	40	20	61	1	Salt/umami/fat	16.3
74	Soy-based milk								Missing	
79	Soy-based drinks								Missing	
83	Soy-based dessert								Missing	
96	Water ice								Missing	
145	Dressing: only natural vinegar dressing								Missing	
164	Kidney or liver products								Missing	
168	Vegetarian burger								Missing	
169	Other meat substitutes								Missing	
170	Gravy								Missing	
175	Room added to dinner meal								Missing	

Appendix D

Supplementary tables

Chapter 5: Dietary taste patterns by sex and weight status in the Netherlands

Table D1 NEVO food group classifcation and use of GloboDiet (sub-) subfood groups to assign mean taste intensity values to untested foods.

	NEVO Food groups	# Taste clusters		GloboDiet subfood groups	GloboDiet sub-subfood groups	# Profiled foods	# Untested nevocodes DNFCS	NQplus
1	Potatoes	2	'Salt, umami & fat' &'Neutral'			7[2]	13	21
2	(Non-) alcoholic drinks	3	'Sweet & sour', 'Bitter' & 'Neutral'	*Non-alcoholic drinks*				
				Coffee, tea and herbal teas				
					Coffee	10	17	11
					Tea	2	0	0
				Waters		3	6	5
				Fruit and vegetable juices & carbonated/soft/ isotonic drinks, diluted syrups		33[1]	98	48
				Alcoholic drinks				
				Wine		4	0	0
				Beer, cider		3	4	4
				Spirits, brandy		1	7	8
3	Bread	2	'Neutral' & 'Sweet & fat'			32	41	56
4	Miscellelaneous	N/A				1	N/A	N/A
5	Eggs	1	'Neutral'			1	3	7
6	Fruit	3	'Sweet & sour', 'Neutral'& 'Sweet & fat'			19	46	58
7	Pastry, Cakes and Biscuits	2	'Sweet & fat' &'Neutral'			48	89	65
8	Cereals and cereal products	2	'Neutral' & 'Sweet & fat'			13	30	45
9	Vegetables	3	'Neutral', 'Sweet & sour' & 'Bitter'			37	95	121
10	Savoury sandwich spreads	2	'Fat' & 'Sweet & sour'			3	3	3
11	Cheese	3	'Salt, umami & fat', 'Fat' &'Neutral'			16	31	40
12	Herbs and spices	N/A				1	N/A	N/A
13	Milk and milk products	3	'Sweet & fat', 'Sweet & sour' & 'Neutral'	*Dairy products*				
				Milk		4	5	6
				Milk beverages		6	10	5
				Yogurt		15	26	24
				Fromage blanc, petits suisses		3	4	5
				Cream desserts, puddings		9	19	19
				Sugar and confectionary				
				Ice-cream		4	2	1
14	Soy products	N/A				1	N/A	N/A
15	Nuts, seeds and savoury snacks	2	'Salt, umami & fat' & 'Neutral'	*Fruits, nuts and olives*				
				Nuts and seeds		8	11	12
				Savoury snacks		31[1]	21	24

Appendix D

Table D1 continued

NEVO Food groups		# Taste clusters		GloboDiet subfood groups	GloboDiet sub-subfood groups	# Profiled foods	# Untested nevocodes DNFCS	# Untested nevocodes NQplus
16	Pulses	1	'Neutral'			2	3	10
17	Preparations	N/A				N/A	N/A	N/A
18	Mixed dishes	3	'Salt, umami & fat', 'Neutral'& 'Sweet & sour'			8[2]	13	22
19	Soups	1	'Salt, umami & fat'			9	16	14
20	Sugar, sweets, sweet spreads and sweet sauces	3	'Sweet & fat', 'Sweet & sour', 'Neutral'			37	47	42
21	Fat, oils, and savoury sauces	3	'Fat', 'Salt, umami & fat' & 'Sweet & sour'	*Fat*		21	32	26
				Sauces				
					Tomato sauces	3	5	3
					Dressing sauces	2	7	4
					Mayonnaises and similars	5	10	6
					Unclassified and other sauces	3	57	28
22	Fish	3	'Salt, umami & fat', 'Neutral' & 'Sweet & sour'			14	25	39
23	Meat, meat products and poultry	3	'Salt, umami & fat', 'Neutral' & 'Fat'	*Poultry*		1	7	5
				Meat, meat products		53[1]	80	119

[1] Remaining foods in NEVO food group; [2] Matched one-by-one with untested foods based on similarities in macronutrient and sodium content

Table D2 Mean taste intensity values for the 14 NEVO and 20 GloboDiet food groups and the classification into taste clusters

NEVO	GloboDiet				Mean taste intensity values (0-100)						Cluster	
Food group	Food group	Sub fg1	Sub fg2	Food group name	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name
3				Bread	9	3	2	13	1	11	2	Neutral
5				Eggs	5	2	1	10	8	26	2	Neutral
6				Fruit	30	22	2	3	2	10	3	Sweet/sour
7				Pastry, Cakes and Biscuits	46	3	2	10	1	31	5	Sweet/fat
8				Cereals and cereal products	18	2	2	8	1	11	2	Neutral
9				Vegetables	9	9	6	5	4	8	2	Neutral
10				Savoury sandwich spreads	23	17	2	27	8	57	1	Fat
11				Cheese	6	19	3	37	19	60	4	Salt/umami/fat
15				Nuts, seeds and savoury snacks	11	4	1	40	17	34	4	Salt/umami/fat
16				Pulses	13	4	2	24	13	15	2	Neutral
19				Soups	11	9	1	41	28	26	4	Salt/umami/fat
20				Sugar, sweets, sweet spreads and sweet sauces	58	4	5	9	1	41	5	Sweet/fat
22				Fish	4	13	2	31	26	36	4	Salt/umami/fat
23				Meat, meat products and poultry	6	7	1	39	21	50	4	Salt/umami/fat
15	4	2		Nuts and seeds	13	2	4	19	8	37	2	Neutral
13	5	1		Milk	11	13	1	3	1	21	2	Neutral
13	5	2		Milk beverages	39	6	5	5	1	27	5	Sweet/fat
13	5	3		Yogurt	30	34	2	3	1	31	3	Sweet/sour
13	5	4		Fromage blanc and petits suisses	26	34	1	2	1	39	3	Sweet/sour
13	5	6		Cream desserts and puddings	43	3	5	4	1	47	5	Sweet/fat
20	11	5	1	Ice cream	46	2	3	6	1	51	5	Sweet/fat
2	13	0/1/2		Non-alcoholic beverages	42	30	4	3	1	4	3	Sweet/sour
2	13	4		Waters	1	6	8	1	1	4	2	Neutral
2	14	1		Wine	12	43	25	1	1	1	3	Sweet/sour
2	14	3		Beer and cider	7	17	52	2	1	1	6	Bitter
2	14	4		Spirits and brandy	22	13	25	2	1	4	6	Bitter
23	7	2	1	Chicken and hen	6	7	1	18	13	29	2	Neutral
21	10			Fat and oils	3	2	2	13	4	88	1	Fat
2	13	3	1	Coffee	11	6	51	2	1	7	6	Bitter
2	13	3	2	Tea	12	5	18	1	1	2	2	Neutral
21	15	1	0	Unclassified sauces	15	16	2	47	23	55	4	Salt/umami/fat
21	15	1	1	Tomato sauces	26	29	1	34	26	30	4	Salt/umami/fat
21	15	1	2	Dressing sauces	13	49	2	41	13	66	1	Fat
21	15	1	3	Mayonnaises and similars	12	35	1	28	9	73	1	Fat

Table D3 Mean taste intensity values for the 476 profiled foods and the classification into taste clusters and NEVO and GloboDiet food groups

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
455	Peanut butter	27	2	2	24	2	69	1	Fat	26.0	10				Savoury sandwich spreads
541	Peanut butter with nut pieces	24	4	2	33	8	65	1	Fat	27.2	10				Savoury sandwich spreads
719	Cheese cream soft Mon Chou	7	15	1	21	4	79	1	Fat	2.9	11				Cheese
728	Cheese cream soft Boursin	8	32	2	40	12	69	1	Fat	28.6	11				Cheese
1487	Cheese Brie 60+	4	11	13	38	14	68	1	Fat	25.0	11				Cheese
1650	Cheese goat fresh	5	45	1	32	11	61	1	Fat	37.6	11				Cheese
2678	Dairy spread plain/herbs	9	20	1	30	19	71	1	Fat	18.4	11				Cheese
1808	Creme fraiche	4	33	1	8	2	64	1	Fat	27.6	13	5	7	1	Milk and milk products
310	Butter unsalted	3	1	0	4	1	95	1	Fat	27.7	21	10	2	0	Fat and oils
313	Oil soya	3	3	3	5	6	90	1	Fat	22.7	21	10	1	0	Fat and oils
317	Oil sunflower seed	2	1	1	4	1	91	1	Fat	25.7	21	10	1	0	Fat and oils
451	Mayonnaise	10	33	1	25	8	76	1	Fat	19.6	21	15	1	3	Mayonnaises and similars
458	Salad cream 25% oil	11	33	2	32	8	68	1	Fat	24.7	21	15	1	3	Mayonnaises and similars
465	Sauce for chips 25% oil	12	37	1	28	8	74	1	Fat	24.8	21	15	1	3	Mayonnaises and similars
601	Oil olive	1	0	17	3	1	98	1	Fat	34.3	21	10	1	0	Fat and oils
879	Butter salted	3	1	0	32	2	92	1	Fat	22.9	21	10	2	0	Fat and oils
1260	Mayonnaise yoghurt based 25% oil	15	32	1	24	7	69	1	Fat	21.9	21	15	1	3	Mayonnaises and similars
1839	Low fat margarine product tub Becel Ligh	1	1	0	3	1	78	1	Fat	23.7	21	10	3	0	Fat and oils
1847	Margarine product tub Becel Dieet	1	1	1	3	1	83	1	Fat	24.0	21	10	3	0	Fat and oils
2059	Low fat margarine 40% fat <17 g sat	3	1	0	12	2	89	1	Fat	19.9	21	10	3	0	Fat and oils
2060	Low fat margarine prod 35% fat <10 g sat	2	1	1	2	1	84	1	Fat	24.7	21	10	3	0	Fat and oils
2062	Margarine 80% fat 17-24 g saturates	4	4	0	10	2	84	1	Fat	16.8	21	10	3	0	Fat and oils
2063	Margarine 80% fat >24 g saturates	2	1	1	14	0	94	1	Fat	22.9	21	10	3	0	Fat and oils
2065	Margarine product 70% fat >17 g sat	2	2	1	14	2	84	1	Fat	16.5	21	10	3	0	Fat and oils
2066	Cooking fat liquid 97% fat <17 g sat	8	8	1	56	23	90	1	Fat	41.1	21	10	3	0	Fat and oils
2067	Cooking fat solid 97% fat >17 g sat	5	3	1	19	16	92	1	Fat	19.9	21	10	3	0	Fat and oils
2072	Margarine product 60% fat <17 g sat	2	5	1	4	2	78	1	Fat	20.3	21	10	3	0	Fat and oils
2077	Margarine liq 80% fat <17 g saturates	3	2	1	13	2	88	1	Fat	18.3	21	10	3	0	Fat and oils
2423	Low fat margarine prod Blue Band Idee	3	2	0	13	1	83	1	Fat	16.8	21	10	3	0	Fat and oils
2466	Salad dressing vinaigrette	10	56	2	41	11	66	1	Fat	48.4	21	15	1	2	Dressing sauces
2468	Salad dressing honey/mustard	15	41	2	40	14	66	1	Fat	37.0	21	15	1	2	Dressing sauces
2471	Mayonnaise product approx 35% oil	12	41	1	30	14	76	1	Fat	29.7	21	15	1	3	Mayonnaises and similars

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
2472	Oil wok average	4	1	1	9	12	91	1	Fat	22.3	21	10	1	0	Fat and oils
2558	Margarine liq 80% fat < 17g sat unsalted	3	1	1	9	1	87	1	Fat	20.7	21	10	3	0	Fat and oils
2562	Cooking fat liq 97%fat <17g sat unsalted	8	5	1	32	10	88	1	Fat	17.7	21	10	3	0	Fat and oils
2711	Margarine product AlbertHeijn Bewust	5	5	1	7	2	91	1	Fat	21.1	21	10	3	0	Fat and oils
1432	Bacon rasher fried in non-stick coating pan	4	3	4	21	9	61	1	Fat	21.7	23				Meat, meat products and poultry
982	Potatoes wo skins boiled average	5	2	1	8	7	13	2	Neutral	6.6	1				Potatoes
1456	Chips pre-fried (deep-fried)	9	3	0	15	7	42	2	Neutral	29.2	1				Potatoes
2325	Potatoes boiled with skin av	6	2	1	6	8	9	2	Neutral	8.6	1				Potatoes
411	Mineral water Spa	1	1	4	1	1	4	2	Neutral	16.7	2	13	4		Waters
645	Tea prepared	4	5	20	1	1	2	2	Neutral	23.7	2	13	3	2	Tea
747	Mineral water average	2	17	19	2	0	3	2	Neutral	26.4	2	13	4		Waters
1885	Water average	1	1	2	1	1	5	2	Neutral	16.2	2	13	4		Waters
2389	Fruit drink conc can Albert Heijn	37	5	1	2	0	1	2	Neutral	31.4	2	11	4	0	Non-alcoholic beverages
377645	Tea with sugar	20	4	16	1	0	2	2	Neutral	22.7	2	13	3	2	Tea
227	Crispbakes Dutch	12	2	1	9	1	4	2	Neutral	10.7	3				Bread
228	Crackers cream	5	1	1	8	1	7	2	Neutral	9.8	3				Bread
230	Roll white soft	8	4	2	13	1	13	2	Neutral	4.8	3				Bread
236	Bread brown wheat	4	2	2	12	0	8	2	Neutral	9.5	3				Bread
241	Bread white milk based	7	2	0	11	0	12	2	Neutral	6.5	3				Bread
246	Bread wholemeal average	4	3	2	11	1	7	2	Neutral	9.5	3				Bread
248	Bread white water based	5	2	2	11	0	9	2	Neutral	8.2	3				Bread
249	Bread wheat malt Tarvo	5	3	2	12	0	8	2	Neutral	8.8	3				Bread
565	Toast	3	1	1	9	0	4	2	Neutral	13.0	3				Bread
655	Crispbakes Dutch wholemeal	11	2	1	10	1	4	2	Neutral	10.4	3				Bread
975	Crispbread sesame	5	1	1	15	0	4	2	Neutral	12.8	3				Bread
1361	Bread white Turkish	5	2	1	14	1	11	2	Neutral	7.8	3				Bread
1779	Crispbread wholemeal	5	4	4	11	1	2	2	Neutral	13.0	3				Bread
2277	Bread Blue Band Goede Start white bread	5	2	1	11	0	9	2	Neutral	8.4	3				Bread

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
2350	Bread multigrain average w seeds	4	2	2	13	1	9	2	Neutral	8.8	3				Bread
2357	Bread wholemeal w sunflower seeds	4	2	4	14	1	9	2	Neutral	9.1	3				Bread
2369	Breadsticks	5	1	1	20	0	5	2	Neutral	14.7	3				Bread
2703	Bread wholemeal w seeds	5	5	4	14	1	9	2	Neutral	8.4	3				Bread
2707	Bread corn w sunflower seeds	7	1	1	11	1	11	2	Neutral	6.2	3				Bread
2789	Bread ciabatta no filling	6	3	1	18	1	8	2	Neutral	10.8	3				Bread
2790	Bread pita white	7	2	1	13	3	14	2	Neutral	4.9	3				Bread
2793	Baguette white	8	3	1	18	0	12	2	Neutral	9.3	3				Bread
2794	Baguette brown	6	2	1	17	0	10	2	Neutral	9.8	3				Bread
2795	Roll white hard	7	3	1	14	1	10	2	Neutral	7.0	3				Bread
2796	Roll brown hard	6	4	1	14	1	9	2	Neutral	7.9	3				Bread
2797	Roll brown soft	7	4	2	13	1	12	2	Neutral	5.4	3				Bread
2798	Roll wholemeal soft	7	3	2	16	1	10	2	Neutral	8.0	3				Bread
2803	Bun currant/raisin	26	7	2	11	1	18	2	Neutral	17.4	3				Bread
2804	Bun wholemeal w muesli	23	6	1	12	1	14	2	Neutral	13.9	3				Bread
2816	Bread Tijger white	7	2	1	13	0	12	2	Neutral	6.6	3				Bread
2818	Croissant average	13	2	1	19	1	35	2	Neutral	23.8	3				Bread
84	Eggs chicken boiled average	5	2	1	10	8	26	2	Neutral	14.2	5				Eggs
137	Olives tinned/glass	4	6	4	31	18	19	2	Neutral	26.0	6				Fruit
151	Banana	29	2	1	1	1	24	2	Neutral	24.2	6				Fruit
168	Pear without skin	30	8	1	1	1	9	2	Neutral	23.4	6				Fruit
2748	Pear with skin	30	6	1	1	1	10	2	Neutral	22.9	6				Fruit
252	Biscuit sweet	24	1	0	8	0	8	2	Neutral	16.5	7				Pastry, Cakes and Biscuits
258	Biscuits averaged	27	1	1	11	1	12	2	Neutral	17.8	7				Pastry, Cakes and Biscuits
263	Biscuit brown/wholemeal	24	1	1	10	0	8	2	Neutral	16.1	7				Pastry, Cakes and Biscuits
873	Biscuit fortifd w currants LigaEvergreen	36	3	1	13	1	11	2	Neutral	26.6	7				Pastry, Cakes and Biscuits
1481	Rice cakes puffed	3	0	1	7	1	4	2	Neutral	13.4	7				Pastry, Cakes and Biscuits
2232	Biscuit fruit	30	5	1	7	1	12	2	Neutral	20.9	7				Pastry, Cakes and Biscuits
209	Breakfast cereal Cornflakes Kellogg's	14	2	1	9	2	5	2	Neutral	10.2	8				Cereals and cereal products
225	Breakfast cereal Brinta	6	1	2	6	1	20	2	Neutral	10.0	8				Cereals and cereal products
658	Rice white boiled	3	2	2	2	4	5	2	Neutral	14.0	8				Cereals and cereal products
659	Pasta plain average boiled	3	2	1	3	1	16	2	Neutral	11.4	8				Cereals and cereal products

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
1014	Rice brown boiled	3	2	1	3	2	9	2	Neutral	11.7	8				Cereals and cereal products
2004	Breakfast cereal All-Bran Fruit n Fibre	19	2	1	10	1	5	2	Neutral	13.1	8				Cereals and cereal products
2157	Pasta wholemeal boiled	4	2	2	6	1	13	2	Neutral	8.5	8				Cereals and cereal products
2359	Wrap/Tortilla	11	1	1	11	2	14	2	Neutral	4.4	8				Cereals and cereal products
2366	Muesli crunchy plain/w fruit	35	8	1	10	1	10	2	Neutral	26.0	8				Cereals and cereal products
2675	Muesli crunchy w nuts	34	1	1	14	0	11	2	Neutral	25.1	8				Cereals and cereal products
2809	Muesli w fruit	11	4	2	4	1	5	2	Neutral	11.3	8				Cereals and cereal products
7	Endive raw	4	1	10	1	1	2	2	Neutral	18.0	9				Vegetables
8	Endive boiled	3	1	8	1	2	6	2	Neutral	15.3	9				Vegetables
15	Cauliflower boiled	6	4	3	3	4	11	2	Neutral	8.8	9				Vegetables
16	Kale curly boiled	3	1	7	2	2	4	2	Neutral	15.5	9				Vegetables
20	Mushrooms boiled	7	3	2	5	18	18	2	Neutral	15.6	9				Vegetables
26	Celeriac boiled	12	3	3	3	3	11	2	Neutral	8.3	9				Vegetables
27	Cucumber wo skin raw	7	2	2	1	1	2	2	Neutral	15.7	9				Vegetables
32	Sweet pepper green boiled	7	5	19	3	4	15	2	Neutral	18.1	9				Vegetables
37	Leek boiled	6	3	5	2	3	9	2	Neutral	10.7	9				Vegetables
46	Lettuce head raw	5	3	9	1	1	2	2	Neutral	17.2	9				Vegetables
54	Cabbage oxheart boiled	3	3	6	1	1	6	2	Neutral	14.7	9				Vegetables
55	Brussel sprouts boiled	8	2	19	5	9	7	2	Neutral	18.9	9				Vegetables
59	Bean sprouts boiled	8	6	11	2	3	6	2	Neutral	14.3	9				Vegetables
64	Onions boiled	7	4	3	2	5	12	2	Neutral	9.1	9				Vegetables
68	Chicory boiled	5	1	11	2	1	7	2	Neutral	14.9	9				Vegetables
71	Carrots raw average	15	4	2	2	2	4	2	Neutral	13.9	9				Vegetables
72	Carrots boiled average	15	2	1	2	3	10	2	Neutral	10.9	9				Vegetables
135	Pea garden super fine tinned	15	2	1	11	6	9	2	Neutral	7.4	9				Vegetables
136	Peas and carrots tinned	13	2	1	16	8	9	2	Neutral	8.9	9				Vegetables
139	Beans French tinned	7	3	3	14	6	11	2	Neutral	5.4	9				Vegetables
143	Carrots tinned	15	2	2	10	3	11	2	Neutral	6.2	9				Vegetables
146	Spinach frozen boiled	7	4	8	4	3	7	2	Neutral	11.0	9				Vegetables
650	Cabbage red w apple pieces frozen boiled	24	10	4	15	10	12	2	Neutral	17.1	9				Vegetables
651	Spinach creamed frozen boiled	6	3	2	30	10	16	2	Neutral	20.8	9				Vegetables
885	Sweet pepper red boiled	14	11	3	2	4	9	2	Neutral	12.7	9				Vegetables

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
920	Broccoli boiled	6	5	4	4	6	8	2	Neutral	9.6	9				Vegetables
951	Beans French boiled	9	3	2	4	4	9	2	Neutral	8.0	9				Vegetables
953	Peas frozen boiled	15	2	1	4	5	8	2	Neutral	10.3	9				Vegetables
966	Courgettes boiled	7	1	2	2	4	9	2	Neutral	10.5	9				Vegetables
1399	Lettuce iceberg raw	9	2	3	1	1	4	2	Neutral	14.0	9				Vegetables
2734	Tomato average raw	10	19	3	3	12	10	2	Neutral	18.9	9				Vegetables
2739	Cucumber w skin raw	6	4	4	1	1	3	2	Neutral	15.1	9				Vegetables
2741	Sweet pepper yellow boiled	16	8	2	3	3	12	2	Neutral	10.8	9				Vegetables
1955	Cheese Mozzarella	2	7	1	9	3	40	2	Neutral	28.1	11				Cheese
279	Milk whole	12	4	1	3	1	20	2	Neutral	10.9	13	5	1		Milk
286	Milk semi-skimmed	12	4	1	3	1	20	2	Neutral	10.9	13	5	1		Milk
294	Milk skimmed	14	5	1	2	1	18	2	Neutral	11.3	13	5	1		Milk
199	Cashew nuts unsalted	10	1	1	14	11	39	2	Neutral	26.8	15	4	2		Nuts and seeds
205	Mixed nuts and raisins	24	8	4	5	4	24	2	Neutral	19.0	15				Nuts, seeds and savoury snacks
206	Walnuts unsalted	5	1	12	2	6	22	2	Neutral	16.2	15	4	2		Nuts and seeds
264	Biscuit salted average	6	1	0	45	4	17	2	Neutral	35.1	15				Nuts, seeds and savoury snacks
265	Puff pastry baked	3	2	2	32	1	15	2	Neutral	23.0	15				Nuts, seeds and savoury snacks
267	Pretzel sticks	4	1	1	47	1	9	2	Neutral	37.5	15				Nuts, seeds and savoury snacks
872	Sunflower seeds	6	2	3	3	2	23	2	Neutral	13.1	15	4	2		Nuts and seeds
1937	Crisps tortilla unflavoured	5	1	1	29	4	21	2	Neutral	20.9	15				Nuts, seeds and savoury snacks
1943	Japanese rice cracker mix w peanuts	16	1	1	26	16	18	2	Neutral	21.0	15				Nuts, seeds and savoury snacks
2147	Japanese rice cracker mix wo peanuts	9	2	1	28	10	9	2	Neutral	19.1	15				Nuts, seeds and savoury snacks
2176	Pine nuts	9	2	6	8	4	40	2	Neutral	26.9	15	4	2		Nuts and seeds
197	Beans baked in tomato sauce tinned	18	6	1	28	16	17	2	Neutral	22.9	16				Pulses
660	Beans brown tinned	8	1	2	19	9	13	2	Neutral	10.3	16				Pulses
467	Pancake	15	2	1	8	2	35	2	Neutral	22.6	18				Mixed dishes
2347	Tortellini boiled	8	4	1	25	15	24	2	Neutral	21.0	18				Mixed dishes
447	Chewing gum without sugar	29	2	2	1	0	4	2	Neutral	23.8	20				Sugar, sweets, sweet spreads and sweet sauces
819	Cod boiled	2	3	2	13	12	20	2	Neutral	13.1	22				Fish
1590	Tuna in water tinned	4	16	2	25	22	19	2	Neutral	27.1	22				Fish
1610	Salmon farmed prep in microwave oven	3	9	1	18	25	27	2	Neutral	27.2	22				Fish

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
2297	Tuna (pan-fried)	4	11	1	12	10	13	2	Neutral	11.1	22				Fish
2299	Tilapia (pan-fried)	6	5	1	12	15	21	2	Neutral	13.8	22				Fish
1400	Beef rump steak (pan-fried)	5	7	1	17	18	24	2	Neutral	19.4	23				Meat, meat products and poultry
1415	Beef steak tartare (pan-fried)	4	5	1	15	10	31	2	Neutral	20.0	23				Meat, meat products and poultry
1418	Pork fillet (pan-fried)	5	9	1	16	14	30	2	Neutral	21.2	23				Meat, meat products and poultry
1420	Pork chop (pan-fried)	4	10	1	16	18	25	2	Neutral	20.6	23				Meat, meat products and poultry
1422	Pork tenderloin (pan-fried)	4	9	1	17	14	34	2	Neutral	24.9	23				Meat, meat products and poultry
1634	Chicken fillet (pan-fried)	6	7	1	18	13	29	2	Neutral	20.0	23	7	2	1	Chicken and hen
1788	Pork rib chop (pan-fried)	4	4	0	16	14	21	2	Neutral	14.9	23				Meat, meat products and poultry
1790	Pork schnitzel not breaded (pan-fried)	5	7	1	18	16	25	2	Neutral	19.0	23				Meat, meat products and poultry
383	Juice apple	35	44	2	1	0	1	3	Sweet/sour	14.8	2	13	1		Non-alcoholic beverages
395	Soft drink cola with caffeine	41	23	5	1	0	1	3	Sweet/sour	19.7	2	13	2		Non-alcoholic beverages
400	Soft drink wo caffeine	51	33	6	2	0	3	3	Sweet/sour	22.5	2	13	2		Non-alcoholic beverages
410	Juice orange pasteurized	32	42	2	1	0	2	3	Sweet/sour	12.4	2	13	1		Non-alcoholic beverages
417	Juice drink	50	33	7	2	0	4	3	Sweet/sour	21.3	2	13	2		Non-alcoholic beverages
423	Wine white dry	12	45	21	1	1	1	3	Sweet/sour	29.6	2	14	1		Wine
425	Whey drink light Rivella	35	26	7	3	1	1	3	Sweet/sour	15.4	2	13	2		Non-alcoholic beverages
1294	Whey drink Taksi w sugar	50	29	1	5	0	3	3	Sweet/sour	22.2	2	13	2		Non-alcoholic beverages
1463	Fruit juice dk minimal 2 fruits	51	34	3	3	0	7	3	Sweet/sour	20.9	2	13	1		Non-alcoholic beverages
1523	Cola light soft drink with caffeine	46	20	3	1	0	1	3	Sweet/sour	24.5	2	13	2		Non-alcoholic beverages
1655	Fruit juice concentrated	62	46	0	0	0	6	3	Sweet/sour	33.9	2	11	4	0	Non-alcoholic beverages
1810	Fruit drink concentrate Karvan Cevitam	42	8	1	2	0	2	3	Sweet/sour	31.4	2	11	4	0	Non-alcoholic beverages
1878	Fruit juice drink Roosvicee Multivit	39	35	1	2	0	1	3	Sweet/sour	14.0	2	13	1		Non-alcoholic beverages

Appendix D

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
1932	Juice orange with pulp	21	50	5	2	0	4	3	Sweet/sour	19.4	2	13	1		Non-alcoholic beverages
2042	Sports drink AA High Energy	56	19	1	5	0	3	3	Sweet/sour	31.5	2	13	2		Non-alcoholic beverages
2079	Breakfast drink HeroFruitontbijt p 100ml	39	32	1	2	0	11	3	Sweet/sour	9.7	2	13	1		Non-alcoholic beverages
2086	Ice tea	39	29	4	3	2	5	3	Sweet/sour	12.5	2	13	2		Non-alcoholic beverages
2134	Juice drink Dubbelfrisss	37	23	1	2	0	4	3	Sweet/sour	16.3	2	13	2		Non-alcoholic beverages
2135	Juice drink Vruchtenfris/Tintelfruit	37	35	1	2	0	1	3	Sweet/sour	12.9	2	13	2		Non-alcoholic beverages
2136	Lemonade squash Dubbelfrisss light	33	31	1	1	0	1	3	Sweet/sour	12.6	2	13	2		Non-alcoholic beverages
2138	Juice drink Spa&Fruit still	36	19	0	3	0	2	3	Sweet/sour	20.2	2	13	2		Non-alcoholic beverages
2142	Wine white sweet	16	38	18	2	1	1	3	Sweet/sour	23.6	2	14	1		Wine
2434	Juice drink Wicky	43	32	1	4	0	2	3	Sweet/sour	16.2	2	13	1		Non-alcoholic beverages
2436	Juice drink w sugar & sw	53	24	3	2	0	4	3	Sweet/sour	26.3	2	13	2		Non-alcoholic beverages
2480	Energy drink Golden Power/Bullit	42	33	5	2	0	1	3	Sweet/sour	16.0	2	13	2		Non-alcoholic beverages
2507	Juice multifruit	40	30	3	1	0	2	3	Sweet/sour	14.9	2	13	1		Non-alcoholic beverages
2610	Wine rose	13	43	24	1	1	1	3	Sweet/sour	30.3	2	14	1		Wine
2634	Fruit juice dk minimal 2 fruits w vit C	43	26	1	2	0	4	3	Sweet/sour	17.6	2	13	1		Non-alcoholic beverages
2639	Smoothie fruit	37	39	3	4	0	15	3	Sweet/sour	8.0	2	13	1		Non-alcoholic beverages
2672	Energy drink Red Bull/Euroshopper/Rodeo	55	39	10	3	0	4	3	Sweet/sour	26.6	2	13	2		Non-alcoholic beverages
2755	Juice orange freshly squeezed	31	61	11	2	0	6	3	Sweet/sour	27.4	2	13	1		Non-alcoholic beverages
147	Apple without skin average	20	38	2	1	0	4	3	Sweet/sour	14.0	6				Fruit
148	Strawberries	18	34	1	1	0	8	3	Sweet/sour	14.1	6				Fruit
150	Pineapple	34	34	1	2	0	5	3	Sweet/sour	8.4	6				Fruit
160	Grapes with skin average	30	25	2	1	0	5	3	Sweet/sour	13.0	6				Fruit
165	Manderins	26	31	3	1	1	4	3	Sweet/sour	10.6	6				Fruit
171	Orange	19	47	8	1	0	3	3	Sweet/sour	19.5	6				Fruit
177	Pineapple in syrup tinned	38	20	0	3	0	6	3	Sweet/sour	18.4	6				Fruit
179	Apple sauce tinned	46	21	0	2	2	13	3	Sweet/sour	21.5	6				Fruit
183	Fruit cocktail in syrup tinned	37	10	0	2	1	9	3	Sweet/sour	26.7	6				Fruit
189	Peaches in syrup tinned	31	14	2	2	1	9	3	Sweet/sour	21.8	6				Fruit
875	Apple with skin average	22	40	1	1	1	3	3	Sweet/sour	13.8	6				Fruit
1056	Kiwi fruit	19	51	4	1	0	7	3	Sweet/sour	20.4	6				Fruit
1321	Biscuit fortified Liga Fruitkick	33	18	0	10	0	16	3	Sweet/sour	19.3	7				Pastry, Cakes and Biscuits
74	Cabbage sauerkraut cooked	6	70	4	17	2	4	3	Sweet/sour	45.0	9				Vegetables
132	Gherkins sweet pickled	12	69	1	9	2	7	3	Sweet/sour	39.1	9				Vegetables

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
144	Silver-skin onions sweet pickled glass	10	53	2	12	2	10	3	Sweet/sour	28.3	9				Vegetables
575	Sandwich spread original	19	45	1	24	13	36	3	Sweet/sour	36.7	10				Savoury sandwich spreads
278	Yoghurt full fat	2	71	2	3	1	28	3	Sweet/sour	48.6	13	5	3		Yogurt
289	Buttermilk	6	37	1	5	2	24	3	Sweet/sour	27.8	13	5	1		Milk
301	Yoghurt low fat	2	67	2	3	1	25	3	Sweet/sour	44.8	13	5	3		Yogurt
305	Fromage frais low fat	2	51	1	0	1	35	3	Sweet/sour	40.5	13	5	4		Fromage blanc and petits suisses
657	Yoghurt drink	32	27	1	4	1	29	3	Sweet/sour	19.5	13	5	3		Yogurt
931	Fromage frais low fat with fruit	29	29	1	3	0	37	3	Sweet/sour	26.4	13	5	4		Fromage blanc and petits suisses
1502	Yoghurt half fat	6	49	2	1	1	27	3	Sweet/sour	32.3	13	5	3		Yogurt
1721	Yoghurt vanilla half fat	26	27	0	4	1	35	3	Sweet/sour	25.5	13	5	3		Yogurt
1813	Yakult	50	38	3	3	3	13	3	Sweet/sour	19.6	13	5	3		Yogurt
1832	Yoghurt drink Vifit fruit	34	27	0	4	1	26	3	Sweet/sour	17.3	13	5	3		Yogurt
1833	Yoghurt l fat w fruit/van w sw Optimel	33	32	1	5	1	33	3	Sweet/sour	21.9	13	5	3		Yogurt
1834	Yoghurt drink w sweeteners Optimel	42	27	2	2	1	24	3	Sweet/sour	18.9	13	5	3		Yogurt
2052	Dairy dr Milk&Fruit strawberry-cherry	31	26	2	5	1	20	3	Sweet/sour	12.7	13	5	2		Milk beverages
2257	Breakfast drink Goede Morgen original	30	24	1	3	1	30	3	Sweet/sour	21.8	13	5	3		Yogurt
1486	Mashed potatoes with cabbage sauerkraut	4	48	3	28	4	31	3	Sweet/sour	42.6	18				Mixed dishes
450	Boiled sweets	46	19	2	2	0	7	3	Sweet/sour	23.1	20				Sugar, sweets, sweet spreads and sweet sauces
462	Ketchup tomato	28	42	1	29	22	27	3	Sweet/sour	36.4	21	15	1	1	Tomato sauces
1100	Herring pickled (sweet)sour	4	73	3	36	18	39	3	Sweet/sour	64.4	22				Fish
121	Potatoes mashed prep w semi-sk milk+margarine	7	3	1	44	15	36	4	Salt/umami/fat	13.9	1				Potatoes
948	Rosti prepared without fat	9	3	1	35	15	29	4	Salt/umami/fat	20.3	1				Potatoes
1150	Potatoes sliced frozen (pan-fried)	6	1	1	26	13	45	4	Salt/umami/fat	20.5	1				Potatoes
2834	Potato waffels/balls frozen (deep-fried)	7	3	1	40	13	45	4	Salt/umami/fat	11.9	1				Potatoes
413	Tomato juice	10	23	1	32	33	14	4	Salt/umami/fat	37.1	2	13	1		Non-alcoholic beverages
441	Yeast extract Marmite	11	23	23	62	64	19	4	Salt/umami/fat	58.7	4				Miscellelaneous
511	Cheese Edam 40+	4	21	3	45	16	50	4	Salt/umami/fat	15.8	11				Cheese
513	Cheese Gouda 48+ average	6	18	1	41	17	51	4	Salt/umami/fat	12.6	11				Cheese
515	Cheese spread 48+	6	22	5	55	18	67	4	Salt/umami/fat	29.3	11				Cheese

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
517	Cheese spread 20+	4	14	5	41	30	70	4	Salt/umami/fat	26.8	11				Cheese
804	Cheese sheep fresh	4	10	1	38	44	53	4	Salt/umami/fat	23.1	11				Cheese
1302	Cheese cream soft Paturain	6	27	1	50	17	65	4	Salt/umami/fat	28.7	11				Cheese
1382	Cheese 30+	7	16	2	40	18	46	4	Salt/umami/fat	9.0	11				Cheese
1723	Cheese 20+	5	14	1	39	21	55	4	Salt/umami/fat	12.0	11				Cheese
1725	Cheese Leerdammer/Maasdammer 45+	6	10	2	29	28	50	4	Salt/umami/fat	14.8	11				Cheese
2518	Cheese goat hard	9	22	2	37	24	62	4	Salt/umami/fat	21.8	11				Cheese
824	Mustard	6	47	10	37	5	31	4	Salt/umami/fat	45.6	12				Herbs and spices
1215	Soya sauce sweet	42	9	4	61	27	17	4	Salt/umami/fat	48.1	14				Soy products
122	Crisps potato average	11	5	1	43	17	30	4	Salt/umami/fat	17.1	15				Nuts, seeds and savoury snacks
266	Snack sausage roll puff pastry	7	4	1	45	17	55	4	Salt/umami/fat	13.0	15				Nuts, seeds and savoury snacks
269	Prawn crackers	12	1	0	29	26	33	4	Salt/umami/fat	20.0	15				Nuts, seeds and savoury snacks
546	Peanuts coated	11	3	2	43	24	43	4	Salt/umami/fat	7.0	15	4	2		Nuts and seeds
618	Cocktail snacks Nibbits	7	3	0	42	26	39	4	Salt/umami/fat	9.4	15				Nuts, seeds and savoury snacks
876	Peanuts salted	8	1	2	40	7	45	4	Salt/umami/fat	18.0	15	4	2		Nuts and seeds
901	Snack sausage roll w bread dough pastry	9	6	1	38	19	31	4	Salt/umami/fat	15.6	15				Nuts, seeds and savoury snacks
1488	Pastry puff cheese filled (deep-fried)	6	10	1	54	23	62	4	Salt/umami/fat	20.9	15				Nuts, seeds and savoury snacks
1505	Crisps potato light unflavoured	8	2	0	57	6	40	4	Salt/umami/fat	24.5	15				Nuts, seeds and savoury snacks
1699	Biscuits & snacks cheesy averaged	6	2	0	41	8	24	4	Salt/umami/fat	27.1	15				Nuts, seeds and savoury snacks
1935	Nuts mixed salted	12	1	4	32	11	41	4	Salt/umami/fat	18.5	15	4	2		Nuts and seeds
2163	Crisps maize Bugles	13	3	0	46	19	30	4	Salt/umami/fat	18.0	15				Nuts, seeds and savoury snacks
2362	Sausage Dutch Frikandel frozen (deep-fried)	9	5	1	45	21	55	4	Salt/umami/fat	11.2	15				Nuts, seeds and savoury snacks
2370	Cocktail snacks based on corn or wheat	12	8	1	55	37	49	4	Salt/umami/fat	19.9	15				Nuts, seeds and savoury snacks
2527	Biscuit savoury Sultana	10	4	1	42	24	15	4	Salt/umami/fat	30.7	15				Nuts, seeds and savoury snacks
2529	Potato crisps oven baked	15	8	1	44	18	31	4	Salt/umami/fat	16.7	15				Nuts, seeds and savoury snacks
2547	Chines noodle ball (deep-fried)	9	3	1	45	37	54	4	Salt/umami/fat	17.8	15				Nuts, seeds and savoury snacks
2548	Croquette meat ragout frozen (deep-fried)	9	6	1	44	25	63	4	Salt/umami/fat	18.2	15				Nuts, seeds and savoury snacks
2549	Springroll frozen (deep-fried)	11	6	1	36	26	51	4	Salt/umami/fat	9.5	15				Nuts, seeds and savoury snacks
2551	Croissant w ham and cheese	10	4	1	38	16	43	4	Salt/umami/fat	9.8	15				Nuts, seeds and savoury snacks

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
2617	Bread stuffed Bapao meat	18	6	0	35	25	36	4	Salt/umami/fat	15.4	15				Nuts, seeds and savoury snacks
2706	Cassave crackers	15	1	1	31	19	29	4	Salt/umami/fat	22.4	15				Nuts, seeds and savoury snacks
2923	Crisps potato unflavoured	4	4	1	48	8	25	4	Salt/umami/fat	26.8	15				Nuts, seeds and savoury snacks
2924	Crisps potato flavoured	11	7	1	47	26	40	4	Salt/umami/fat	8.6	15				Nuts, seeds and savoury snacks
2926	Crisps potato light flavoured	12	7	0	47	17	44	4	Salt/umami/fat	9.1	15				Nuts, seeds and savoury snacks
2929	Crisps potato Lays Sensations flavoured	12	4	0	54	14	38	4	Salt/umami/fat	17.9	15				Nuts, seeds and savoury snacks
646	Spaghetti Bolognese	9	11	0	29	25	37	4	Salt/umami/fat	15.6	18				Mixed dishes
1483	Mashed potatoes with kale without meat	6	6	3	41	13	30	4	Salt/umami/fat	18.7	18				Mixed dishes
1485	Mashed potatoes with carrots and onions	10	6	1	37	11	34	4	Salt/umami/fat	17.5	18				Mixed dishes
1491	Lasagne bolognese	12	8	1	42	32	55	4	Salt/umami/fat	13.7	18				Mixed dishes
1837	Nasi	6	2	1	39	27	38	4	Salt/umami/fat	11.4	18				Mixed dishes
1914	Pizza margherita	16	4	1	35	15	35	4	Salt/umami/fat	17.2	18				Mixed dishes
761	Soup clear with meat and vegetables	12	3	1	37	37	24	4	Salt/umami/fat	26.8	19				Soups
762	Soup clear w meat vegetables and noodles	7	7	1	42	21	22	4	Salt/umami/fat	23.5	19				Soups
766	Soup main course w legumes and meat	6	8	2	40	22	40	4	Salt/umami/fat	6.3	19				Soups
792	Soup thickened w meat and vegetables	19	22	1	32	32	20	4	Salt/umami/fat	33.1	19				Soups
797	Soup vegetable based dried packet prep	8	3	1	45	31	23	4	Salt/umami/fat	24.6	19				Soups
800	Soup vegetable based tinned prepared	19	16	1	32	27	26	4	Salt/umami/fat	25.4	19				Soups
802	Soup legume based ready made prepared	7	10	2	44	20	37	4	Salt/umami/fat	9.3	19				Soups
1528	Stock from cube prepared	7	3	1	57	41	21	4	Salt/umami/fat	34.4	19				Soups
2932	Soup cup-a-soup prepared	10	6	3	39	21	25	4	Salt/umami/fat	20.9	19				Soups
584	Ketchup curry	31	22	1	33	22	32	4	Salt/umami/fat	30.6	21	15	1	1	Tomato sauces
616	Peanut sauce jar prepared	32	9	2	41	14	60	4	Salt/umami/fat	29.2	21	15	1	0	Unclassified sauces
1524	Sauce tomato ready made jar	20	24	1	39	33	31	4	Salt/umami/fat	25.9	21	15	1	1	Tomato sauces
2178	Pesto	5	12	2	57	23	54	4	Salt/umami/fat	18.1	21	15	1	0	Unclassified sauces
2612	Tapenade olive	9	26	1	43	32	52	4	Salt/umami/fat	20.5	21	15	1	0	Unclassified sauces
348	Shrimps Dutch peeled boiled	8	4	1	33	31	31	4	Salt/umami/fat	19.2	22				Fish
350	Herring salted	3	11	2	50	40	58	4	Salt/umami/fat	23.5	22				Fish
602	Salmon tinned	4	8	2	26	28	32	4	Salt/umami/fat	21.7	22				Fish
814	Fish fingers fried	6	4	1	41	23	51	4	Salt/umami/fat	8.0	22				Fish
818	White fish fillet in batter deep-fried	5	4	1	32	27	48	4	Salt/umami/fat	12.5	22				Fish
1096	Salmon smoked	3	10	1	53	36	57	4	Salt/umami/fat	21.5	22				Fish

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
1586	Mackerel fillet smoked	3	8	1	42	44	52	4	Salt/umami/fat	22.7	22				Fish
1589	Tuna in oil tinned	3	19	2	37	31	36	4	Salt/umami/fat	17.4	22				Fish
106	Duck whole fried in non-stick coating pan	4	7	2	16	27	37	4	Salt/umami/fat	27.8	23				Meat, meat products and poultry
319	Corned beef	4	8	1	43	23	44	4	Salt/umami/fat	4.9	23				Meat, meat products and poultry
324	Sausage smoked cooked average	6	20	1	42	18	59	4	Salt/umami/fat	18.5	23				Meat, meat products and poultry
328	Ham smoked raw	3	4	1	65	27	57	4	Salt/umami/fat	27.3	23				Meat, meat products and poultry
335	Liver pate	8	8	1	46	20	65	4	Salt/umami/fat	20.4	23				Meat, meat products and poultry
336	Luncheon meat tinned	8	8	1	37	24	49	4	Salt/umami/fat	6.3	23				Meat, meat products and poultry
340	Beef smoke-dried	2	8	0	59	19	38	4	Salt/umami/fat	20.2	23				Meat, meat products and poultry
566	Sausage frankfurter tinned	6	12	1	48	28	55	4	Salt/umami/fat	13.2	23				Meat, meat products and poultry
567	Sausage luncheon meat	4	8	1	37	19	49	4	Salt/umami/fat	8.6	23				Meat, meat products and poultry
638	Salami sausage saveloy	3	14	1	47	20	58	4	Salt/umami/fat	15.9	23				Meat, meat products and poultry
639	Bacon rashers streaky	4	6	0	53	21	76	4	Salt/umami/fat	33.2	23				Meat, meat products and poultry
640	Liver sausage	7	3	2	41	32	63	4	Salt/umami/fat	20.8	23				Meat, meat products and poultry
642	Pate	15	6	2	46	26	66	4	Salt/umami/fat	22.5	23				Meat, meat products and poultry
783	Sausage with smoked bacon-bits	7	9	0	44	32	62	4	Salt/umami/fat	19.2	23				Meat, meat products and poultry
784	Ham lean boiled	5	5	0	46	31	41	4	Salt/umami/fat	11.4	23				Meat, meat products and poultry
785	Ham shoulder medium fat boiled	8	6	1	45	23	39	4	Salt/umami/fat	7.7	23				Meat, meat products and poultry
810	Beef steak tartare spiced filet americ	8	5	0	41	19	51	4	Salt/umami/fat	8.2	23				Meat, meat products and poultry
1152	Salami	3	19	1	51	21	56	4	Salt/umami/fat	18.3	23				Meat, meat products and poultry
1155	Minced meat loaf fried	4	6	1	38	21	50	4	Salt/umami/fat	8.4	23				Meat, meat products and poultry
1162	Sausage cooked	3	5	0	37	23	47	4	Salt/umami/fat	8.6	23				Meat, meat products and poultry
1239	Liver pate sausage	5	6	4	40	19	63	4	Salt/umami/fat	19.0	23				Meat, meat products and poultry
1405	Minced beef (pan-fried)	4	3	1	22	11	49	4	Salt/umami/fat	24.6	23				Meat, meat products and poultry
1417	Sausage pork Braadworst (pan-fried)	6	6	0	54	24	67	4	Salt/umami/fat	25.3	23				Meat, meat products and poultry
1425	Pork shoulder chop (pan-fried)	4	2	0	24	12	47	4	Salt/umami/fat	22.6	23				Meat, meat products and poultry
1431	Kromesky meat filled (pan-fried)	7	4	1	48	19	60	4	Salt/umami/fat	17.3	23				Meat, meat products and poultry

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
1434	Minced beef/pork (pan-fried)	4	2	1	24	12	45	4	Salt/umami/fat	22.5	23				Meat, meat products and poultry
1435	Hamburger (pan-fried)	9	5	1	46	31	54	4	Salt/umami/fat	13.2	23				Meat, meat products and poultry
1643	Chicken nuggets prepared in oven	7	3	1	35	21	49	4	Salt/umami/fat	10.1	23				Meat, meat products and poultry
1771	Liver pate/Berliner liver sausage	7	11	2	31	27	59	4	Salt/umami/fat	18.1	23				Meat, meat products and poultry
1776	Ham lean grilled	4	9	1	43	26	40	4	Salt/umami/fat	7.6	23				Meat, meat products and poultry
2300	Sausage smoked lean cooked	3	21	1	51	23	54	4	Salt/umami/fat	18.3	23				Meat, meat products and poultry
2301	Sausage smoked beef cooked	4	23	1	56	27	62	4	Salt/umami/fat	26.7	23				Meat, meat products and poultry
2334	Minced meat beef/pork w egg/brcrumbs (meatball)	9	7	1	43	24	57	4	Salt/umami/fat	12.0	23				Meat, meat products and poultry
2339	Beef olives (pan-fried)	6	8	1	47	19	55	4	Salt/umami/fat	12.0	23				Meat, meat products and poultry
2340	Pork schnitzel breaded (pan-fried)	5	1	1	37	10	46	4	Salt/umami/fat	16.4	23				Meat, meat products and poultry
2363	Minced meat w ham and cheese (pan-fried)	4	6	1	41	29	55	4	Salt/umami/fat	12.6	23				Meat, meat products and poultry
2364	Chicken schnitzel (pan-fried)	6	2	1	35	13	42	4	Salt/umami/fat	14.6	23				Meat, meat products and poultry
2365	Chicken cordon bleu (pan-fried)	5	7	1	46	28	60	4	Salt/umami/fat	16.6	23				Meat, meat products and poultry
2654	Sandwich meat chicken	4	6	1	37	17	26	4	Salt/umami/fat	21.4	23				Meat, meat products and poultry
2768	Sausage raw beef	5	13	3	42	21	64	4	Salt/umami/fat	19.6	23				Meat, meat products and poultry
2997	Sausage grill	6	8	0	39	21	63	4	Salt/umami/fat	18.3	23				Meat, meat products and poultry
3025	Bacon lean smoked (pan-fried)	6	6	0	67	15	61	4	Salt/umami/fat	31.0	23				Meat, meat products and poultry
3027	Pork shoarma seasoning (pan-fried)	11	3	0	50	32	59	4	Salt/umami/fat	19.5	23				Meat, meat products and poultry
3030	Sausage beef Braadworst (pan-fried)	5	4	1	48	19	58	4	Salt/umami/fat	15.9	23				Meat, meat products and poultry
3031	Pork sparerib (oven)	15	2	0	38	29	53	4	Salt/umami/fat	14.2	23				Meat, meat products and poultry
463	Fruit drink concentrate undiluted	70	15	1	2	0	5	5	Sweet/fat	39.7	2	11	4	0	Non-alcoholic beverages
497	Fruit drink concentrate fruitmix	65	18	0	0	0	5	5	Sweet/fat	38.9	2	11	4	0	Non-alcoholic beverages
2355	Bread white w sugar Suikerbrood	51	3	1	12	0	37	5	Sweet/fat	4.9	3				Bread

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
33	Raisins dried	51	11	0	2	1	13	5	Sweet/fat	26.2	6				Fruit
1887	Dates fresh	46	3	0	2	1	19	5	Sweet/fat	20.4	6				Fruit
2379	Raisins soaked in water	48	15	0	3	1	17	5	Sweet/fat	23.8	6				Fruit
240	Cake Dutch spiced Ontbijtkoek	42	2	5	8	1	22	5	Sweet/fat	18.0	7				Pastry, Cakes and Biscuits
251	Apple pie Dutch w shortbread w marg	54	14	1	11	2	47	5	Sweet/fat	14.2	7				Pastry, Cakes and Biscuits
254	Cake sponge Dutch Eierkoek	38	1	1	7	1	18	5	Sweet/fat	23.6	7				Pastry, Cakes and Biscuits
255	Gateau with whipped cream	48	3	0	7	1	51	5	Sweet/fat	14.4	7				Pastry, Cakes and Biscuits
257	Almond paste filled tarts average	56	1	2	9	1	37	5	Sweet/fat	6.8	7				Pastry, Cakes and Biscuits
259	Macaroons	58	1	1	9	1	28	5	Sweet/fat	12.8	7				Pastry, Cakes and Biscuits
260	Biscuit sponge fingers	51	0	0	7	0	11	5	Sweet/fat	27.1	7				Pastry, Cakes and Biscuits
261	Biscuit spiced Speculaas	39	1	1	11	1	13	5	Sweet/fat	27.6	7				Pastry, Cakes and Biscuits
262	Biscuit Dutch shortbread spritsstukken	38	1	1	15	0	27	5	Sweet/fat	18.3	7				Pastry, Cakes and Biscuits
468	Cream slice Dutch Tompouce	54	2	0	4	1	40	5	Sweet/fat	7.5	7				Pastry, Cakes and Biscuits
480	Biscuit chocolate coated Chocoprins	59	1	4	13	1	41	5	Sweet/fat	11.0	7				Pastry, Cakes and Biscuits
481	Biscuit shortbread Bastogne	51	0	3	11	2	23	5	Sweet/fat	15.5	7				Pastry, Cakes and Biscuits
486	Flan with fruit filling	46	32	1	11	0	35	5	Sweet/fat	27.9	7				Pastry, Cakes and Biscuits
489	Flan filled with rice pudding	35	1	0	13	2	44	5	Sweet/fat	18.4	7				Pastry, Cakes and Biscuits
633	Meringue cake Bokkenpootje	57	1	5	8	0	40	5	Sweet/fat	8.1	7				Pastry, Cakes and Biscuits
635	Biscuits Dutch krakeling	53	0	0	11	0	24	5	Sweet/fat	15.1	7				Pastry, Cakes and Biscuits
713	Waffle syrup average	56	1	1	8	1	30	5	Sweet/fat	10.2	7				Pastry, Cakes and Biscuits
789	Cake butter Dutch Boterkoek	52	2	0	18	0	58	5	Sweet/fat	23.3	7				Pastry, Cakes and Biscuits
854	Gateau fatless sponge w fruit & cream	46	13	1	7	0	45	5	Sweet/fat	12.4	7				Pastry, Cakes and Biscuits
855	Biscuit spiced Speculaas w almnd paste	60	1	3	15	0	47	5	Sweet/fat	15.5	7				Pastry, Cakes and Biscuits
925	Cake Dutch spiced Ontbijtkoek wholemeal	41	1	2	9	1	17	5	Sweet/fat	23.0	7				Pastry, Cakes and Biscuits
1471	Biscuit chocolate	35	1	8	13	0	23	5	Sweet/fat	22.6	7				Pastry, Cakes and Biscuits
1473	Doughnuts plain	44	1	1	12	1	49	5	Sweet/fat	14.6	7				Pastry, Cakes and Biscuits
1475	Eclair with whipped cream filling	44	1	0	8	1	47	5	Sweet/fat	12.7	7				Pastry, Cakes and Biscuits
1965	Biscuit fortified Liga Milkbreak	36	2	1	14	1	20	5	Sweet/fat	23.8	7				Pastry, Cakes and Biscuits
2227	Biscuit filled Prince	47	1	0	13	0	24	5	Sweet/fat	15.6	7				Pastry, Cakes and Biscuits
2233	Cake Dutch spiced Ontbijtkoek w raisin	45	6	5	10	1	31	5	Sweet/fat	8.9	7				Pastry, Cakes and Biscuits
2393	Cake raisins-	46	1	0	11	0	44	5	Sweet/fat	10.0	7				Pastry, Cakes and Biscuits
2395	Chocolate eclair	56	3	5	9	1	62	5	Sweet/fat	25.3	7				Pastry, Cakes and Biscuits

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
2398	Cake Dutchspiced Ontbijtkoek w rockcandy	52	1	3	11	3	21	5	Sweet/fat	17.3	7				Pastry, Cakes and Biscuits
2401	Tarts filled with jam	61	10	2	11	1	41	5	Sweet/fat	12.5	7				Pastry, Cakes and Biscuits
2403	Cup cake iced	70	2	1	8	0	38	5	Sweet/fat	19.7	7				Pastry, Cakes and Biscuits
2405	Chocolate chip cookie	47	0	4	13	0	29	5	Sweet/fat	11.5	7				Pastry, Cakes and Biscuits
2413	Cake wrapped in marzipan and chocolate	70	2	6	5	1	56	5	Sweet/fat	27.3	7				Pastry, Cakes and Biscuits
2560	Apple turnover	62	6	1	12	1	33	5	Sweet/fat	13.0	7				Pastry, Cakes and Biscuits
2661	Waffle Luikse	47	1	0	8	0	24	5	Sweet/fat	14.8	7				Pastry, Cakes and Biscuits
2662	Waffle soft-/sugar-/flash-	49	1	0	9	0	28	5	Sweet/fat	10.9	7				Pastry, Cakes and Biscuits
2696	Biscuit Dutch Amaretti Bitterkoekjes	50	1	12	10	1	27	5	Sweet/fat	14.2	7				Pastry, Cakes and Biscuits
2698	Cake chocolate made wo butter	39	1	3	7	1	29	5	Sweet/fat	14.9	7				Pastry, Cakes and Biscuits
2776	Flan apple and crumble topping	49	15	1	11	0	42	5	Sweet/fat	11.9	7				Pastry, Cakes and Biscuits
2832	Cake chocolate made w butter	44	1	9	11	0	40	5	Sweet/fat	10.3	7				Pastry, Cakes and Biscuits
2002	Breakfast prod Coco Pops Kellogg's	41	1	5	12	0	13	5	Sweet/fat	26.9	8				Cereals and cereal products
2676	Muesli crunchy w chocolate	45	0	3	12	0	17	5	Sweet/fat	22.1	8				Cereals and cereal products
272	Milk chocolate-flavoured full fat	37	2	7	6	0	39	5	Sweet/fat	14.7	13	5	2		Milk beverages
276	Custard chocolate full fat	34	1	6	4	1	40	5	Sweet/fat	18.0	13	5	6		Cream desserts and puddings
282	Custard vanilla full fat	33	3	1	2	1	39	5	Sweet/fat	19.0	13	5	6		Cream desserts and puddings
284	Yoghurt low fat with fruit	42	24	1	2	1	33	5	Sweet/fat	22.5	13	5	3		Yogurt
736	Pudding vanilla	48	2	0	4	0	51	5	Sweet/fat	15.2	13	5	6		Cream desserts and puddings
767	Mousse chocolate	46	1	14	3	1	49	5	Sweet/fat	17.6	13	5	6		Cream desserts and puddings
863	Yoghurt full fat with fruit	40	28	1	4	1	42	5	Sweet/fat	26.3	13	5	3		Yogurt
915	Chocolate pudding with sauce	42	1	9	5	0	48	5	Sweet/fat	15.6	13	5	6		Cream desserts and puddings
917	Fromage frais half fat w fruit	48	22	1	3	1	45	5	Sweet/fat	19.8	13	5	4		Fromage blanc and petits suisses
938	Pudding semolina with red currant sauce	46	10	2	6	3	46	5	Sweet/fat	11.5	13	5	6		Cream desserts and puddings
1464	Milk chocolate-flavoured semi-skimmed	42	4	7	5	1	35	5	Sweet/fat	10.2	13	5	2		Milk beverages
1720	Custard several flavours full fat	36	3	8	4	1	42	5	Sweet/fat	16.7	13	5	6		Cream desserts and puddings
1916	Cream whipped with added sugar	49	2	0	2	1	51	5	Sweet/fat	15.7	13	5	7	1	Milk and milk products
1970	Milk chocolate-flavoured Chocomel light	40	1	8	6	1	35	5	Sweet/fat	12.6	13	5	2		Milk beverages
2244	Yoghurt cream- with fruit	40	27	1	2	1	44	5	Sweet/fat	26.3	13	5	3		Yogurt
2278	Yoghurt full fat w fruit/muesli Activia	34	20	2	4	1	37	5	Sweet/fat	22.9	13	5	3		Yogurt
2496	Dairy drink Campina fruitmilk	35	1	0	4	2	18	5	Sweet/fat	25.8	13	5	2		Milk beverages
2520	Pudding airy average	63	9	2	8	5	55	5	Sweet/fat	22.3	13	5	6		Cream desserts and puddings

Appendix D

Table D3 continued

Food code	Product description	Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
		Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
2539	Custard soft & airy Campina	42	0	0	4	1	49	5	Sweet/fat	16.2	13	5	6		Cream desserts and puddings
2760	Hot chocolate from vending machine	48	2	8	5	0	14	5	Sweet/fat	24.4	13	5	2		Milk beverages
2823	Yoghurt full fat stracciatella	31	25	5	5	1	43	5	Sweet/fat	28.9	13	5	3		Yogurt
2345	Peanuts sugar coated	42	1	4	11	2	41	5	Sweet/fat	10.6	15	4	2		Nuts and seeds
2387	Popcorn sweet puffed	43	2	1	8	1	21	5	Sweet/fat	18.5	15				Nuts, seeds and savoury snacks
303	Ice cream dairy cream based	48	2	0	5	0	52	5	Sweet/fat	15.8	20	11	5	1	Ice cream
427	Syrup apple	64	29	3	6	1	28	5	Sweet/fat	29.3	20				Sugar, sweets, sweet spreads and sweet sauces
431	Chocolate milk	55	1	5	7	0	66	5	Sweet/fat	29.2	20				Sugar, sweets, sweet spreads and sweet sauces
432	Chocolate plain	44	6	39	4	1	58	5	Sweet/fat	41.9	20				Sugar, sweets, sweet spreads and sweet sauces
433	Chocolate flakes milk	60	1	6	3	0	34	5	Sweet/fat	12.2	20				Sugar, sweets, sweet spreads and sweet sauces
435	Chocolate flakes plain	52	0	10	6	0	37	5	Sweet/fat	8.6	20				Sugar, sweets, sweet spreads and sweet sauces
436	Spread chocolate hazelnut	63	1	3	9	3	69	5	Sweet/fat	34.2	20				Sugar, sweets, sweet spreads and sweet sauces
442	Coloured confetti fruit-flavoured	69	3	0	3	0	12	5	Sweet/fat	32.0	20				Sugar, sweets, sweet spreads and sweet sauces
443	Honey	76	1	3	4	0	29	5	Sweet/fat	27.3	20				Sugar, sweets, sweet spreads and sweet sauces
444	Spread chocolade plain	66	1	8	9	0	69	5	Sweet/fat	35.6	20				Sugar, sweets, sweet spreads and sweet sauces
445	Jam	74	19	1	3	0	27	5	Sweet/fat	29.8	20				Sugar, sweets, sweet spreads and sweet sauces
453	Peppermint	44	0	1	5	0	2	5	Sweet/fat	36.6	20				Sugar, sweets, sweet spreads and sweet sauces
461	Toffees	66	1	1	11	0	47	5	Sweet/fat	18.9	20				Sugar, sweets, sweet spreads and sweet sauces
484	Jam reduced sugar	58	19	1	4	0	26	5	Sweet/fat	20.2	20				Sugar, sweets, sweet spreads and sweet sauces
485	Ice cream dairy cornet	47	4	4	7	1	50	5	Sweet/fat	13.2	20	11	5	1	Ice cream

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
487	Candybar Mars	64	3	4	10	1	57	5	Sweet/fat	23.9	20				Sugar, sweets, sweet spreads and sweet sauces
520	Liquorice Dutch type salted	40	6	1	42	6	28	5	Sweet/fat	37.1	20				Sugar, sweets, sweet spreads and sweet sauces
522	Liquorice Dutch type sweet	33	2	4	19	1	22	5	Sweet/fat	26.0	20				Sugar, sweets, sweet spreads and sweet sauces
524	M&M's chocolate	57	2	3	7	2	28	5	Sweet/fat	11.8	20				Sugar, sweets, sweet spreads and sweet sauces
525	Candybar Milky Way	67	3	4	10	0	65	5	Sweet/fat	32.2	20				Sugar, sweets, sweet spreads and sweet sauces
528	Candybar Snickers	62	1	2	15	2	60	5	Sweet/fat	26.5	20				Sugar, sweets, sweet spreads and sweet sauces
717	Chocolate bar milk with nuts	65	2	3	11	5	64	5	Sweet/fat	30.8	20				Sugar, sweets, sweet spreads and sweet sauces
750	Marsh mellows	65	2	0	2	0	33	5	Sweet/fat	16.9	20				Sugar, sweets, sweet spreads and sweet sauces
751	Liquorice allsorts	65	1	1	10	0	24	5	Sweet/fat	20.3	20				Sugar, sweets, sweet spreads and sweet sauces
752	Wine gums	49	21	0	4	0	22	5	Sweet/fat	23.1	20				Sugar, sweets, sweet spreads and sweet sauces
845	Candybar Twix	64	0	2	10	0	47	5	Sweet/fat	17.3	20				Sugar, sweets, sweet spreads and sweet sauces
1508	Chocolates filled/Belguim chocolate	64	1	7	6	0	66	5	Sweet/fat	32.1	20				Sugar, sweets, sweet spreads and sweet sauces
1962	Chocolate confetti milk	60	1	3	6	0	34	5	Sweet/fat	10.9	20				Sugar, sweets, sweet spreads and sweet sauces
1963	Chocolate confetti plain	54	1	6	6	0	35	5	Sweet/fat	6.7	20				Sugar, sweets, sweet spreads and sweet sauces
1964	Spread chocolate milk	62	1	6	10	2	65	5	Sweet/fat	30.3	20				Sugar, sweets, sweet spreads and sweet sauces
2251	Ice cream dairy w chocolate coating	40	1	3	4	1	55	5	Sweet/fat	21.3	20	11	5	1	Ice cream
2375	Chocolate plain w nuts	38	1	31	8	2	57	5	Sweet/fat	36.3	20				Sugar, sweets, sweet spreads and sweet sauces

Appendix D

Table D3 continued

		Mean taste intensity values (0-100)						Cluster			NEVO	GloboDiet			
Food code	Product description	Sweet	Sour	Bitter	Salt	Umami	Fat	#	Name	Distance	Food group	Food group	Sub fg1	Sub fg2	Food group name
2380	Toffee w chocolate	68	1	3	10	0	64	5	Sweet/fat	32.0	20				Sugar, sweets, sweet spreads and sweet sauces
2416	Ice cream stracciatella-	47	1	4	7	1	47	5	Sweet/fat	11.0	20	11	5	1	Ice cream
2533	Wine gum w liquorice	48	7	1	26	0	21	5	Sweet/fat	24.6	20				Sugar, sweets, sweet spreads and sweet sauces
2595	Candybar KitKat	59	1	3	12	0	47	5	Sweet/fat	13.8	20				Sugar, sweets, sweet spreads and sweet sauces
2656	Chocolate confetti mix white and plain	56	1	4	6	0	37	5	Sweet/fat	7.0	20				Sugar, sweets, sweet spreads and sweet sauces
2666	Spread chocolate Duo Penotti hazelnut	66	1	2	9	2	70	5	Sweet/fat	36.3	20				Sugar, sweets, sweet spreads and sweet sauces
2870	Candybar Lion	59	1	2	13	0	42	5	Sweet/fat	11.5	20				Sugar, sweets, sweet spreads and sweet sauces
390	Beer pilsner	6	17	55	1	1	1	6	Bitter	12.4	2	14	3		Beer and cider
414	Soft drink tonic	24	22	38	2	0	1	6	Bitter	18.4	2	13	2		Non-alcoholic beverages
421	Whisky	22	13	25	2	1	4	6	Bitter	23.6	2	14	4		Spirits and brandy
422	Wine red	8	46	38	1	2	2	6	Bitter	35.6	2	14	1		Wine
644	Coffee prepared	2	9	63	3	1	4	6	Bitter	19.7	2	13	3	1	Coffee
1468	Beer >7 vol% alcohol	7	20	53	2	2	1	6	Bitter	12.4	2	14	3		Beer and cider
1519	Beer alcohol free <0,1 vol%	9	13	49	2	0	2	6	Bitter	5.0	2	14	3		Beer and cider
2477	Coffee cappuccino instant prepared	8	9	44	2	1	8	6	Bitter	6.1	2	13	3	1	Coffee
2647	Coffee w sugar and milk vending machine	26	10	36	3	1	18	6	Bitter	22.2	2	13	3	1	Coffee
274644	Coffee with coffee creamer powder	3	5	59	2	0	7	6	Bitter	17.1	2	13	3	1	Coffee
280644	Coffee with coffee creamer full fat	6	8	54	2	1	7	6	Bitter	10.7	2	13	3	1	Coffee
285644	Coffee with coffee creamer half fat	4	6	60	3	1	7	6	Bitter	17.0	2	13	3	1	Coffee
377644	Coffee with sugar	25	5	43	1	1	3	6	Bitter	15.3	2	13	3	1	Coffee
1088644	Coffee with sweetener p tablet Natrena	17	2	46	1	0	4	6	Bitter	11.1	2	13	3	1	Coffee
1593644	Coffee with sweetener aspartame/acesulfa	10	2	51	2	1	3	6	Bitter	11.0	2	13	3	1	Coffee
10002-644	Coffee with stevia	8	2	50	1	0	4	6	Bitter	11.1	2	13	3	1	Coffee
63	Onions raw	9	8	31	3	3	3	6	Bitter	16.1	9				Vegetables

Table D4 Percentage of total energy intake (mean±SD) from each taste group based on cluster analyses stratified by gender, age, BMI and educational level, and averaged over 2 days of 24h recalls in the Dutch National Food Consumption Survey and for tested foods only[1].

	Percentage of energy from taste clusters					
	Fat	Sweet/ sour	Neutral	Sweet/ fat	Bitter	Salt/ umami/fat
Men (n=687)	11±7	10±8$^{*¥}$	38±12$^{*¥}$	11±9$^{*¥}$	8±10$^{*¥}$	23±11$^{*¥}$
Age (years)						
19-30 (N=343)	11±7	11±8^{a}	37±13	10±9^{a}	7±10	24±11^{a}
30-50 (N=344)	10±7	9±7^{b‡}	39±11	12±9^{b†}	8±9	21±11^{b‡}
BMI (kg/m^2)						
18.5-25.0 (normal, N=363)	11±7	11±8	38±12	12±9	8±10	21±11^{a}
25-30 (overweight, N=244)	10±7	10±7	37±12	11±9	8±10	24±11^{b‡}
>30 (obese, N=80)	10±6	9±7	40±12	9±8	5±9	26±11^{b‡}
Education (highest)						
Low (1-3, N=186)	10±8	10±8	37±12	12±9	7±9	24±13
Medium (4-5, N=351)	11±7	10±8	37±12	11±9	9±11	23±10
High (6-7, N=150)	10±6	11±7	40±12	11±9	6±8	22±11
Women (n=664)	10±6	13±9$^{*¥}$	41±13$^{*¥}$	14±10$^{*¥}$	3±6$^{*¥}$	20±11$^{*¥}$
Age (years)						
19-30 (N=323)	9±6	14±10^{a}	40±13	13±11	3±6	21±11
30-50 (N=341)	10±6	12±9^{b‡}	41±12	14±10	3±6	20±11
BMI (kg/m^2)						
18.5-25.0 (normal, N=351)	10±7	14±9^{a‡}	40±13	14±10	3±6	19±11^{a}
25-30 (overweight, N=173)	9±6	13±9^{a†}	41±13	13±10	3±5	21±12^{ab}
>30 (obese, N=140)	10±7	11±9^{b}	42±12	13±10	3±8	23±10^{b‡}
Education (highest)						
Low (1-3, N=183)	10±6	13±9	39±13	14±11	3±7	21±11
Medium (4-5, N=336)	10±6	13±9	41±13	13±10	3±6	20±11
High (6-7, N=145)	10±6	13±9	42±12	14±10	3±6	20±10

[1] MANCOVA, multivariate ANCOVA was performed including all tastes and subgroups. If the overall effect was significant ($p<0.05$), ANCOVA was used to compare subgroups within each taste group ($p<0.05$, Bonferroni corrected). For age and gender, independent samples t-tests were used ($p<0.05$, Bonferroni corrected). Models for gender were adjusted for age, BMI and education; models for age were adjusted for BMI and education; models for BMI were adjusted for age and education; models for education were adjusted for age and BMI. [a,b] Superscript letters indicate significant differences, same letters indicate no significant difference between mean values. * Indicates significant difference between men and women. † $p<0.05$, ‡ $p<0.01$, ¥ $p<0.001$.

Appendix D

Table D5 Percentage of total energy intake (mean±SD) from each taste group based on cluster analyses stratified by gender, age, BMI and educational level, and averaged over 2 days of 24h recalls in the NQplus study and for tested foods only[1].

	Percentage of energy from taste clusters					
	Fat	Sweet/ sour	Neutral	Sweet/fat	Bitter	Salt/ umami/ fat
Men (n=498)	10±7	11±7[*¥]	40±13	14±10[*‡]	9±9[*¥]	17±10
Age (years)						
20-30 (N=19)	10±10	11±8	41±12	10±7	8±10[ab]	20±12
30-50 (N=127)	10±7	11±8	42±13	13±10	7±8[a]	18±10
51+ (N=352)	10±6	11±7	39±13	14±10	10±10[b‡]	16±10
BMI (kg/m^2)						
18.5-25.0 (normal, N=185)	9±6	11±7	40±12	15±10[a]	9±8	16±9
25-30 (overweight, N=243)	10±7	11±8	39±13	13±10[ab]	10±9	17±11
>30 (obese, N=70)	11±6	10±7	41±13	11±8[b‡]	8±10	19±10
Education (highest)						
Low (1-3, N=30)	9±6	9±6	42±13	15±8	9±9	17±9
Medium (4-5, N=134)	9±6	12±8	40±13	14±10	8±9	17±11
High (6-7, N=334)	10±7	11±7	40±12	13±10	9±9	17±10
Women (n=449)	11±7	13±8[*¥]	40±13	16±11[*‡]	4±5[*¥]	16±11
Age (years)						
20-30 (N=48)	9±7	13±7	41±13	18±13	2±3[a‡]	17±11
30-50 (N=159)	11±7	12±9	41±13	18±12	3±4[a¥]	16±11
51+ (n=242)	11±7	14±8	39±12	15±11	5±6[b]	16±10
BMI (kg/m^2)						
18.5-25.0 (normal, N=245)	11±8[a]	13±8	40±12	17±12	4±5	15±11[a]
25-30 (overweight, N=144)	9±6[b†]	14±9	40±13	16±11	4±5	16±10[ab]
>30 (obese, N=60)	10±6	12±9	39±13	16±12	3±5	20±12[b‡]
Education (highest)						
Low (1-3, N=25)	10±8	12±8	43±15	17±12	3±5	16±13
Medium (4-5, N=147)	11±7	14±9	40±13	17±11	3±4	16±11
High (6-7, N=277)	11±7	13±8	39±12	16±12	4±6	16±10

[1] MANCOVA, multivariate ANCOVA was performed including all tastes and subgroups. If the overall effect was significant ($p<0.05$), ANCOVA was used to compare subgroups within each taste group ($p<0.05$, Bonferroni corrected). For gender independent samples t-tests were used ($p<0.05$, Bonferroni corrected). Models for gender were adjusted for age, BMI and education; models for age were adjusted for BMI and education; models for BMI were adjusted for age and education; models for education were adjusted for age and BMI. [a,b] Superscript letters indicate significant differences, same letters indicate no significant difference between mean values. [*] Indicates significant difference between men and women. † $p<0.05$, ‡ $p<0.01$, ¥ $p<0.001$.

Table D6 Percentage of total energy intake (mean±SD) from each taste group based on cluster analyses stratified by gender, age, BMI and educational level, and averaged over 2 days of 24h recalls in the Dutch National Food Consumption Survey and for accurate and high energy reporters only[1].

	Percentage of energy from taste clusters					
	Fat	Sweet/ sour	Neutral	Sweet/ fat	Bitter	Salt/ umami/fat
Men (n=381)	11±6	10±7[*¥]	33±10[*†]	13±9[*¥]	9±9[*¥]	24±9[*‡]
Age (years)						
19-30 (N=201)	11±6	11±8[a]	32±11	12±9	8±9	24±9
30-50 (N=180)	11±6	9±6[b‡]	33±9	15±8	9±8	23±9
BMI (kg/m^2)						
18.5-25.0 (normal, N=243)	11±6	10±7	33±10	14±9	8±8	23±9[a]
>25 (overweight/obese, N=138)	11±6	9±6	32±11	12±9	10±9	25±9[b†]
Education (highest)						
Low (1-3, N=110)	11±7	10±8	33±10	13±9	8±9	24±10
Medium (4-5, N=201)	11±6	10±7	32±10	14±9	9±9	24±9
High (6-7, N=70)	11±5	10±5	34±10	14±9	8±9	22±10
Women (n=309)	11±6	13±8[*¥]	35±10[*†]	17±10[*¥]	3±5[*¥]	21±9[*‡]
Age (years)						
19-30 (N=141)	11±6	14±8[a]	33±10[a]	17±10	3±5[a]	22±9
30-50 (N=168)	11±6	12±8[b‡]	36±10[b†]	16±10	4±6[b†]	21±9
BMI (kg/m^2)						
18.5-25.0 (normal, N=200)	11±6	13±8	35±11	17±10	3±6	20±9[a]
>25 (overweight/obese, N=109)	11±6	12±8	33±8	16±9	3±5	24±9[b¥]
Education (highest)						
Low (1-3, N=82)	11±6	13±8	33±10	18±11	4±5	22±9
Medium (4-5, N=157)	11±7	13±8	35±10	16±9	4±5	21±9
High (6-7, N=70)	11±5	12±7	36±10	18±9	3±5	21±9

[1] MANCOVA, multivariate ANCOVA was performed including all tastes and subgroups. If the overall effect was significant ($p<0.05$), ANCOVA was used to compare subgroups within each taste group ($p<0.05$, Bonferroni corrected). For age, BMI and gender, independent samples t-tests were used ($p<0.05$, Bonferroni corrected). Models for gender were adjusted for age, BMI and education; models for age were adjusted for BMI and education; models for BMI were adjusted for age and education; models for education were adjusted for age and BMI. [a,b] Superscript letters indicate significant differences, same letters indicate no significant difference between mean values. [*] Indicates significant difference between men and women. † $p<0.05$, ‡ $p<0.01$, ¥ $p<0.001$.

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Table D7 Percentage of total energy intake (mean±SD) from each taste group based on cluster analyses stratified by gender, age, BMI and educational level, and averaged over 2 days of 24h recalls in the NQplus study and for accurate and high energy reporters only[1].

	Percentage of energy from taste clusters					
	Fat	Sweet/ sour	Neutral	Sweet/fat	Bitter	Salt/ umami/ fat
Men (n=197)	8±4	10±6*‡	38±9	15±9	7±6$^{*¥}$	22±9
Age (years)						
20-30 (N=12)	10±7	9±6	34±8	14±8	8±9	25±13
30-50 (N=47)	9±5	11±7	40±8	13±7	5±5	23±7
51+ (N=138)	8±4	10±5	38±9	15±9	7±6	22±9
BMI (kg/m^2)						
18.5-25.0 (normal, N=104)	8±4	10±6	39±8	15±9	6±6	22±8
>25 (overweight/obese, N=93)	9±5	10±5	37±9	14±9	8±6	24±10
Education (highest)						
Low (1-3, N=12)	8±5	8±5	39±9	16±8	5±5	24±10
Medium (4-5, N=53)	8±4	10±6	38±8	15±9	6±7	23±8
High (6-7, N=132)	8±4	10±5	38±9	14±9	7±6	22±9
Women (n=227)	9±5	12±6*‡	38±10	16±9	4±4$^{*¥}$	21±10
Age (years)						
20-30 (N=27)	8±5	11±5^{ab}	42±11	16±8	2±2^{a}	22±9
30-50 (N=79)	9±5	10±5^{a}	39±9	18±9	3±4^{ab}	21±10
51+ (n=121)	9±5	13±6$^{b¥}$	38±10	16±9	4±4^{b†}	21±9
BMI (kg/m^2)						
18.5-25.0 (normal, N=160)	9±5	12±5	40±10	16±9	3±4^{a}	20±10^{a}
>25 (overweight/obese, N=67)	8±4	12±6	37±10	16±9	4±4^{b†}	23±9^{b†}
Education (highest)						
Low (1-3, N=12)	7±4	11±6	44±9^{a†}	17±10	2±4	19±7^{ab}
Medium (4-5, N=56)	10±6	12±6	36±9^{b}	16±8	3±4	25±10^{a}
High (6-7, N=159)	9±5	12±5	39±10^{a†}	16±9	4±4	20±9^{b‡}

[1] MANCOVA, multivariate ANCOVA was performed including all tastes and subgroups. If the overall effect was significant ($p<0.05$), ANCOVA was used to compare subgroups within each taste group ($p<0.05$, Bonferroni corrected). For gender independent samples t-tests were used ($p<0.05$, Bonferroni corrected). Models for gender were adjusted for age, BMI and education; models for age were adjusted for BMI and education; models for BMI were adjusted for age and education; models for education were adjusted for age and BMI. ^{a,b} Superscript letters indicate significant differences, same letters indicate no significant difference between mean values. * Indicates significant difference between men and women. † $p<0.05$, ‡ $p<0.01$, ¥ $p<0.001$.

Table D8 Percentage of total energy intake (mean±SD) from each taste group based on cluster analyses stratified by gender, age, BMI and educational level, and averaged over 2 days of 24h recalls in the Dutch National Food Consumption Survey excluding low and high energy reporters at the individual level[1].

	Percentage of energy from taste clusters					
	Fat	Sweet/ sour	Neutral	Sweet/ Fat	Bitter	Salt/ umami/fat
Men (n=617)	11±6*‡	10±7$^{*¥}$	34±10$^{*¥}$	13±9$^{*¥}$	8±8$^{*¥}$	24±9$^{*¥}$
Age (years)						
19-30 (n=312)	11±6	11±7^{a}	34±11	12±9^{a}	7±8^{a}	25±9^{a}
30-50 (n=305)	11±6	9±6$^{b¥}$	35±9	14±8^{b†}	9±8^{b‡}	23±9^{b†}
BMI (kg/m^2)						
18.5-25.0 (normal, n=340)	11±6	10±7	35±10	14±9	8±8	23±9^{a}
25-30 (overweight, n=219)	11±6	10±7	34±10	13±8	8±8	25±9^{ab}
>30 (obese n=58)	11±6	9±6	35±10	11±8	6±8	26±10^{b†}
Education (highest)						
Low (1-3, n=165)	11±7	10±7	34±10	13±9	7±8	24±10
Medium (4-5, n=319)	11±6	10±7	34±10	13±9	8±9	24±9
High (6-7, n=133)	11±5	11±6	36±9	13±9	6±7	23±10
Women (n=570)	10±6*‡	12±8$^{*¥}$	37±11$^{*¥}$	16±10$^{*¥}$	3±5$^{*¥}$	21±10$^{*¥}$
Age (years)						
19-30 (n=265)	10±6	13±8^{a}	36±11	16±10	3±5^{a}	21±10
30-50 (n=305)	10±6	11±8^{b‡}	37±11	16±9	4±6^{b†}	21±9
BMI (kg/m^2)						
18.5-25.0 (normal, n=328)	10±6	13±8^{a}	37±11	17±10	4±5	20±10^{a}
25-30 (overweight, n=144)	10±5	13±8^{a}	36±10	15±9	3±5	23±10^{b†}
>30 (obese, n=98)	11±6	10±7^{b†}	38±11	16±10	3±5	23±8^{ab}
Education (highest)						
Low (1-3, n=157)	11±6	12±8	35±11	16±10	4±6	23±10
Medium (4-5, n=283)	10±6	13±8	37±11	16±10	3±5	21±10
High (6-7, n=130)	10±6	12±7	38±11	17±10	3±4	20±9

[1] MANCOVA, multivariate ANCOVA was performed including all tastes and subgroups. If the overall effect was significant ($p<0.05$), ANCOVA was used to compare subgroups within each taste group ($p<0.05$, Bonferroni corrected). For age and gender, independent samples t-tests were used ($p<0.05$, Bonferroni corrected). Models for gender were adjusted for age, BMI and education; models for age were adjusted for BMI and education; models for BMI were adjusted for age and education; models for education were adjusted for age and BMI. [a,b] Superscript letters indicate significant differences, same letters indicate no significant difference between mean values. [*] Indicates significant difference between men and women. † $p<0.05$, ‡ $p<0.01$, ¥ $p<0.001$.

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Table D9 Percentage of total energy intake (mean±SD) from each taste group based on cluster analyses stratified by gender, age, BMI and educational level, and averaged over 2 days of 24h recalls in the NQplus study excluding low and high energy reporters at the individual level[1].

	Percentage of energy from taste clusters					
	Fat	Sweet/ sour	Neutral	Sweet/fat	Bitter	Salt/ umami/ fat
Men (n=431)	8±4	10±6[*¥]	39±9	13±8[*‡]	7±6[*¥]	23±9[*†]
Age (years)						
20-30 (n=19)	8±6	11±6	36±7	11±7	6±8[ab]	27±11
30-50 (n=107)	8±5	9±6	39±8	13±8	6±5[a]	24±9
51+ (n=305)	8±4	10±6	38±10	13±9	8±7[b‡]	22±9
BMI (kg/m^2)						
18.5-25.0 (normal, n=175)	8±4	10±6	40±9[a]	14±9	7±6	21±9[a]
25-30 (overweight, n=206)	8±5	10±6	37±10[b‡]	13±8	8±7	24±10[b†]
>30 (obese, n=50)	9±4	9±6	36±9[b†]	10±6	8±6	27±8[b¥]
Education (highest)						
Low (1-3, n=23)	8±4	7±4	38±9	15±7	7±7	25±9
Medium (4-5, n=115)	8±4	10±6	38±9	13±8	7±6	24±9
High (6-7, n=293)	8±4	10±6	38±10	13±8	8±6	23±9
Women (n=391)	8±5	12±6[*¥]	39±10	15±9[*‡]	4±4[*¥]	22±10[*‡]
Age (years)						
20-30 (n=38)	7±5	12±5	41±10	15±8	1±2[a¥]	24±9
30-50 (n=135)	8±5	11±7	40±9	17±10	3±4[a‡]	21±9
51+ (n=218)	9±5	13±6	38±10	14±8	4±4[b]	22±10
BMI (kg/m^2)						
18.5-25.0 (normal, n=231)	9±5[a]	12±6	40±10	15±9	3±4	20±10[a]
25-30 (overweight, n=115)	7±4[b†]	12±6	38±10	16±9	4±4	23±9[b†]
>30 (obese, n=45)	9±4[ab]	12±6	37±8	16±9	4±5	24±9[ab]
Education (highest)						
Low (1-3, n=20)	8±5	11±6	43±10	14±9	2±4	22±9
Medium (4-5, n=125)	9±5	12±7	38±10	16±9	3±3	22±10
High (6-7, n=246)	8±5	12±6	39±9	15±9	4±4	21±9

[1] MANCOVA, multivariate ANCOVA was performed including all tastes and subgroups. If the overall effect was significant ($p<0.05$), ANCOVA was used to compare subgroups within each taste group ($p<0.05$, Bonferroni corrected). For gender independent samples t-tests were used ($p<0.05$, Bonferroni corrected). Models for gender were adjusted for age, BMI and education; models for age were adjusted for BMI and education; models for BMI were adjusted for age and education; models for education were adjusted for age and BMI. [a,b] Superscript letters indicate significant differences, same letters indicate no significant difference between mean values. [*] Indicates significant difference between men and women. † $p<0.05$, ‡ $p<0.01$, ¥ $p<0.001$.

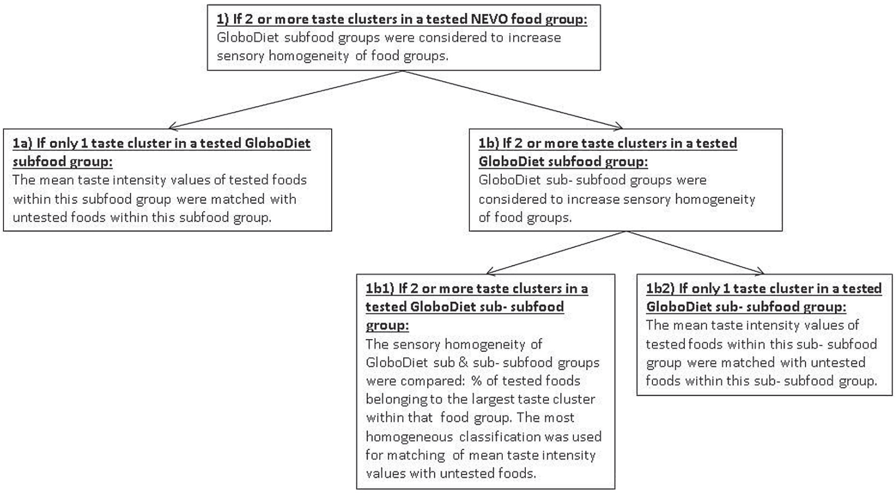

Figure D1 Decision tree for assigning mean taste intensity values to untested foods. The level of sensory homogeneity was defined using cluster analyses on tested foods' taste intensity values.

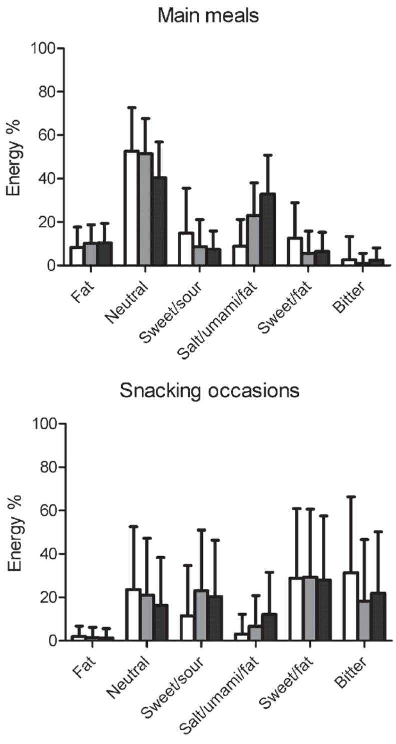

Figure D2 Mean (and SD) percentage of energy from each taste cluster for main meals[1] and snacking occasions[2] separately, shown for the NQplus study (Ntotal=944).

[1]Breakfast ( ), n=938; lunch ( ), n=932; dinner ( ), n=943. [2]During the morning ( ), n=907; during the afternoon ( ), n=919; during the evening ( ), n=905.

Appendix D

Appendix E

Supplementary tables

Chapter 6: Dietary taste patterns of diets based on Dutch dietary guidelines, a Mediterranean diet, a Paleo diet and diet quality compared with current Dutch dietary patterns in women

Table E1 Dietary intake from 6 taste groups, expressed in % energy and % amount (gram), including and excluding beverages

Taste groups	% Energy				% Amount (gram)			
	DNFCS (reference)	Dutch Dietary guidelines	Mediterranean	Paleo	DNFCS (reference)	Dutch Dietary guidelines	Mediterranean	Paleo
Including beverages								
Neutral	38±11	64	53	38	53±19	64	57	50
Sweet/sour	13±8	12	15	19	22±15	20	21	27
Sweet/fat	15±10	3	3	8	5±4	1	1	2
Fat	10±6	11	8	15	1±1	2	1	2
Salt/umami/fat	21±10	7	19	18	7±4	3	17	13
Bitter	3±5	3	1	1	12±13	10	3	6
Excluding beverages								
Neutral	41±12	65	52	43	48±13	63	54	51
Sweet/sour	5±6	11	15	13	13±13	24	23	26
Sweet/fat	17±11	3	4	8	12±9	2	1	3
Fat	12±7	12	8	17	4±3	3	1	3
Salt/umami/fat	25±12	7	20	20	23±12	5	18	17
Bitter	0±0	1	1	0	0±1	4	4	0

*DNFCS; Dutch National Food Consumption Survey 2007-2010; n=664 women aged 19-50 years. ‡Dutch food-based dietary guidelines for women aged 19-50 years.

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In case I forgot someone: blame it on my pregnancy dementia!

About the author

Curriculum vitae

Astrid van Langeveld was born in Haarlem, the Netherlands on January 24th 1988. After completing secondary school (atheneum, Mendelcollege in Haarlem) in 2006, she started studying the Bachelor's programme in Nutrition and Health at Wageningen University. During her BSc she did a minor Brain & Cognition at the University of Leiden, the Netherlands. After her BSc she continued with the double degree MSc programme in Sensory Science of Wageningen University and Copenhagen University. As part of the MSc programme, she studied five months in Copenhagen to attend several courses. She completed her MSc thesis on the neurobiological mechanisms (fMRI) behind food preferences at the Wageningen University, resulting in co-authorship. This was followed by a MSc internship at the University Medical Center Utrecht on the neural correlates (fMRI) of food choice duration. After finishing her MSc in 2013, Astrid started working as a research and teaching assistant in the chair group of Sensory Science and Eating Behaviour, at the Wageningen University. In 2015 she was appointed as a PhD candidate at this chair group. Her research focused on dietary taste patterns in the Netherlands, as described in this thesis. During her PhD, Astrid joined the educational programme of the graduate school VLAG. She attended several (inter)national conferences and courses and was involved in teaching and supervising BSc and MSc thesis students. During her PhD she was awarded with a travel award for the 12th Pangborn Sensory Science Symposium. In addition, she received a postgraduate bursary award to present her work at the 40th anniversary meeting of the British Feeding and Drinking Group. After submitting her PhD thesis, Astrid started working as a manager Nutrition and Health at the Knowledge Centre Sugar & Nutrition, the Netherlands.

List of publications

Publications in peer-reviewed journals

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van Langeveld AWB, Gibbons S, Koelliker Y, Civille GV, de Vries JHM, de Graaf C, Mars M (2017) The relationship between taste and nutrients in commonly consumed foods from the United States. *Food Quality and Preference* 57, 1-7.

Van den Bosch I, Dalenberg J, Renken R, van Langeveld AWB, Smeets PAM, Boesveldt S, de Graaf C (2014) To Like or not to Like: Neural substrates of subjective flavor preferences. *Behavioural Brain Research* 269, 128-137.

Submitted publications

van Langeveld AWB, Teo PS, Feskens, EJM, de Graaf C, Mars M, de Vries JHM. Evaluation of taste-related energy intake as assessed by FFQ against 24-h recalls and biomarkers of exposure – the Nutrition Questionnaires plus study. *Submitted.*

Van den Boer J, van Langeveld AWB, Harms L, de Graaf C, Mars M. How much slow and fast calories are we consuming? Food consumption in terms of energy intake rate. *Submitted*.

Papers in preparation for submission

van Langeveld AWB, Nguyen AN, de Vries JHM, de Graaf C, Franco OH, Mars M, Voortman T. Development of dietary taste patterns in early childhood and its associations with maternal and child characteristics. *In preparation for submission*.

van Langeveld AWB, Teo PS, de Vries JHM, de Graaf C, Mars M. Dietary taste patterns of diets based on Dutch dietary guidelines, a Mediterranean diet, a Paleo diet and diet quality compared with current Dutch dietary taste patterns in women. *In preparation for submission*.

Overview of completed training activities

Discipline specific courses and activities

2015	Postgraduate Course on the Production and Use of Food Composition Data in Nutrition	NL	
2016	Exposure Assessment in Nutrition Research (4th edition)	NL	
2016	Seventh European Conference on Sensory and Consumer Research	FR	oral
2016	40th British Feeding and Drinking Group	UK	oral
2017	41st British Feeding and Drinking Group	UK	poster
2017	12th Pangborn Sensory Science Symposium	US	poster
2016	Dutch Nutritional Science Days	NL	oral
2017	Dutch Nutritional Science Days	NL	oral
2014	WeVo	NL	
2017	WeVo	NL	
2017	WeVo	NL	oral
2017	ILSI: Dietary Sweetness is it an issue?	NL	poster
2018	Nutrition Netherlands (de Eetprikkel)	NL	poster

General courses and activities

2014	Job interviews; how to make a difference?	NL
2015	Effective behaviour in your professional surroundings	NL
2014	Conversation skills one-to-one	NL
2014	Brain based teaching	NL
2017	Scientific writing	NL
2017	Open Access Lunch meeting	NL
2016	NAV workshop talking to the media	NL
2015	Voice Matters	NL
2017	Workshop networking	NL
2017	Career Orientation	NL

Optional courses and activities

’13-’18	Meetings Sensory Science and Eating Behaviour group	NL	
’15-’18	PhD meetings Department of Human Nutrition	NL	
2015	Writing VLAG proposal	NL	
2016	Consortium meeting	NL	
2017	Wageningen University PhD symposium	NL	oral
2017	NAV autumn forum about salt guidelines	NL	
2017	VLAG meeting ‘working in industry’	NL	
2017	Provide lecture Nutriscience VLAG course	NL	oral

Colophon

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