Check for updates

RESEARCH ARTICLE

Basic taste sensitivity, eating behaviour, and propensity of dairy foods of preadolescent children: How are they related?

[version 1; peer review: awaiting peer review]

Ervina Ervina [1,2], Ingunn Berget [3], Siv Borghild Skeie[2], Valérie L. Almli [1,2]

[1]Department of Sensory and Consumer Sciences, Nofima, Norwegian Institute of Food, Fisheries and Aquaculture Research, Ås, 1430, Norway
[2]Department of Chemistry, Biotechnology and Food Science (KBM), The Norwegian University of Life Science, Ås, 1433, Norway
[3]Department of Raw Materials and Process Optimization, Nofima, Norwegian Institute of Food, Fisheries and Aquaculture Research, Ås, 1430, Norway

Open Peer Review

Reviewer Status *AWAITING PEER REVIEW*
. . . .
Any reports and responses or comments on the article can be found at the end of the article.

Abstract

Background: Taste sensitivity has been reported to influence children's eating behaviour and contribute to their food preferences and intake. This study aimed to investigate the associations between taste sensitivity and eating behaviour in preadolescents.
Methods: Children's taste sensitivity was measured by detection threshold with five different concentration levels of sweetness (sucrose), sourness (citric acid), saltiness (sodium chloride), bitterness (caffeine, quinine), and umami (monosodium glutamate). In addition, the Child Eating Behaviour Questionnaire (CEBQ), the Food Propensity Questionnaire (FPQ), and the children's body weight and height were completed by the parents. Children conducted the sensory evaluation test at schools while parents completed the questionnaires online.
Results: A total of 69 child-parent dyads participated. Taste sensitivity was significantly associated with eating behaviour in food responsiveness, emotional overeating, and desire to drink. Children who were less sensitive to caffeine bitterness (higher detection threshold) had higher food responsiveness scores, while those who were less sensitive to sweetness and caffeine bitterness had higher emotional overeating scores. In addition, children who were less sensitive to sourness and bitterness of both caffeine and quinine demonstrated to have higher scores in desire to drink. There was no association between taste sensitivity and FPQ, but significant differences were observed across children's body mass index (BMI) regarding their FPQ of dairy food items, indicating higher consumption of low-fat milk in the overweight/obese compared to the normal-weight subjects. There was no significant difference in taste sensitivity according to BMI. Children's eating behaviour differed across BMI, demonstrating a positive association between BMI and food approach, and a negative association between BMI and food

avoidance.

Conclusions: This study contributes to the preliminary understanding of the relationships between taste sensitivity and eating behaviour in preadolescents which could be used to develop effective strategies to promote healthy eating practices in children by considering their taste sensitivity.

Keywords
Detection threshold, Basic tastes, Eating behaviour, Food propensity, Dairy foods, Preadolescents, BMI

This article is included in the Excellent Science gateway.

Corresponding author: Ervina Ervina (ervina@nofima.no)

Author roles: Ervina E: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Berget I**: Conceptualization, Formal Analysis, Methodology, Supervision, Validation, Writing – Review & Editing; **Skeie SB**: Methodology, Supervision, Validation, Writing – Review & Editing; **L. Almli V**: Conceptualization, Investigation, Methodology, Resources, Supervision, Validation, Writing – Review & Editing

Introduction

Taste significantly influences children's food preference, choice, and intake (Boesveldt *et al.*, 2018; De Cosmi *et al.*, 2017; Nguyen *et al.*, 2015). Previous studies reported that children aged 11–13 years have different intensity perceptions of basic tastes (Ervina *et al.*, 2020; Overberg *et al.*, 2012) which demonstrate individual differences in taste sensitivity among preadolescents. Individual differences for sweetness sensitivity based on detection threshold were observed in 7-14-year-old children (Joseph *et al.*, 2016). Moreover, children aged 9–11 years also have different sensitivity thresholds to bitterness (Hartvig *et al.*, 2014). Other basic tastes such as saltiness, sourness, and umami have been reported to be perceived differently in terms of their intensity perception by preadolescent subjects (Kildegaard *et al.*, 2011; Kim & Lee, 2009; Liem, 2017; Overberg *et al.*, 2012).

The individual differences in taste sensitivity could influence food preferences, people with low sensitivity to sweetness and fattiness have been reported to prefer a higher intensity of these tastes in their foods to meet their optimum liking (Cox *et al.*, 2016; Papantoni *et al.*, 2021). In addition, low sensitivity to a basic taste could be related to body weight (Donaldson *et al.*, 2009; Overberg *et al.*, 2012). For example, children with low sensitivity to sweet taste will seek a higher intensity of sweetness (more sugar) which can result in a higher calorie intake and a possible increase in body weight (Cox *et al.*, 2016; Donaldson *et al.*, 2009; Papantoni *et al.*, 2021). Moreover, obese children have been reported to have a lower sensitivity to sweet taste compared to normal-weight children (Overberg *et al.*, 2012). On the other hand, subjects with high sensitivity to bitterness prefer food with a low concentration of this taste (Bell & Tepper, 2006; Hartvig *et al.*, 2014), thus hindering them to consume bitter dominant foods such as vegetables (Oellingrath *et al.*, 2013). This could contribute to the insufficiency of vegetable consumption in children. Norwegian children aged eight and 13 years were reported to have a vegetable intake below the recommended level (Hansen *et al.*, 2016). Moreover, 11-year-old children were shown to have high preferences for sugary, salty, and fatty foods (Ervina *et al.*, 2020), which are characterized as high caloric and poorly nutritious foods (Liem & Russell, 2019). These preferences for certain foods in children could be related to their taste sensitivity and eating behaviour.

Children's taste sensitivity has been reported to be associated with their eating behaviour. A study by Farrow & Coulthard (2012) suggested that five-year-old children with higher taste sensitivity were more susceptible to being selective eaters compared to children with low taste sensitivity. Moreover, sensitivity to sweetness and bitterness measured by detection threshold in 8-9-year-old children was demonstrated to be correlated with their food preferences and lifestyle (Rodrigues *et al.*, 2020). The individual differences in perceiving taste at a genetic level were reported to be associated with eating behaviour (Chamoun *et al.*, 2018; Hughes & Frazier-Wood, 2016). The genetic variation in the sweet taste receptor, T1R2, has been reported to be associated with sugar consumption,

and positively correlated with the risk of dental caries. On the other hand, the bitter taste receptor, T2R38 has been shown to influence children's eating behaviour with regards to preference and intake of vegetables (Chamoun *et al.*, 2018), suggesting that children with low bitterness sensitivity have a higher preference for and intake of vegetables (Keller *et al.*, 2002; Shen *et al.*, 2016; Tepper, 2008).

Taste sensitivity may also be related to food exposure. A study by Vennerød *et al.* (2017) showed that pre-school children aged 4–5 years who were more sensitive to sweetness were also less frequently exposed to sweet foods. In children aged 12–13 years a more frequent consumption of fast food was associated with decreasing sensitivity to saltiness and, as a consequence, their preference for saltier beansprout soups increased (Kim & Lee, 2009). A recent study by Mohd Nor *et al.* (2021) demonstrated that exposure to bitter vegetables in children aged 3–5 years was able to increase liking and intake of these bitter vegetables that were initially disliked. Exposure to different flavours and tastes during early childhood is associated with children's food acceptability and eating behaviour when they grow older (Nicklaus, 2016). Frequent exposures to certain basic tastes have been reviewed to be associated with increased hedonic and intensity perceptions, and this could directly influence taste satiation (Li *et al.*, 2020). A study by Kershaw & Mattes (2018) indicated that taste exposure was more crucial than sensory sensitivity in determining food preferences and eating behaviour. Further, children aged 4–5 years who were not sensitive to 6-n-propylthiouracil (PROP) bitterness (non-tasters) had a higher acceptance of cheese and full-fat milk compared to sensitive subjects (tasters) (Keller *et al.*, 2002). Dairy products constitute one of the main structures in Norwegian children's diet at age 9 to 13 years (Hansen *et al.*, 2016). This food category provides a diverse range of essential nutrients that are highly important for children's growth and development (Givens, 2020). Therefore, it is of interest to investigate the influence of children's taste sensitivity on their exposure to dairy foods.

Understanding the relationship between taste sensitivity and eating behaviour in preadolescent children will contribute to developing an appropriate strategy to promote healthy eating behaviour for this age group. This is important because preadolescence is a critical period for the development of lifelong eating habits (Gibson *et al.*, 2012) but at the same time, children in this age group have also been reported to be selective eaters (Houldcroft *et al.*, 2014) and they may have a risk of developing childhood obesity (Boesveldt *et al.*, 2018; Leonie *et al.*, 2018). Good eating practices that have been built and developed in preadolescence can be sustained until adolescence and may be persistent until adulthood (Nicklaus, 2016). Therefore, it is important to shape eating behaviour towards healthy food preferences at this age. To achieve this, it is important to investigate the mechanisms and determinants of child eating behaviour including the physiological aspects such as taste sensitivity. According to Nicklaus (2020), to date, comprehensive studies regarding eating and drinking habits of preadolescent children in relation

to their taste sensitivity perceptions are still limited, which suggests the need for more research to be conducted within this field.

The main objective of this study was to investigate the association between children's basic taste sensitivity and their eating behaviour. In addition, the association between basic taste sensitivity and food propensity was investigated, with particular emphasis on dairy foods. The study used two bitter compounds, caffeine and quinine, since it has been shown that preadolescent subjects have different sensitivity perceptions for different bitter taste compounds (Ervina *et al.*, 2020; Meyerhof *et al.*, 2010). Moreover, the relationships between taste sensitivity, eating behaviour, and children's body mass index (BMI) were also explored.

Methods

Ethics statement

This study has been granted approval from the Norwegian Center for Research Data (NSD) No. 715734 for the data collection, the use of data for research and publication, and data management (including data processing and storage). The study is also followed the Declaration of Helsinki, while data protection has followed the General Data Protection Regulation (GDPR). A signed informed consent (written) from both the children and parents was required to participate in the study. In addition, the children's verbal consent was obtained at the beginning of the sensory testing. The consent was both for participation and the use of data for research and publication purposes.

Participants

A total of 69 children (mean age 10.9 ± 0.2 years, 46.5% boys) and their parents (one parent per child) participated in the study. They were recruited from the 6th grade in two primary schools located in Ski, Nordre Follo region, in Norway. The schools were selected because of their location (13 km away) from the research institute (Nofima, Ås), aiming to minimize the possibility of the involvement of the parents who worked in the institute and knew the project. The recruitment of the participants and data collection were conducted between August-November 2019. Originally, all the 6th grade cohort from the two schools (118 children) were invited to the study,

wherein 11 did not return the consent form, one returned the form but did not complete the test, and 37 children completed the test, but their parents did not complete the questionnaire. The children performed the basic taste sensitivity test at schools while parents completed the questionnaire regarding their child's eating behaviour and food propensity online. The participating classes received a common reward for their participation in the study, however, all the children and parents' participation were voluntary.

Children's basic taste sensitivity measurement

The children's taste sensitivity was measured by detection threshold. They were instructed to evaluate five different concentration levels of sucrose (sweet), citric acid (sour), sodium chloride (salty), monosodium glutamate (umami), caffeine (bitter) and quinine (bitter) dissolved in water (Table 1). The concentration of the basic taste stimulus was adapted from a study by Knof *et al.* (2011) and Ahrens (2015) that was previously used to measure taste sensitivity of more than 1800 participants aged 6–9 years. All the taste compounds were food grade and purchased from Merck Kga, Germany. The samples were prepared two days before the evaluation at the sensory laboratory in Nofima, Ås. The taste compounds were dissolved in tap water, placed in a disposable cup, and served to the children at around 10 ml each. Each taste compound was distinguished by different symbols, cloud (sucrose), moon (citric acid), flower (sodium chloride), sun (caffeine), star (quinine), and leaf (umami), while the different concentrations were marked by numbers from 1 (representing the lowest concentration level) to 5 (the highest concentration level). The children did not receive any information regarding the symbols, and they did not know that each series of five cups actually carried the same taste compound, or that the cup numbers corresponded to increasing concentrations. They were only informed that they would taste samples in five series of five cups marked with symbols, that different tastes could be present in any of the cups, and that the numbers on the cups indicated the order in which they should taste the samples for each series.

The children evaluated the samples in a staircase order for each series of the taste compound, starting with the lowest concentration (level 1) to the highest concentration (level 5).

Table 1. Concentration level of taste compounds for detection threshold.

Taste	Taste compound	Level 1 (g/l)	Level 2 (g/l)	Level 3 (g/l)	Level 4 (g/l)	Level 5 (g/l)
Sweet	Sucrose	3.0	6.0	9.0	12.0	16.0
Sour	Citric acid	0.05	0.1	0.16	0.2	0.25
Salty	Sodium chloride	0.2	0.4	0.8	1.2	1.6
Umami	Monosodium glutamate	0.1	0.3	0.6	1.2	1.5
Bitter	Caffeine	0.05	0.1	0.15	0.2	0.27
Bitter	Quinine	0.0014	0.0017	0.0023	0.0038	0.006

The children were asked "what is the taste inside this cup?" and they had to compare the sample (inside the cup) with water as a reference. They had seven options to choose from to describe the taste of each cup: "water", "sweet", "sour", "salty", "bitter", "umami", in addition to the option of "I don't know". For any symbol series and cup, the children were free to choose among these seven available options according to their perceptions. Thus, they could use the same option as many times as they wanted without limitations. It was technically possible to re-taste the previous cups of the same series (same taste compound, same symbol) but they could not re-taste samples from the previous series (different symbol). To ensure this practice, children were instructed to discard all the cups from their table after each series, so they could not interfere with the previous tasted series.

The detection threshold was obtained as the level where they could start to differentiate the sample from water (Webb et al., 2015), i.e. choose other options than "water". Note that the level in which the children either chose the options of "I don't know" or wrongly answered the actual taste quality was also recorded as their detection threshold, as we expect they perceived the sample to be different from water. The taste series were evaluated in a randomized balanced order across children. The randomization was generated by the software (EyeQuestion, version 5.0.7.7, Elst, The Netherlands). The same software was also used to record the children's responses in an online setup using a tablet. Alternatively, a free online platform such as SurveyMonkey, SurveySparrow or Google Forms could also be used. However, a limitation would be that the randomization procedure that could not be generated by these alternative platforms. The children always received a reminder on their screen to rinse their mouth with water and to eat crackers to clean their palate between tastings of each cup. The sensory evaluation was conducted in a game-like approach called "the taste detective" (Ervina et al. (2020). The application of this game-like concept aimed to increase the participation and completion rate of the children and to create a fun and engaging test activity (Jilani et al., 2019; Laureati et al., 2015).

Questionnaires to children's parents

The parents were provided a link to an online questionnaire (EyeQuestions, version 5.0.7.7, Elst, The Netherlands) that was sent to their email addresses. The online questionnaire consisted of three parts. The first part asked for information regarding the family profiles such as the parent's education level, the person in charge of preparing meals at home (mother, father, mother and father, others, buy/take-away), frequency of eating together with the family at each mealtime (breakfast, lunch, dinner, and evening meal), and frequency of the children having snacks or sweets per week. These responses were recorded in a frequency score option of 1= "never/rarely", 2= "1–3 times per week", 3= "4–6 times per week", and 4= "everyday". In addition, parents reported the weight (in kg) and height (in cm) of their child, which was then used to calculate the child's BMI. The second part of the questionnaire consisted of the Child Eating Behaviour Questionnaire

(CEBQ), while the Food Propensity Questionnaire (FPQ) was completed in the third part. It required approximately 30–35 minutes for the parents to complete the questionnaires.

Child Eating Behaviour Questionnaire (CEBQ). The CEBQ was borrowed from a study by Wardle et al. (2001) and includes 35 statements categorized into eight different dimensions to measure children's eating behaviour. The dimensions consist of food responsiveness (five items), enjoyment of food (four items), emotional overeating (four items), desire to drink (three items), satiety responsiveness (five items), slowness in eating (four items), emotional undereating (four items), and food fussiness (six items). The eight domains of the CEBQ assessed two global response patterns to foods known as "food approach" (includes food responsiveness, emotional overeating, enjoyment of food, desire to drink) and "food avoidance" (satiety responsiveness, slowness in eating, emotional undereating, food fussiness) (Vandeweghe et al., 2016). The complete explanation of each dimension in CEBQ has been previously reviewed (Freitas et al., 2018).

The parent's responses to the CEBQ were recorded in a five-point agreement scale ranging from 1= "completely disagree", 2= "disagree", 3= "neither agree nor disagree", 4= "agree", and 5= "completely agree" (Wardle et al., 2001). The questionnaire was translated from English to Norwegian, then back-translated for validation and adjustments by the research team and colleagues at the department, in Nofima, Ås. The CEBQ has good reliability and validity to evaluate eating behaviour in children aged 5–6 years (Quah et al., 2019), 5–12 years (Njardvik et al., 2018), and 7–12 years (Tay et al., 2016). Moreover, the CEBQ has been applied in different countries (Santos et al., 2011; Sleddens et al., 2008; Tay et al., 2016), and the results indicated that CEBQ is a good instrument to evaluate eating behaviour in children (Freitas et al., 2018).

The Food Propensity Questionnaire (FPQ). The FPQ was completed by the parents and aims to measure how often the children ate the selected food items. The questionnaire consisted of nine different food categories involving 81 selected food items such as 1) starchy foods (bread, pasta, rice, and potatoes), 2) spreads, toppings, and sandwich fillings, 3) breakfast cereals, 4) dairy products, 5) meat, fish, seafoods, soups, 6) vegetables, 7) fruits and berries, 8) desserts, cake, snacks, and sweets, and 9) drinks. The dairy products consisted of 14 items: brown whey cheese, semi-hard cheese, spreadable cheese, parmesan, butter, whole milk, low-fat milk, skimmed milk, fermented milk, chocolate/strawberry-flavoured milk, plain yogurt, fruit yogurt, ice cream, and dairy pudding. The focus is brought on the dairy category in the present study because a previous study reported a significant contribution of dairy foods in Norwegian children's daily intake (Hansen et al., 2016). The FPQ questionnaire was adapted from a previous Norwegian dietary survey by Totland et al. (2012). The food items were then further categorized according to their basic taste profiles into sweet, sour, salty, bitter, and umami foods. The categorization follows a study by Martin et al. (2014) who developed a food taste database of nearly 600

food items based on a Spectrum™-like profiling approach by trained panellists. The parent's responses regarding how often their child eats these selections of foods were recorded in a six-point scale of eating frequency ranging from 1= "never/rarely", 2= "1–3 times per month", 3= "1–3 times per week", 4= "4–6 times per week", 5= "daily", and 6= "more than once a day". The list of food items was presented and evaluated in a random order within categories across parents.

Data analysis

The children's BMI was calculated from the weight (kg) and height (cm) reported by the parents. The classification for the weight status into obesity, overweight, normal, and underweight groups followed the BMI/age chart standard for school-age children based on WHO (2007). In the present paper, the classification of children according to their weight status will be divided into two groups; the normal weight group consisted of underweight and normal BMI, whereas the overweight and obese subjects were merged into an overweight/obese group. Parent's education, responsible person for preparing meals at home, frequency of eating together in the family, and frequency of eating snacks or sweets of the children were analysed descriptively.

The association between taste sensitivity and eating behaviour was investigated using linear regression with the CEBQ score as the response variable and detection threshold of the six different taste compounds employed as the explanatory variables. The models were computed for each CEBQ domain and each taste compound separately (eight CEBQ domains and six taste compounds).

The FPQ score of eating frequency for each food item was converted into Daily Frequency Equivalence (DFE) following a study by Laureati et al. (2020). The score was computed by converting the eating frequency scale proportionally into one equivalence a day (the score of DFE= 1, meaning that the food item was consumed daily). The DFE score for eating frequency in the present study became as follows: DFE 0 = never/rarely, 0.07 = 1–3 times/month, 0.25 = 1–3 times/week, 1 = daily, 2 = more than once a day. The relationship between taste sensitivity and food propensity was analysed using a mixed model ANOVA with FPQ score (DFE) as a response variable. The detection threshold level and different taste quality of sweet, sour, salty, bitter-caffeine, and umami were employed as explanatory variables. In this model, the interaction between the detection threshold and taste quality was included and children was involved as random effect. The restricted maximum likelihood (REML) method was applied for fitting the model. To further investigate the effect of FPQ per food taste (i.e., sweet foods, sour foods, salty foods, etc.), five linear regression models were computed with taste detection threshold as explanatory variable and FPQ scores per food as response variables. The detection threshold of caffeine was chosen to represent the bitterness sensitivity as this compound has more commonly been used in taste sensitivity and dietary studies than quinine (Ahrens, 2015; James et al., 1997; Puputti et al., 2019; Rodrigues et al., 2020). Moreover, caffeine is used as

the standard for measuring the bitterness sensitivity according to the international standardisation organization, ISO (2011).

The association between FPQ for dairy products and taste sensitivity was also evaluated using mixed model ANOVA. The FPQ score was employed as response variable while the detection threshold, dairy food items, and BMI were involved as explanatory variables. The models were computed separately for each basic taste and children nested within BMI was involved as a random effect. The significant differences across different BMI status (normal/underweight vs. overweight/obese) for each dairy food item was further computed using student t-test.

The association between taste sensitivity and BMI was investigated using linear regression models. The models were computed separately for each taste compound (sweet, sour, salty, bitter-caffeine, bitter-quinine, umami) as explanatory variables, BMI score was employed as a response variable, and gender as a control variable. Principal component analysis (PCA) was applied to map the associations between CEBQ, taste detection threshold, and BMI. The PCA was computed with children as rows and CEBQ (per domain) as columns, BMI and detection threshold were involved as supplementary variables. The significant differences between BMI groups of each eating behaviour domain were computed using a student t-test. All data were analysed using the XLSTAT Sensory version 2020.3.1 (Addinsoft, Paris, France).

Results

Family eating habits and children's BMI distribution

Most of the parents who participated in this study have a university degree (at least Bachelor's) as their highest level of education (79%). Mothers were most frequently responsible for cooking at home (55%), while fathers alone accounted for only 10%. Shared meal responsibility (mother and father) applied in 33% of the homes. Most of the children ate dinner together with their parents almost every day (93%), quite often for breakfast (46%) but less often for lunch (10%). In addition, more than 90% of the parents gave their child snacks or sweets 1–3 times per week.

Based on the computed BMI, most of the children were categorized to have a normal weight status (68%, n=46, 47% boys), followed by overweight (28%, n=19, 50% boys), obese (4%, n=3, 33% boys), and one child was categorized as underweight (1%, n=1). The gender distribution was quite balanced across the BMI groups.

Children's taste sensitivity and eating behaviour

The children's taste detection threshold was positively associated with some aspects of their eating behaviour, the effect size was, however, small with regression coefficients in the range 0.19 to 0.39 (Figure 1). A significant and positive association was found between food responsiveness and threshold for bitter caffeine (p=0.04). Children who were less sensitive (higher detection threshold), to caffeine bitterness had a higher food responsiveness score which indicates that these subjects tend to overeat. In addition, children less sensitive
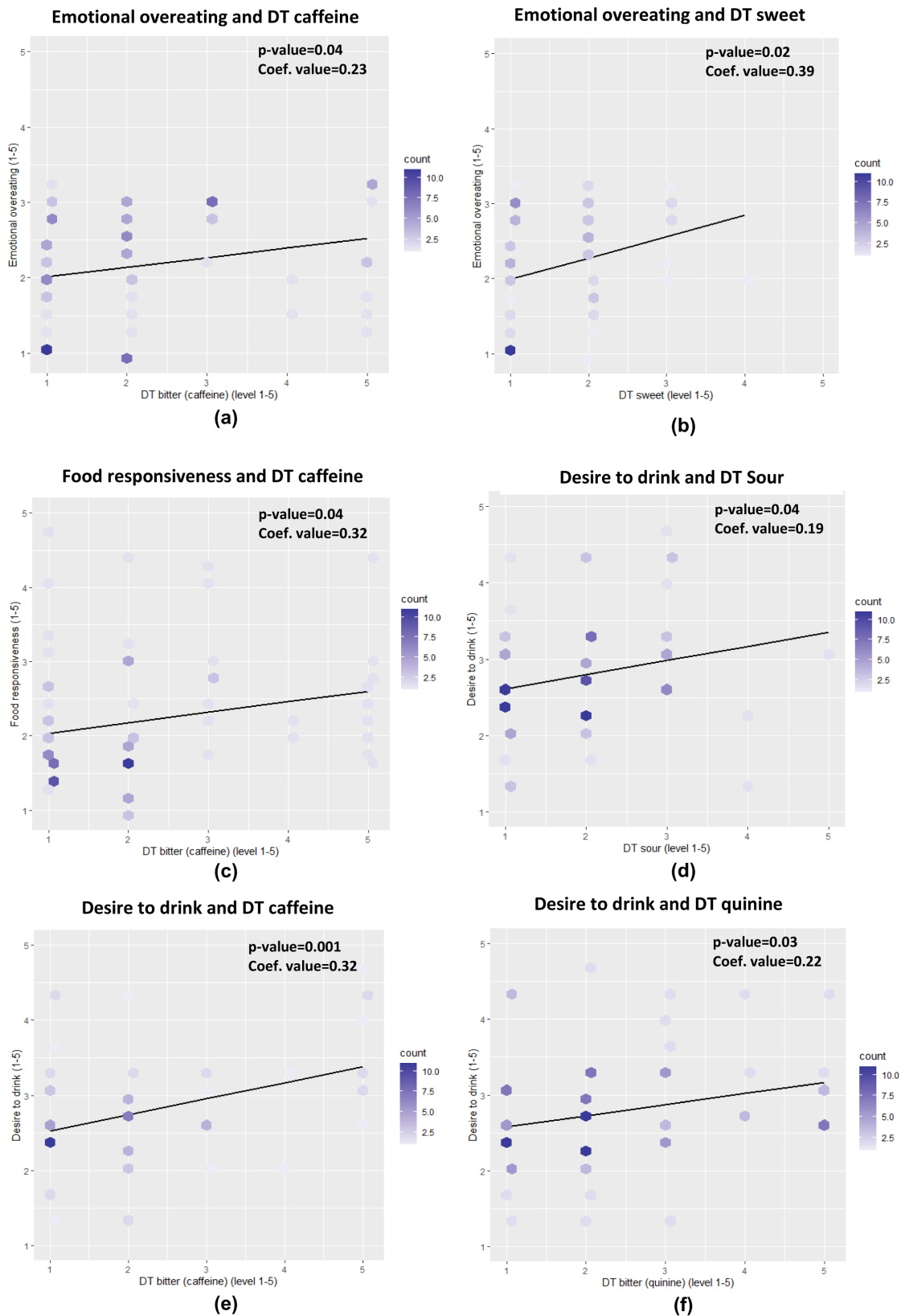
Figure 1. The associations between children's taste sensitivity and eating behaviour for emotional overeating (**a**, **b**), food responsiveness (**c**), and desire to drink (**d**, **e**, **f**) (DT= detection threshold).

to sweetness (p=0.02) and caffeine bitterness (p=0.04), also have a significantly higher score for emotional overeating. Significant and positive associations were also found in sourness (p=0.04), bitterness of caffeine (p<0.01) and quinine (p=0.03) towards the desire to drink, demonstrating that children who were less sensitive to these tastes have a higher score for desire to drink.

Relationships between eating behaviour (CEBQ), food propensity (FPQ), and weight status (BMI)

The Cronbach's alpha of CEBQ showed a good internal consistency for both food approach and food avoidance (Cronbach's alpha = 0.84 and 0.75, respectively) and each of the CEBQ domains also showed a good internal consistency (all Cronbach's alpha ≥ 0.75) except for food fussiness and desire to drink (0.63 and 0.66, respectively). The PCA analysis showed that food responsiveness, emotional overeating, desire to drink, and enjoyment of food were positively associated with the children's BMI (Figure 2). In contrast, satiety responsiveness, slowness in eating, and food fussiness were associated with lower BMI on factor 1. The student t-test comparing the two groups (normal and overweight/obese) for each eating behaviour domain demonstrated a significantly higher score (p≤0.05) for overweight/obese children in

emotional overeating and food responsiveness. Moreover, normal weight subjects have a significantly higher score (p≤0.05) in satiety responsiveness and slowness in eating compared to the overweight/obese subjects. The PCA biplot (Figure 2) also displays positive associations between BMI and detection thresholds, where the detection thresholds were included as supplementary variables.

Based on linear regression, our results did not show a significant influence of taste sensitivity on children's BMI. Neither could we detect any significant effect of children's basic taste sensitivity on FPQ score in general, showing that taste sensitivity threshold did not relate to frequency consumption of certain foods. However, when the BMI variable was involved in the model, there were significant differences in the FPQ for the selected dairy products between the normal weight and overweight/obese children. These differences were significant for semi-hard cheese (p=0.08), fermented milk (p=0.02), skimmed milk (p=0.03), and chocolate/strawberry flavoured milk (p≤0.01), showing that normal weight subjects frequently consumed these dairy food items compared to overweight/obese (Figure 3). Moreover, there was a tendency for the overweight/obese group to consume more low-fat milk (0.5–1.8% fat) compared to the normal weight group (p=0.1).
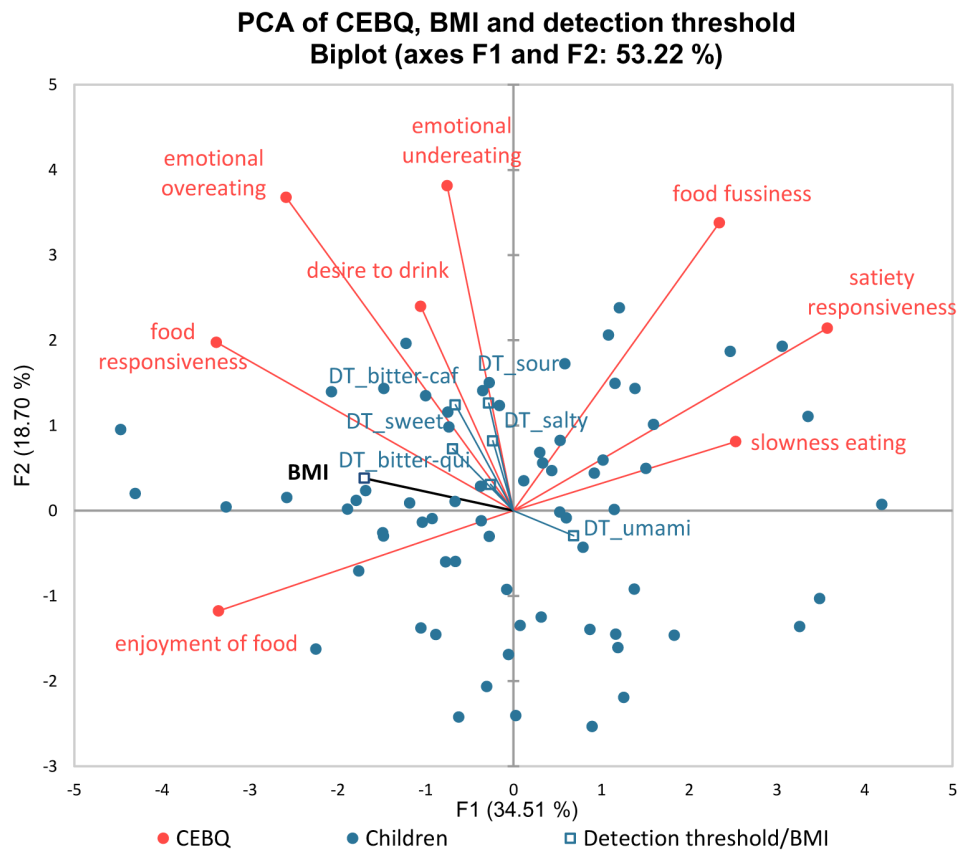

Figure 2. PCA biplot of CEBQ, detection thresholds, and BMI (DT=detection threshold; PCA = principal component analysis; CEBQ = Child Eating Behaviour Questionnaire; BMI = body mass index).
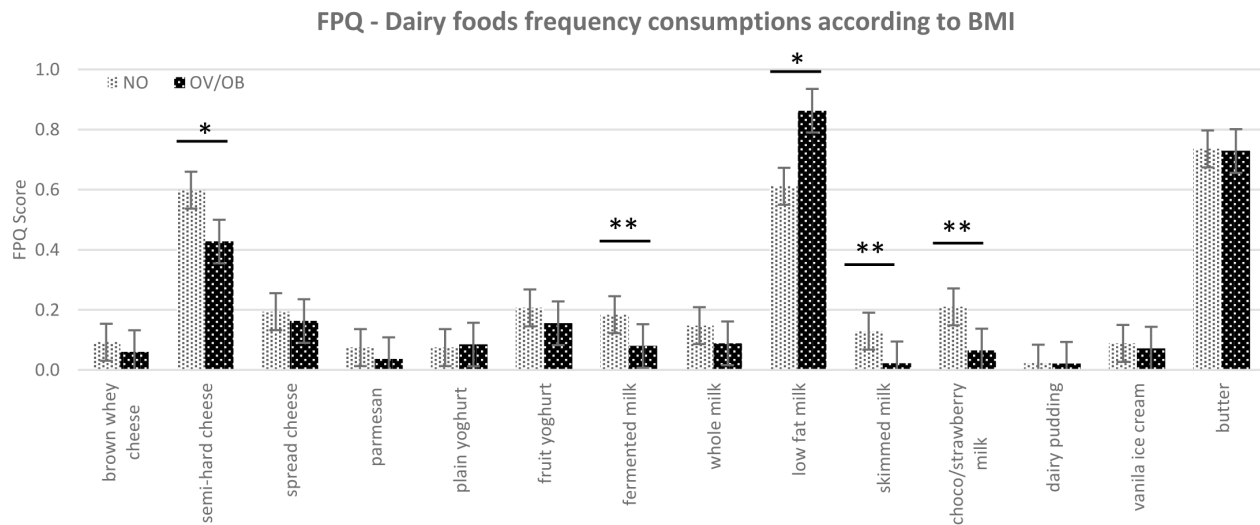
FPQ - Dairy foods frequency consumptions according to BMI

Figure 3. The food frequency consumption (FPQ) of dairy food items according to children's BMI (NO=normal weight children; OV/OB=overweight/obese children; FPQ = Food Propensity Questionnaire; BMI = body mass index), *p≤0.1, **p≤0.05 based on mean value on student t-test.

Discussion

Children's BMI

According to the Norwegian Institute of Public Health (2018), the prevalence for overweight and obesity in nine-year-old children was recorded to be 18% and 3%, respectively, where girls have a slightly higher prevalence of overweight (19%). These numbers corroborate a previous study by Juliusson *et al.* (2010) who calculated the overweight and obesity prevalence with more than 6000 Norwegian school children from 2–19 years old. Their research highlighted a higher prevalence of overweight and/or obesity in children aged 6–11 years (17%) than in younger children aged 2–5 years (12.7%) and the risk was increased with lower parental education. Our results showed a higher number for overweight (28%) compared to the literature. This could be due to erroneous data from parents since the BMI data were not collected by direct anthropometry measurement and could also be an artefact of our small sample size or reflect regional differences. Despite the increase in prevalence of obesity in Europe, Norway was able to keep the obesity rate lower compared to other European countries. A recent study comparing obesity prevalence in Europe in primary school children demonstrated that overweight, obesity, and severe obesity prevalence vary greatly across Europe with the highest value recorded in southern Europe (Greece and Spain, total prevalence 42–47%), while countries in northern Europe have lower prevalence (Norway, Sweden, 23–25%) (Spinelli *et al.*, 2019).

Associations between children's basic taste sensitivity and eating behaviour

The results showed that children who were less sensitive to caffeine bitterness have a higher food responsiveness score. Bitter taste is commonly associated with food aversion (Reed & Knaapila, 2010; Reed *et al.*, 2006) and this taste acts as a "barrier"

for humans not to ingest poisonous foods (Mennella & Bobowski, 2015) since bitter taste is biologically linked with poisonous substances (Reed & Knaapila, 2010). The higher food responsiveness score reflects a higher appetite and an increased desire to eat (French *et al.*, 2012). The association between low sensitivity to bitterness and higher food responsiveness could be explained by the loosening "barrier" of bitter taste that may be triggering children to eat more food types, and therefore more food in general. A study by Goldstein *et al.* (2007) also provides a similar result to our study, showing that nine-year-old children who were less sensitive to bitterness of PROP had a higher daily energy intake compared to children who were sensitive to bitterness. This result shows an association between bitterness sensitivity and food intake that could correspond to food responsiveness in CEBQ.

Emotional overeating in CEBQ represents an increase in food intake as a response to negative emotions such as anxiety, anger, and boredom (Freitas *et al.*, 2018). Our results show that children who were less sensitive to sweetness and bitterness of caffeine have a higher emotional overeating score. This could increase their food intake when they experience negative emotions. Comfort foods such as sweet and fatty foods have been reported to be typically consumed in the presence of negative emotions (Jacques *et al.*, 2019; Michels *et al.*, 2012; Pilska & Nesterowicz, 2016; van Strien *et al.*, 2013). Negative emotions can modulate desire to eat (Macht, 2008) and subjects with emotional eating attitudes have learned to cope with their negative feelings by eating comfort foods as a way to find satisfaction (Adam & Epel, 2007; Macht, 2008; Michels *et al.*, 2012). Michels *et al.* (2012) also conclude that eating triggered by negative emotions in children aged 5–12 years was positively correlated with their sweet food consumption. In addition, Ashi *et al.* (2017) reported that

children aged 13–15 years who were less sensitive to sweetness had a significantly higher intake for sweet foods. These findings could support the association between sweet taste sensitivity and emotional overeating behaviour found in our study. Further, several studies have suggested that low sensitivity to bitterness could increase children's food intake (Goldstein *et al.*, 2007; Keller & Adise, 2016; Tepper *et al.*, 2011). Previous studies also report that food intake in children could be modulated by negative emotions (Hill *et al.*, 2018; Macht, 2008; Michels *et al.*, 2012). This could explain the relationships found between sensitivity to bitterness and emotional overeating in this study.

Our results also show that taste sensitivity for sourness and bitterness (both caffeine and quinine) were significantly associated with desire to drink. The CEBQ domain for desire to drink aimed to identify children's desire for drinking, in particular for sweetened beverages, and this domain has previously been associated with food approach (Freitas *et al.*, 2018; Quah *et al.*, 2019; Sweetman *et al.*, 2008; Vandeweghe *et al.*, 2016; Wardle *et al.*, 2001). Our result corroborates with a previous study by Mennella *et al.* (2005), which demonstrated that 5-10-year-old children who were not sensitive to PROP bitterness had heightened preferences for sweet beverages and soft drinks, and preferred more sugar added in their cereals and beverages. Interestingly, the sourness perception and thirst regulation occurred via the same acid-sensing receptor cell, which is called polycystic kidney disease 2-like 1 (PKD2L1) (Bichet, 2018; Gravina *et al.*, 2013). A study by Zocchi *et al.* (2017) also revealed that mice without PKD2L1 showed a total loss in water and acid responses, indicating that this receptor plays an important role in both water and sourness perceptions. This suggests that the activation in the receptor cell PKD2L1 due to sourness perception could modulate desire to drink. The involvement of the same receptor in the molecular mechanism of perception could be a potential underlying reason for the significant relationship found between sourness sensitivity and desire to drink in this study.

Caffeine and quinine sensitivities and eating behaviour

In our study, children's food responsiveness and emotional overeating were associated with sensitivity to caffeine bitterness but not to quinine bitterness. Preadolescent children demonstrated individual differences in the perception of different bitter compounds such as caffeine and quinine, as was reported in a previous paper using data from the same participants (Ervina *et al.*, 2020). The different bitter taste compounds have different bitterness profiles, and they elicit various intensity perceptions of bitterness (Kamerud & Delwiche, 2007; Yokomukai *et al.*, 1993). Compared to the other four basic tastes, bitter taste has the largest number and greatest variety of compounds, with more than 25 bitterness receptors responsible for bitter taste perceptions in humans (Meyerhof *et al.*, 2010; Roura *et al.*, 2015). Caffeine and quinine may not activate the same bitterness receptors, and this could result in differences in bitterness perception (Kamerud & Delwiche, 2007). Moreover, these two bitter compounds are not found in the same foods, which may also explain the different

relationships between bitterness in quinine and caffeine and eating behaviour in children.

Eating behaviour is influenced by many factors (DeCosta *et al.*, 2017; Scaglioni *et al.*, 2018) such as parental feeding practices, family environments, parents' education and economic condition, the obesogenic environment, and media exposure. Our results indicate that taste sensitivity also modulates eating behaviour in preadolescents.

Relationship between basic taste sensitivity and FPQ
According to our results, no significant associations were found between taste detection threshold and FPQ score for any of the five taste modalities. Further analyses did not show any systematic relationships between detection thresholds and food propensity for a given taste (i.e., between sweet threshold and sweet foods, salty threshold with salty foods, etc.). These results indicate that basic taste sensitivity did not systematically relate to the eating frequency of foods with the same dominant basic taste.

Parents of preadolescents still act as the primary food providers at home and have control over their child's eating practices (Houldcroft *et al.*, 2016). Moreover, preadolescents have been characterized as curious and autonomous eaters, but their drinking and eating habits are still framed by their parental food practices (Nicklaus, 2020). The children's eating frequency recorded by FPQ may not, however, capture what is children's "actual" consumption but rather indicate what is "served" to them by their parents. FQP filled in by parents will, for instance, not reflect food that is consumed without parental supervision (i.e., eating outside home). In the USA, as many as 35% of children in early adolescence have been reported to eat outside home, with a big contribution of fast food (Reicks *et al.*, 2015). The FQP may therefore have low precision when it comes to revealing possible relations between food frequency and taste sensitivity. Differences between reports by parents and children could be of interest for follow-up studies. Further studies on relations between taste sensitivity and food propensity should both involve a more complete FPQ, as well as a larger number of subjects.

Association between dairy food propensity and children's BMI
There were significant differences in the frequency consumption of dairy foods across different BMIs. The differences were significant in fermented milk, skimmed milk, and flavoured milk (chocolate/strawberry milk). Low-fat milk is the only dairy food that was consumed more frequently by the overweight/obese group, while the other dairy foods (semi-hard cheese, fermented milk, skimmed milk, and flavoured milk) were consumed more frequently by normal-weight children or consumed in nearly equal frequency between the groups (for example butter and cheese spread).

The Norwegian legislation (2015) classifies pasteurized milk into three categories according to fat content; full fat milk (≥ 3.5% fat), low-fat milk (0.5–1.8% fat), and skimmed milk

(< 0.5% fat). The Norwegian Directorate of Health (2016) recommends low-fat milk for regular consumption. Milk is a standard lunch drink in Norway, and it is therefore also recommended that schools in Norway only serve drinking milk with ≤ 0.7% fat content (low-fat). This could explain the higher consumption of low-fat milk compared to whole milk or skimmed milk in our results. Moreover, the higher consumption of low-fat milk in the overweight/obese group probably appears because parents choose dairy milk products with lower fat content when they realize their child is overweight/obese, especially as almost 80% of the parents in this study had a high education level (bachelor's degree or higher). This could also be the reason for the lower cheese and flavoured milk consumption in overweight/obese children since these products have a high fat or sugar content. Parental education level has been reported to be positively associated with diet quality of children aged 10–11 years (Cribb et al., 2011; van Ansem et al., 2014). These diets are characterized by a lower intake in sugar and fat (Fernandez-Alvira et al., 2013). Moreover, in the obesogenic environment, control and monitoring of children's food environment and intake by parents were essential to reduce children's weight status to be close to normal weight (Gahagan, 2012). In addition, a recent systematic and meta-analysis review by Vanderhout et al. (2020) suggested that higher consumption of whole milk is associated with low adiposity in childhood, which could be related to the results found in our study.

Relationships between children's basic taste sensitivity, BMI, and eating behaviour

Our results did not show a significant association between taste sensitivity and BMI in preadolescents. However, previous studies suggest that overweight and obese children have a lower taste sensitivity (Cox et al., 2016; Overberg et al., 2012; Papantoni et al., 2021; Rodrigues et al., 2020). The reason we could not find a relationship between taste sensitivity and BMI could be due to our small data set and the unbalanced number of children between the BMI groups (70% normal weight and 30% overweight/obese). However, Cox et al. (2016) reported that the relationship between taste sensitivity and weight in children is still debatable and requires more evidence. A recent study investigating taste sensitivity and BMI in children aged 7–12 years found no significant differences for sweetness and bitterness sensitivity between the normal-weight and overweight groups (Lim et al., 2021). A similar result was also reported by Alexy et al. (2011) in a study involving a large sample set of 574 children and adolescents aged 10–17 years. Their study concluded that there was no significant difference in basic taste sensitivity across different BMIs. Factors other than taste sensitivity such as food preferences, parental feeding practices, genetic factors, obesogenic environment, and family social economic status have been reported to play significant roles in the determination of children's BMI (Donaldson et al., 2009; Leonie et al., 2018; Lytle, 2009; Scaglioni et al., 2018; Woo Baidal et al., 2016).

Correlations were found between children's BMI and their eating behaviour based on the PCA mapping. The results indicated that the food approach domains such as food responsiveness, emotional overeating, desire to drink, and enjoyment of foods were positively associated with children's BMI, while food avoidance such as satiety responsiveness, slowness in eating, and food fussiness were negatively correlated with children's BMI. The differences between the BMI groups were confirmed with student t-tests. Our results corroborate previous studies that used the same CEBQ instrument (Sanchez et al., 2016; Santos et al., 2011; Viana et al., 2008; Webber et al., 2009). These results are also in agreement with several other previous studies (French et al., 2012; Santos et al., 2011; Tay et al., 2016; Webber et al., 2009). Eating behaviour of food approach in CEBQ has previously been associated with increased BMI in children (Braet & Van Strien, 1997; Vandeweghe et al., 2016).

The PCA mapping also demonstrated that a higher detection threshold (lower taste sensitivity), may relate to a higher BMI, and this might be associated with the food-approach domain of CEBQ. Children's BMI has been reported to differ according to their taste sensitivity (Cox et al., 2016; Overberg et al., 2012; Papantoni et al., 2021) and children's eating behaviour in the food approach domain was also strongly correlated with higher BMI (Freitas et al., 2018; French et al., 2012; Quah et al., 2019; Sanchez et al., 2016). This indicates that taste sensitivity could mediate the complex interplay between eating behaviour and BMI in preadolescent children.

Study limitations

Our study involved a limited number of participants and an unbalanced number of children for each BMI group, as a result of recruitment of whole school classes. We recommend involving more participants and to have a balanced number between normal and overweight/obese subjects for future studies. One possibility could be by involving hospitals or healthcare centres that are dealing with obesity treatment in children. Moreover, the children's BMI was determined by a parent-reported questionnaire of body weight and height. An actual anthropometric measurement of children's weight and height is recommended for more precise data (Linchey et al., 2019).

There was a possibility of cross-modal correspondence effect in our study between taste and visual stimuli because we were using different symbols to label different taste compounds of the samples. For example, the use of a "cloud" symbol to represent sweet taste could influence children's perception due to this cross-modal effect. Spence (2011) reported that cross-modal correspondence between different sensory modalities such as between visual and taste stimuli could influence taste perception. A previous study also reports a significant association between certain symbols and specific taste of cheeses, suggesting a moderate effect of cross-modal correspondence in sensory perceptions (Spence et al., 2013).

Conclusion

This study aimed to investigate the association between taste sensitivity and eating behaviour in preadolescents. The results

indicate a positive association between higher detection threshold (lower sensitivity) and higher scores in the food approach domain of CEBQ. There was no influence of children's taste sensitivity on their food propensity. However, children differed according to their BMI for the propensity of dairy foods. Further, our results confirmed a positive relationship between children's BMI and food approach, and a negative relationship between BMI and food avoidance. To our current knowledge, this is the first study to investigate the association between taste sensitivity and eating behaviour in 11-year-old children with all basic tastes (sweetness, sourness, saltiness, bitterness, umami) and with two bitter taste compounds of caffeine and quinine employed in the study. This study contributes to understanding the association between taste sensitivity and eating behaviour of preadolescent children by considering their taste sensitivity. The results could be used as preliminary findings to design future studies involving a larger number of participants as well as other cultures.

Data availability
Underlying data
Zenodo: Taste sensitivity and eating behaviour of preadolescent children - extended data. https://doi.org/10.5281/zenodo.5468625 (Ervina, 2021).

This project contains the following underlying data within the file 'Extended data taste sensitivity and eating behaviour (2).xlsx':

- Complete data (consisted of children's and parents' responses, including the taste detection threshold data, parents' education, children's BMI, CEBQ and FPQ)

- CEBQ data (consisted of parents' responses for each domain of CEBQ)

Extended data
Zenodo: Taste sensitivity and eating behaviour of preadolescent children - extended data. https://doi.org/10.5281/zenodo.5468625 (Ervina, 2021).

This project contains the following extended data within the file 'Extended data taste sensitivity and eating behaviour (2).xlsx':

- CEBQ_Quest (CEBQ questionnaire in English and Norwegian)

- FPQ_Quest (FPQ questionnaire in English)

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).

References

Adam TC, Epel ES: **Stress, eating and the reward system.** *Physiol Behav.* 2007; **91**(4): 449–458.
PubMed Abstract | **Publisher Full Text**

Ahrens W: **Sensory taste preferences and taste sensitivity and the association of unhealthy food patterns with overweight and obesity in primary school children in Europe—a synthesis of data from the IDEFICS study.** *Flavour.* 2015; **4**(1): 8.
Publisher Full Text

Alexy U, Schaefer A, Sailer O, *et al.*: **Sensory Preferences and Discrimination Ability of Children in Relation to Their Body Weight Status.** *J Sens Stud.* 2011; **26**(6): 409–412.
Publisher Full Text

Ashi H, Campus G, Berteus Forslund H, *et al.*: **The Influence of Sweet Taste Perception on Dietary Intake in Relation to Dental Caries and BMI in Saudi Arabian Schoolchildren.** *Int J Dent.* 2017; **2017**: 4262053.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Bell KI, Tepper BJ: **Short-term vegetable intake by young children classified by 6-n-propylthoiuracil bitter-taste phenotype.** *Am J Clin Nutr.* 2006; **84**(1): 245–251.
PubMed Abstract | **Publisher Full Text**

Bichet DG: **Vasopressin and the Regulation of Thirst.** *Ann Nutr Metab.* 2018; **72 Suppl 2**: 3–7.
PubMed Abstract | **Publisher Full Text**

Boesveldt S, Bobowski N, McCrickerd K, *et al.*: **The changing role of the senses in food choice and food intake across the lifespan.** *Food Qual Prefer.* 2018; **68**: 80–89.
Publisher Full Text

Braet C, Van Strien T: **Assessment of emotional, externally induced and restrained eating behaviour in nine to twelve-year-old obese and non-obese children.** *Behav Res Ther.* 1997; **35**(9): 863–873.
PubMed Abstract | **Publisher Full Text**

Chamoun E, Mutch DM, Allen-Vercoe E, *et al.*: **A review of the associations between single nucleotide polymorphisms in taste receptors, eating behaviors, and health.** *Crit Rev Food Sci Nutr.* 2018; **58**(2): 194–207.
PubMed Abstract | **Publisher Full Text**

Cox DN, Hendrie GA, Carty D: **Sensitivity, hedonics and preferences for basic tastes and fat amongst adults and children of differing weight status: A comprehensive review.** *Food Qual Prefer.* 2016; **48**(B): 359–367.
Publisher Full Text

Cribb VL, Jones LR, Rogers IS, *et al.*: **Is maternal education level associated with diet in 10-year-old children?** *Public Health Nutr.* 2011; **14**(11): 2037–2048.
PubMed Abstract | **Publisher Full Text**

De Cosmi V, Scaglioni S, Agostoni C: **Early Taste Experiences and Later Food Choices.** *Nutrients.* 2017; **9**(2): 107.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

DeCosta P, Møller P, Frøst MB, *et al.*: **Changing children's eating behaviour - A review of experimental research.** *Appetite.* 2017; **113**: 327–357.
PubMed Abstract | **Publisher Full Text**

Donaldson LF, Bennett L, Baic S, *et al.*: **Taste and weight: is there a link?** *Am J Clin Nutr.* 2009; **90**(3): 800S–803S.
PubMed Abstract | **Publisher Full Text**

Ervina E: **Taste sensitivity and eating behaviour of preadolescent children-extended data [Excel].** Repository: *Zenodo.* 2021.
http://www.doi.org/10.5281/zenodo.5468625

Ervina E, Berget I, Almli VL: **Investigating the Relationships between Basic Tastes Sensitivities, Fattiness Sensitivity, and Food Liking in 11-Year-Old Children.** *Foods.* 2020; **9**(9): 1315.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Farrow CV, Coulthard H: **Relationships between sensory sensitivity, anxiety and selective eating in children.** *Appetite.* 2012; **58**(3): 842–846.
PubMed Abstract | **Publisher Full Text**

Fernandez-Alvira JM, Mouratidou T, Bammann K, *et al.*: **Parental education and frequency of food consumption in European children: the IDEFICS study.** *Public Health Nutr.* 2013; **16**(3): 487–498.
PubMed Abstract | **Publisher Full Text**

Freitas A, Albuquerque G, Silva C, *et al.*: **Appetite-Related Eating Behaviours: An Overview of Assessment Methods, Determinants and Effects on Children's Weight.** *Ann Nutr Metab.* 2018; **73**(1): 19–29.
PubMed Abstract | **Publisher Full Text**

French SA, Epstein LH, Jeffery RW, *et al.*: **Eating behavior dimensions. Associations with energy intake and body weight. A review.** *Appetite.* 2012; **59**(2): 541–549.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Gahagan S: **Development of eating behavior: biology and context.** *J Dev Behav Pediatr.* 2012; **33**(3): 261–271.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Gibson EL, Kreichauf S, Wildgruber A, *et al.*: **A narrative review of psychological and educational strategies applied to young children's eating behaviours aimed at reducing obesity risk.** *Obes Rev.* 2012; **13 Suppl 1**: 85–95.
PubMed Abstract | **Publisher Full Text**

Givens DI: *MILK Symposium review:* **The importance of milk and dairy foods in the diets of infants, adolescents, pregnant women, adults, and the elderly.** *J Dairy Sci.* 2020; **103**(11): 9681–9699.
PubMed Abstract | **Publisher Full Text**

Goldstein GL, Daun H, Tepper BJ: **Influence of PROP taster status and maternal variables on energy intake and body weight of pre-adolescents.** *Physiol Behav.* 2007; **90**(5): 809–817.
PubMed Abstract | **Publisher Full Text**

Gravina SA, Yep GL, Khan M: **Human biology of taste.** *Ann Saudi Med.* 2013; **33**(3): 217–222.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Hansen LB, Myhre JB, Johansen AMW, *et al.*: **UNGKOST 3 Landsomfattende kostholdsundersøkelse blant elever i 4. -og 8. Klasse i Norge, 2015**. 2016.
Reference Source

Hartvig D, Hausner H, Wendin K, *et al.*: **Quinine sensitivity influences the acceptance of sea-buckthorn and grapefruit juices in 9- to 11-year-old children.** *Appetite.* 2014; **74**: 70–78.
PubMed Abstract | **Publisher Full Text**

Hill DC, Moss RH, Sykes-Muskett B, *et al.*: **Stress and eating behaviors in children and adolescents: Systematic review and meta-analysis.** *Appetite.* 2018; **123**: 14–22.
PubMed Abstract | **Publisher Full Text**

Houldcroft L, Farrow C, Haycraft E: **Perceptions of parental pressure to eat and eating behaviours in preadolescents: The mediating role of anxiety.** *Appetite.* 2014; **80**: 61–69.
PubMed Abstract | **Publisher Full Text**

Houldcroft L, Farrow C, Haycraft E: **Eating Behaviours of Preadolescent Children over Time: Stability, Continuity and the Moderating Role of Perceived Parental Feeding Practices.** *Int J Environ Res Public Health.* 2016; **13**(4): 437.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Hughes SO, Frazier-Wood AC: **Satiety and the Self-Regulation of Food Take in Children: a Potential Role for Gene-Environment Interplay.** *Curr Obes Rep.* 2016; **5**(1): 81–87.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

ISO: **ISO 3972 Methodology of Sensory Analysis**. In *Method of Investigating Sensitivity of Taste*. Geneva, Switzerland International Organization for Standardization. 2011; **3972: 2011**.
Reference Source

Jacques A, Chaaya N, Beecher K, *et al.*: **The impact of sugar consumption on stress driven, emotional and addictive behaviors.** *Neurosci Biobehav Rev.* 2019; **103**: 178–199.
PubMed Abstract | **Publisher Full Text**

James CE, Laing DG, Oram N: **A comparison of the ability of 8– 9-year-old children and adults to detect taste stimuli.** *Physiol Behav.* 1997; **62**(1): 193–197.
PubMed Abstract | **Publisher Full Text**

Jilani H, Peplies J, Buchecker K: **Assessment of Sensory Taste Perception in Children**. In K. Bammann, L. Lissner, I. Pigeot, & W. Ahrens (Eds.), *Instruments for Health Surveys in Children and Adolescents*. 2019; 257–275.
Reference Source

Joseph PV, Reed DR, Mennella JA: **Individual differences among children in sucrose detection thresholds: relationship with age gender, and bitter taste genotype.** *Nurs Res.* 2016; **65**(1): 3–12.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Juliusson PB, Eide GE, Roelants M, *et al.*: **Overweight and obesity in Norwegian children: prevalence and socio-demographic risk factors.** *Acta Paediatr.* 2010; **99**(6): 900–905.
PubMed Abstract | **Publisher Full Text**

Kamerud JK, Delwiche JF: **Individual differences in perceived bitterness predict liking of sweeteners.** *Chem Senses.* 2007; **32**(9): 803–810.
PubMed Abstract | **Publisher Full Text**

Keller KL, Adise S: **Variation in the Ability to Taste Bitter Thiourea Compounds: Implications for Food Acceptance, Dietary Intake, and Obesity Risk in Children.** *Annu Rev Nutr.* 2016; **36**: 157–182.
PubMed Abstract | **Publisher Full Text**

Keller KL, Steinmann L, Nurse RJ, *et al.*: **Genetic taste sensitivity to 6-n-propylthiouracil influences food preference and reported intake in preschool children.** *Appetite.* 2002; **38**(1): 3–12.
PubMed Abstract | **Publisher Full Text**

Kershaw JC, Mattes RD: **Nutrition and taste and smell dysfunction.** *World J Otorhinolaryngol Head Neck Surg.* 2018; **4**(1): 3–10.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Kildegaard H, Tønning E, Thybo AK: **Preference, liking and wanting for beverages in children aged 9–14 years: Role of sourness perception,**

chemical composition and background variables.** *Food Qual Prefer.* 2011; **22**(7): 620–627.
Publisher Full Text

Kim GH, Lee HM: **Frequent consumption of certain fast foods may be associated with an enhanced preference for salt taste.** *J Hum Nutr Diet.* 2009; **22**(5): 475–480.
PubMed Abstract | **Publisher Full Text**

Knof K, Lanfer A, Bildstein MO, *et al.*: **Development of a method to measure sensory perception in children at the European level.** *Int J Obes (Lond).* 2011; **35 Suppl 1**: S131–136.
PubMed Abstract | **Publisher Full Text**

Laureati M, Pagliarini E, Toschi TG, *et al.*: **Research challenges and methods to study food preferences in school-aged children: A review of the last 15 years.** *Food Qual Prefer.* 2015; **46**: 92–102.
Publisher Full Text

Laureati M, Sandvik P, Almli L, *et al.*: **Individual differences in texture preferences among European children: Development and validation of the Child Food Texture Preference Questionnaire (CFTPQ).** *Food Qual Prefer.* 2020; **80**: 103828.
Publisher Full Text

Leonie BH, Wolters M, Börnhorst C, *et al.*: **Dietary habits and obesity in European children.** *Ernaehrungs Umschau international.* 2018; **10**.
Reference Source

Li T, Zhao M, Raza A, *et al.*: **The effect of taste and taste perception on satiation/satiety: a review.** *Food Funct.* 2020; **11**(4): 2838–2847.
PubMed Abstract | **Publisher Full Text**

Liem DG: **Infants' and children's salt taste perception and liking: A review.** *Nutrients.* 2017; **9**(9): 1011.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Liem DG, Russell CG: **The Influence of Taste Liking on the Consumption of Nutrient Rich and Nutrient Poor Foods.** *Front Nutr.* 2019; **6**: 174.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Lim LS, Tang XH, Yang WY, *et al.*: **Taste Sensitivity and Taste Preference among Malay Children Aged 7 to 12 Years in Kuala Lumpur—A Pilot Study.** *Pediatr Rep.* 2021; **13**(2): 245–256.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Linchey JK, King B, Thompson HR, *et al.*: **Parent Underestimation of Child Weight Status and Attitudes towards BMI Screening.** *Health Behav Policy Rev.* 2019; **6**(3): 209–218.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Lytle LA: **Examining the etiology of childhood obesity: The IDEA study.** *Am J Community Psychol.* 2009; **44**(3–4): 338–349.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Macht M: **How emotions affect eating: a five-way model.** *Appetite.* 2008; **50**(1): 1–11.
PubMed Abstract | **Publisher Full Text**

Martin C, Visalli M, Lange C, *et al.*: **Creation of a food taste database using an in-home "taste" profile method.** *Food Qual Prefer.* 2014; **36**: 70–80.
Publisher Full Text

Mennella JA, Bobowski NK: **The sweetness and bitterness of childhood: Insights from basic research on taste preferences.** *Physiol Behav.* 2015; **152**(Pt B): 502–507.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Mennella JA, Pepino MY, Reed DR: **Genetic and environmental determinants of bitter perception and sweet preferences.** *Pediatrics.* 2005; **115**(2): 216–222.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Meyerhof W, Batram C, Kuhn C, *et al.*: **The molecular receptive ranges of human TAS2R bitter taste receptors.** *Chem Senses.* 2010; **35**(2): 157–170.
PubMed Abstract | **Publisher Full Text**

Michels N, Sioen I, Braet C, *et al.*: **Stress, emotional eating behaviour and dietary patterns in children.** *Appetite.* 2012; **59**(3): 762–769.
PubMed Abstract | **Publisher Full Text**

Mohd Nor ND, Houston-Price C, Harvey K, *et al.*: **The effects of taste sensitivity and repeated taste exposure on children's intake and liking of turnip (*Brassica* rapa subsp. rapa); a bitter *Brassica* vegetable.** *Appetite,.* 2021; **157**: 104991.
PubMed Abstract | **Publisher Full Text**

Nguyen SP, Girgis H, Robinson J: **Predictors of children's food selection: The role of children's perceptions of the health and taste of foods.** *Food Qual Prefer.* 2015; **40 Pt A**: 106–109.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Nicklaus S: **Relationships between early flavor exposure, and food acceptability and neophobia.** In P. Etiévant, E. Guichard, C. Salles, & A. Voilley (Eds.), Cambridge: Woodhead Publishing. *Flavor.* 2016; 293–311.
Publisher Full Text

Nicklaus S: **Eating and Drinking in Childhood**. In H. L. Meiselman (Ed.), *Handbook of Eating and Drinking*.Cham: Springer Nature. 2020; 391–412.
Publisher Full Text

Njardvik U, Klar EK, Thorsdottir F: **The factor structure of the Children's Eating Behaviour Questionnaire: A comparison of four models using confirmatory factor analysis.** *Health Sci Rep.* 2018; **1**(3): e28.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Norwegian Institute of Public Health: **Overweight and obesity in adolescents (Indicator 13)**. 2018.
Reference Source

Norwegian-Legislation: **Forskrift om kvalitet på melk og melkeprodukter**. 2015.
Reference Source

Oellingrath IM, Hersleth M, Svendsen MV: **Association between parental motives for food choice and eating patterns of 12- to 13-year-old Norwegian children.** *Public Health Nutr.* 2013; **16**(11): 2023–2031.
PubMed Abstract | **Publisher Full Text**

Overberg J, Hummel T, Krude H, *et al.*: **Differences in taste sensitivity between obese and non-obese children and adolescents.** *Arch Dis Child.* 2012; **97**(12): 1048–1052.
PubMed Abstract | **Publisher Full Text**

Papantoni A, Shearrer GE, Sadler JR, *et al.*: **Longitudinal Associations Between Taste Sensitivity, Taste Liking, Dietary Intake and BMI in Adolescents.** *Front Psychol.* 2021; **12**: 597704.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Pilska M, Nesterowicz J: **Emotional Determinants of Sweets Consumption.** *Journal of Nutrition and Health Sciences.* 2016; **3**(4).
Publisher Full Text

Puputti S, Aisala H, Hoppu U, *et al.*: **Factors explaining individual differences in taste sensitivity and taste modality recognition among Finnish adults.** *J Sens Stud.* 2019; **34**(4): e12506.
Publisher Full Text

Quah PL, Fries LR, Chan MJ, *et al.*: **Validation of the Children's Eating Behavior Questionnaire in 5 and 6 Year-Old Children: The GUSTO Cohort Study.** *Front Psychol.* 2019; **10**: 824.
Publisher Full Text

Reed DR, Knaapila A: **Genetics of taste and smell: poisons and pleasures.** *Prog Mol Biol Transl Sci.* 2010; **94**: 213–240.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Reed DR, Tanaka T, McDaniel AH: **Diverse tastes: Genetics of sweet and bitter perception.** *Physiol Behav.* 2006; **88**(3): 215–226.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Reicks M, Banna J, Cluskey M, *et al.*: **Influence of Parenting Practices on Eating Behaviors of Early Adolescents during Independent Eating Occasions: Implications for Obesity Prevention.** *Nutrients.* 2015; **7**(10): 8783–8801.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Rodrigues L, Silverio R, Costa AR, *et al.*: **Taste sensitivity and lifestyle are associated with food preferences and BMI in children.** *Int J Food Sci Nutr.* 2020; **71**(7): 875–883.
PubMed Abstract | **Publisher Full Text**

Roura E, Aldayyani A, Thavaraj P, *et al.*: **Variability in Human Bitter Taste Sensitivity to Chemically Diverse Compounds Can Be Accounted for by Differential TAS2R Activation.** *Chem Senses.* 2015; **40**(6): 427–435.
PubMed Abstract | **Publisher Full Text**

Sanchez U, Weissstaub G, Santos JL, *et al.*: **GOCS cohort: children's eating behavior scores and BMI.** *Eur J Clin Nutr.* 2016; **70**(8): 925–928.
PubMed Abstract | **Publisher Full Text**

Santos JL, Ho-Urriola JA, González A, *et al.*: **Association between eating behavior scores and obesity in Chilean children.** *Nutrition Journal.* 2011; **10**: 108.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Scaglioni S, De Cosmi V, Ciappolino V, *et al.*: **Factors Influencing Children's Eating Behaviours.** *Nutrients.* 2018; **10**(6): 706.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Shen Y, Kennedy OB, Methven L: **Exploring the effects of genotypical and phenotypical variations in bitter taste sensitivity on perception, liking and intake of brassica vegetables in the UK.** *Food Quality and Preference.* 2016; **50**: 71–81.
Publisher Full Text

Sleddens EF, Kremers SP, Thijs C: **The children's eating behaviour questionnaire: factorial validity and association with Body Mass Index in Dutch children aged 6-7.** *Int J Behav Nutr Phys Act.* 2008; **5**: 49.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Spence C: **Crossmodal correspondences: a tutorial review.** *Atten Percept Psychophys.* 2011; **73**(4): 971–995.
PubMed Abstract | **Publisher Full Text**

Spence C, Ngo MK, Percival B, *et al.*: **Crossmodal correspondences: Assessing

shape symbolism for cheese.** *Food Quality and Preference.* 2013; **28**(1): 206–212.
Publisher Full Text

Spinelli A, Buoncristiano M, Kovacs VA, *et al.*: **Prevalence of Severe Obesity among Primary School Children in 21 European Countries.** *Obes Facts.* 2019; **12**(2): 244–258.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Sweetman C, Wardle J, Cooke L: **Soft drinks and 'desire to drink' in preschoolers.** *Int J Behav Nutr Phys Act.* 2008; **5**: 60.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Tay CW, Chin YS, Lee ST, *et al.*: **Association of Eating Behavior With Nutritional Status and Body Composition in Primary School-Aged Children.** *Asia Pac J Public Health.* 2016; **28**(5 Suppl): 47S–58S.
PubMed Abstract | **Publisher Full Text**

Tepper BJ: **Nutritional Implications of Genetic Taste Variation: The Role of PROP Sensitivity and Other Taste Phenotypes.** *Annu Rev Nutr.* 2008; **28**(1): 367–388.
PubMed Abstract | **Publisher Full Text**

Tepper BJ, Neilland M, Ullrich NV, *et al.*: **Greater energy intake from a buffet meal in lean, young women is associated with the 6-n-propylthiouracil (PROP) non-taster phenotype.** *Appetite.* 2011; **56**(1): 104–110.
PubMed Abstract | **Publisher Full Text**

The Norwegian Directorate of Health: **The Norwegian dietary guidelines**. Oslo: Helsedirektoratet. 2016.
Reference Source

Totland TH, Benedicte KM, Ninna LH, *et al.*: **Norkost 3**. 2012.
Reference Source

van Ansem WJ, Schrijvers CT, Rodenburg G, *et al.*: **Maternal educational level and children's healthy eating behaviour: role of the home food environment (cross-sectional results from the INPACT study).** *Int J Behav Nutr Phys Act.* 2014; **11**: 113.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

van Strien T, Cebolla A, Etchemendy E, *et al.*: **Emotional eating and food intake after sadness and joy.** *Appetite.* 2013; **66**: 20–25.
PubMed Abstract | **Publisher Full Text**

Vanderhout SM, Aglipay M, Torabi N, *et al.*: **Whole milk compared with reduced-fat milk and childhood overweight: a systematic review and meta-analysis.** *Am J Clin Nutr.* 2020; **111**(2): 266–279.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Vandeweghe L, Vervoort L, Verbeken S, *et al.*: **Food Approach and Food Avoidance in Young Children: Relation with Reward Sensitivity and Punishment Sensitivity.** *Front Psychol.* 2016; **7**: 928.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Vennerød FFF, Almli VL, Berget I, *et al.*: **Do parents form their children's sweet preference? The role of parents and taste sensitivity on preferences for sweetness in pre-schoolers.** *Food Qual Prefer.* 2017; **62**: 172–182.
Publisher Full Text

Viana V, Sinde S, Saxton JC: **Children's Eating Behaviour Questionnaire: associations with BMI in Portuguese children.** *Br J Nutr.* 2008; **100**(2): 445–450.
PubMed Abstract | **Publisher Full Text**

Wardle J, Guthrie CA, Sanderson S, *et al.*: **Development of the Children's Eating Behaviour Questionnaire.** *J Child Psychol Psychiat.* 2001; **42**(7): 963–970.
PubMed Abstract | **Publisher Full Text**

Webb J, Bolhuis DP, Cicerale S, *et al.*: **The Relationships Between Common Measurements of Taste Function.** *Chemosens Percept.* 2015; **8**(1): 11–18.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Webber L, Hill C, Saxton J, *et al.*: **Eating behaviour and weight in children.** *Int J Obes (Lond).* 2009; **33**(1): 21–28.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

WHO: **The world health organization standard z-score chart BMI-for-age of school age children 5-19-year-old.** In *Growth references data.* 2007.

Woo Baidal JA, Locks LM, Cheng ER, *et al.*: **Risk Factors for Childhood Obesity in the First 1,000 Days: A Systematic Review.** *Am J Prev Med.* 2016; **50**(6): 761–779.
PubMed Abstract | **Publisher Full Text**

Yokomukai Y, Cowart BJ, Beauchamp GK: **Individual differences in sensitivity to bitter-tasting substances.** *Chem Senses.* 1993; **186**: 669–681.
Publisher Full Text

Zocchi D, Wennemuth G, Oka Y: **The cellular mechanism for water detection in the mammalian taste system.** *Nat Neurosci.* 2017; **20**(7): 927–933.
PubMed Abstract | **Publisher Full Text**