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The ability of 10–11-year-old children to identify basic tastes and their liking towards unfamiliar foods

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ABSTRACT

The involvement of children in sensory evaluation and consumer research continues to increase and has become crucial in the food industry, as children sensory perceptions differ from adults. Research on basic taste sensitivity in children provides contradictory results, with most of the studies not considering the familiarity aspect of the food samples. Familiarity can lead children to memories of the food which are able to influence their taste perception and liking. This study aims to investigate the ability of 10 to 11-year old children in identifying sweetness, saltiness, sourness, and bitterness in unfamiliar food samples. The taste identification data was collected from 98 children using 19 food samples representing the four basic tastes of sweet, sour, salty, and bitter. For each food sample, the children evaluated their familiarity, the basic taste(s) they perceived using the check-all-that-apply (CATA) method and scored their liking. Their basic taste identification ability was investigated by comparing their results to trained panellists as a reference. The food samples were unfamiliar to most of the children (never tasted by 85% of the children on average). Correspondence Analysis (CA) showed that children were able to identify the basic tastes of sweet, sour, salty, and bitter in the unfamiliar foods, with a high congruency to the trained panellists. However, children's identification ability was lower when combinations of dominant basic tastes occurred. Principal Component Analysis (PCA) demonstrated a positive correlation between the presence of sweet taste and the children's liking while sour and bitter tastes showed the opposite.

1. Introduction

Children have become one of the largest market segments for major brands and corporations. The purchasing influence of children under the age of 15 in the USA market is estimated to be more than $300 billion with 60% of this market represented by the foods and beverages sector (Popper & Kroll, 2011). This has resulted in the increasing involvement of children in sensory and consumer research. They participate not only in projects related to product development, but also in studies relating sensory aspects to healthy eating and behaviour (Laureati, Pagliarini, Toschi, & Monteleone, 2015). Performing sensory testing with children is important, but also challenging because they have immature physiological and cognitive abilities (Jilani, Peplies, & Buchecker, 2019). Oram and colleagues (2001) investigated children's chemosensory skills and reported that 8–9 year old children have limited perceptual-attentional skills to analyse the complex stimuli of the combination of basic tastes in sensory testing. Therefore, sensory testing with children should use different methods compared to testing with adults (Popper & Kroll, 2011; Laureati et al., 2015). A rapid sensory method in children such as Check-All-That-Apply (CATA) was suggested by Laureati and Pagliarini (2018) due to its simplicity. Moreover, children have different perception patterns of tastes (Drewnowski, Mennella, Johnson, & Bellisle, 2012) and preferences towards foods compared to adults (Forestell & Mennella, 2015). Children aged 5–10 years old reported to prefer salty taste in broth (Julie A Mennella, Finkbeiner, Lipchock, Hwang, & Reed, 2014), and they preferred a higher level of sweetness in lemonade beverages (Zandstra & de Graaf, 1998) than adults. In addition, children's gustatory and olfactory abilities to investigate food are still questionable, particularly in terms of their taste acuity (Oram, Laing, Freeman, & Hutchinson, 2001; Wendin, Prim, & Magnusson, 2017) and reliability (Visser, Kroeze, Kamps, & Bijleveld, 2000).

Children's taste perception ability begins to develop during the gestation period (Bradley & Stern, 1967; Mistretta and Bradley, 1975) with the exposure of nutrients and tastes from the mother's diet via the amniotic fluid (Mennella, 2007). This implies that children have been

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exposed to different tastes and aroma stimuli even before they were born (Ventura & Worobey, 2013), thus triggering the development of their taste preferences before birth (Birch, 1999; Ganchrow & Mennella, 2003). Taste perception and preferences will further develop as infants are exposed to different tastes and flavours through their mother's milk (Schwartz et al., 2017). A study by Forestell and Mennella (2017), suggested that infants are able to differentiate between the basic taste stimuli of sweet, sour, bitter and umami.

Studies investigating children's basic tastes perception provided contradictory outcomes. A study conducted by Laing et al. (2008) involving seven-year-old children reported that they had good ability to identify four basic tastes and food odorants. With regard to saltiness, some research indicated that children aged 6–12 year old have poor taste perception (Baker, Didcock, Kemm, & Patrick, 1983; Zandstra & de Graaf, 1998; Guinard, 2000) while other studies reported that they have higher taste sensitivity and preferences for salty taste compared to adults (Baker et al., 1983; Beauchamp & Cowart, 1990). On the contrary, Liem (2017) concluded that there was no strong evidence regarding the differences of saltiness sensitivity level between children and adults suggesting that they have a similar perception to the intensity of salty taste. However, Beauchamp and Cowart (1990) report that 5–10 year old children preferred higher concentrations of salt in broth and this result positively correlated with the intake of salty foods in their daily diet but not with their sensitivity to saltiness.

In addition, adolescent children showed a stronger correlation between sodium intake and the perceived intensity of salty taste compared to adults (Quader et al., 2017). Similar results were also obtained for sweetness in 5–10 year old (Mennella, Pepino, & Reed, 2005), 4–6 year old (Vennerød, Nicklaus, Lien, & Almli, 2018) and one-year-old children (Drewnowski et al., 2012). Further, a study from Liem, Mars, and de Graaf (2004) suggests that children as young as five years old showed good consistency in discriminating different sweetness levels in orangeade beverages.

With regard to bitterness, children aged 5–10 years old have been reported to have individual preferences according to their genetic determinants (Mennella et al., 2005) and they have a higher perception for bitter taste than adults (Mennella, Spector, Reed, & Coldwell, 2013). This affects children's food intake of fruit and vegetables (Bell & Tepper, 2006), food preferences (Negri et al., 2012), and food neophobia (Laureati, Bertoli, et al., 2015).

With regard to sourness, there has been inconclusive research investigating children's ability to identify sour taste (Liem & de Graaf, 2004). Vennerød, Hersleth, Nicklaus, and Almli (2017) conducted a taste sensitivity study in 4-year-old children, using equivalent concentration levels of the ISO 3972 standard across basic tastes. These authors observed better taste detection ability for sourness than for the other basic tastes, suggesting the need to decrease the sourness intensity of reference concentrations in the ISO standard. Furthermore, sour taste was not investigated in the other taste sensitivity studies involving 3–10 year old children (Knof et al., 2011; Lanfer et al., 2013). As for umami, age was reported to have a significant effect in perceiving umami taste, indicating that 13-year-old children have a lower sensitivity for this taste than 16–18 year-old adolescents (Overberg, Hummel, Krude, & Wiegand, 2012).

The taste perception ability in 9–11-year old children was previously assessed in a descriptive sensory evaluation test using chocolate products (Sune, Lacroix, & Huondekermadec, 2002). The results showed that the children had good capability in performing a descriptive test, in line with trained panellists. Nevertheless, the same study also revealed that the children had difficulty in describing complex sensory properties such as texture and mouthfeel as was also reported by Oram et al. (2001), suggesting a real semantic gap between children and trained panellists (Sune et al., 2002). Furthermore, as for adults, individual variation between children exists in sensory sensitivity towards different taste stimuli (Blissett & Fogel, 2013).

Most of the research investigating taste sensitivity in children have used aqueous taste solutions (Oram et al., 2001; Knof et al., 2011; Lanfer et al., 2012; Hartvig, Hausner, Wendin, & Bredie, 2014) or model food as the samples. The model foods that have been used in taste sensitivity studies are beverages (Liem & de Graaf, 2004; Vennerød et al., 2018), broth (Beauchamp & Cowart, 1990), or crackers (Lanfer et al., 2013; Mennella et al., 2014) that varied in the concentration level of the target tastes. When familiar food items are used in testing, the familiarity of the food could lead children to associate them with certain taste memories that might affect their taste perception (Laureati & Pagliarini, 2018). This stimulus context of the familiar food may also influence acceptance of the selected target tastes (James, Laing, Oram, & Hutchinson, 1999). As reported by Popper and Kroll (2011), children have the capability to memorize the enjoyment of food both in its taste and experience. Due to the increase in children's involvement in sensory evaluation studies there is a need to study children's ability to perceive and identify taste in complex stimuli. To our knowledge, no previous study has investigated preadolescent's ability to identify basic taste stimuli when the familiarity aspect of the food is taken away. In addition, complex food items were used in this study instead of designed model foods, ensuring more relevance for industry applications.

The objective of this study was to investigate the taste identification ability of 10 to 11-year old children in unfamiliar food samples, as well as their liking for unfamiliar foods representing different basic tastes. This age group was chosen because children this age are not highly neophobic (Dovey, Staples, Gibson, & Halford, 2008) and are able to perform self-administered tests with limited assistance from the experimenters (Popper & Kroll, 2011). Based upon previous research, we expect that children are better able to identify sweet taste than other basic tastes. Moreover, we expect that the combination of basic tastes that naturally exist in food will decrease children's taste identification ability.

2. Method

2.1. Participants

One hundred and five children aged between 10 and 11 years old from two local schools in the Follo region, Akershus district, Norway were invited to the study in late 2013. The ages of the children were not recorded, however, all the children were born in the same calendar year and attended the 5th grade of elementary school. In total, 98 children participated in this study, wherein 53% of the participants were boys and 47% were girls. Both the parents and their children were provided with information about the research objectives and activities in the form of a flyer, and parents had to fill out information addressing any dietary restrictions (i.e. due to religion, beliefs or personal health) of their children. Children who participated in this experiment gave their verbal consent in addition to the signed written consent from their parents. The children in one of the schools were also part of a food exposure intervention study that is controlled for in the data analysis of this study, but not reported in this paper (Nilsen, 2014). The children of the other school were only enrolled in the food tests reported here. The ethical clearance has been approved and all recruitment and data protection processes are in line with the regulation from The Norwegian Centre for Research Data (NSD) and refer to the Declaration of Helsinki.

2.2. Food samples

Nineteen food samples from five categories of dairy, meat based, cereals, fruit and vegetables, and sweets were tested by the children (Table 1). The unfamiliarity aspects of the food were taken into consideration in preselecting the food samples, meaning the selected items are not commonly served in the Norwegian diet, particularly for children, but are available in Norway (i.e. all the food samples were bought in Norway) and not known for triggering reactions of disgust (e.g., we

Table 1
Food samples.

Food Group	Food Samples	Week[1]	Dominant Taste	Evaluated[2] (n)	Unfamiliarity[3]		Actual tasting[4]	
					n	(%)	n	(%)
Dairy	Goat cheese	W1	Sour	92	86	93.5	88	95.6
	Fermented milk	W13	Sour, bitter	86	64	74.4	78	90.7
Meat based	Cocktail salami	W1	Salt	84	76	90.5	81	96.4
	Chorizo	W5	Salt, sweet	87	74	85.1	84	96.6
	Beef jerky	W13	Salt, sweet	89	79	88.8	84	94.4
	Crab stick	W13	Salt, sweet	90	73	81.1	80	88.9
Cereals	Durum wheat semolina	W1	Sweet	92	60	65.2	92	100.0
	Bulgur	W13	Sweet	90	83	92.2	89	98.9
Fruit and vegetables	Cucumber pickle	W1	Sour	94	74	78.7	84	89.4
	Grapefruit	W1	Sour, bitter	93	79	84.9	90	96.8
	Persimmon	W1	Sweet	93	75	80.6	91	97.8
	Artichoke heart	W5	Sour, salt	92	90	97.8	85	92.4
	Goji berry	W5	Bitter	87	80	92.0	85	97.7
	Kumquat	W5	Sour, bitter	90	84	94.4	86	95.6
	Water chestnut	W5	Bitter	92	73	79.4	88	95.6
	Carrot juice	W13	Sweet	89	76	85.4	89	100.0
Sweets	Coconut cubes	W5	Sweet	87	79	90.8	85	97.7
	Root beer	W5	Sweet	91	60	65.9	88	96.7
	Ginger candy	W13	Sweet	89	84	94.4	85	95.5
Mean ± SD				90 ± 3	76 ± 8	84.9	86 ± 4	95.6

[1] week of the food being evaluated.
[2] children who had joined the evaluation.
[3] children who had never tasted the food before the evaluation.
[4] children who chose to taste the food during evaluation.

did not serve snails, very smelly cheeses, etc.). The list of unfamiliar foods was developed by the research team and colleagues based on our experience and cultural knowledge. We validated our sample selection by collecting children's (un)familiarity response to the foods during the test. Moreover, the food samples also needed to reflect the four basic tastes of sweet, sour, salty, and bitter (umami was not included as a target taste as the pretesting indicated that this word was often unfamiliar to children in this age group). A preliminary study was thus conducted in order to select representative food samples based on their dominant taste(s), with dominant taste being defined as the most striking taste perception (Pineau et al., 2009). Seven well-trained sensory panellists were involved to test a total of 46 candidates of unfamiliar food samples. Working in pairs, the panellists determined by consensus one or two dominant basic taste sensations present in each sample. Principal Component Analysis (PCA) was used to map the samples according to its basic taste (PCA bi-plot available in Supplementary materials, Fig. S1). A subset of foods that showed distinct dominant basic taste(s) and were representative of the five food categories (Tugault-Lafleur & Black, 2019) were selected for testing with the children. In the selection process, foods that would be difficult to serve at school due to a long preparation time were not retained.

From the preliminary study, thirty-six unfamiliar food samples were selected in total, among which 15 food samples were used in the food exposure intervention study (Nilsen, 2014) and an additional two represented the umami taste; results from these 17 food samples are not reported here. The present paper reports on 19 unfamiliar food samples tested on the children to investigate their ability to identify sweet, sour, salty and bitter tastes. All the food samples were prepared in the sensory laboratory at Nofima in Aas, Norway and transported to the school on the same day of the evaluation. The food samples were prepared and served in a ready-to-eat form, which meant they were washed, peeled and cut into one bite portion sizes. Durum wheat semolina and bulgur were cooked in water. For practicality and safety reasons, all food samples were served and evaluated at room temperature.

2.3. Test procedure

All the tests were organized and conducted in the children's respective classrooms. A school environment was chosen instead of a laboratory setting because it is important to create a friendly atmosphere for the children (Mennella & Beauchamp, 2008; Jilani et al., 2019). We expected this to encourage them to join the evaluation to taste the unfamiliar food. All the children evaluated the 19 unfamiliar food samples over three sessions conducted in week one (6 items), week five (7 items) and week thirteen (6 items) (Table 1). In the first session (week 1), at the beginning of the test, children were asked to perform a sorting task consisting of 72 food item images in the form of cards. These included different food types (e.g. meat, vegetal and dairy products), as well as variations within a food category (e.g. red and black tomatoes, boiled and fried eggs, grated and cooked carrots). They were asked to sort the cards into two categories of "I have tasted" or "I have never tasted" this food before. The percentage of the tasted food items were recorded as the food variety background (FVB). In order to keep the unfamiliarity aspect during the evaluation, none of the test foods were presented in the sorting task.

In each session, the children were served a set of 6 or 7 unfamiliar food samples on individual trays. The samples were served all at a time, in randomized balanced order within, but not across sessions. The children's responses were recorded in a paper questionnaire. For each food sample, the children first reported their familiarity by choosing from the following options: "I have never seen this food before", "I have seen this food before, but have never tasted it", and "I have tasted this food before" adapted from Aldridge, Dovey, and Halford (2009) and their expected liking was recorded on a seven-point pictorial hedonic scale and measured just before they tasted the food samples. Afterwards, the children were invited to eat the food sample. They could freely eat the whole serving, taste only partially or decline tasting. This was reported on the questionnaire, which offered all three options to make sure the children fully understood that any of these behaviours was accepted. Spitting out could occur but was not reported on the questionnaire. The allergenicity of each sample was always announced (i.e. contains milk, gluten, etc.) before the evaluation to secure that only safe foods were served to each child.

During tasting, the children indicated their response towards their liking on a seven-point pictorial hedonic scale (Popper & Kroll, 2011; Kroll, 1990) and their willingness to taste this food again in the future

(7-point pictorial scale anchored with “NO!!” to the left, “Maybe” in the middle and “YES!!” to the right). The expected liking and the willingness to try the food again in the future are not reported in this paper. Additionally, the children indicated the dominant basic taste sensations that they perceived in a Check-all-that-apply (CATA) question offering four alternatives of sweet, sour, salty and bitter. In addition, children completed the Food Situations Questionnaire (FSQ) from Loewen and Pliner (2000) adapted to the Norwegian culture (e.g. lunch pack for a walk in the forest instead of picnic) to measure food neophobia. The FSQ was distributed to the children in week one and week five to measure the potential effect of the food exposure intervention study conducted in one of the schools. In the present study, it is important to verify that all children had stable FSQ scores at week one and week five to establish that there would be no effect from the food intervention study on the taste identification testing.

The children finished one session of food tasting in about 15 min and during the test they were provided enough break in between the food samples to rinse their mouth with water. All children tasted the same set of food samples in each session. The food samples were served in a 50 ml disposable plastic plate and introduced to the children in a one-bite portion size. The children received the food samples on a tray with rinsing water, plastic spoon, napkins, and a spitting cup along with the questionnaire. For each food sample, the front page of the questionnaire showcased a photo, the name of the food sample, and a short of non-taste-related sensory and non-hedonic information (Fig. 1). This information was provided aiming to break the barrier of the unfamiliar food sample (Mustonen, Rantanen, & Tuorila, 2009) and make it less intimidating to taste the samples (Dazeley & Houston-Price, 2015). During the evaluation, the children were asked to taste the food individually, quietly, and not to talk to one another.

2.4. Data analysis

To assist food sample selection among the original 36 candidate samples, a PCA was conducted on the taste identification response from the trained panel (bi-plots available in Supplementary material, Fig. S1). The FVB and FSQ scores between the two schools were compared using student t-tests to verify that they were similar and could be further analysed as one group. For each food sample, data from children who did not taste it were excluded from the analysis. The children's and trained panellists' taste identifications for each food were recorded as binary data. We conducted two different analyses to investigate the ability of children to identify basic tastes, first Correspondence Analysis (CA), then we developed and calculated a taste identification ability score. CA was performed on the contingency table of children's data with food samples as rows and basic tastes as columns, while taste identifications from the trained panellists were involved as supplementary columns. Additionally, the similarity between the children and the trained panel's taste identification was investigated by computing the RV coefficient for factors 1 and 2 from the distinct correspondence analyses. The closer the RV coefficient is to one, the higher the similarity between the matrices (Næs, Brockhoff, & Oliver, 2010).

The taste identification ability score was calculated for each child using the trained panellists' identification data as a reference for each food sample. Children received a score of 1 for each correctly ticked taste, and a score of -1 for each incorrect or omitted taste. For example, grapefruit is dominated by bitter and sour taste. If the children ticked only sour and not bitter, they received a score of $+1$ for sour and -1 for bitter; if they ticked both tastes they received $+1$ for each taste, and if they ticked none of these tastes they received -1 for each taste. As there were 19 samples, the ability scores per taste ranged between -19 as the lowest and 19 as the highest. The average of the score per taste was also calculated and compared.

A mixed model Analysis of Variance (ANOVA) was used to investigate the effects of gender and taste identification ability on liking. In this model, children were included as random effect and the restricted maximum likelihood (REML) method was used for fitting the model. The Agglomerative Hierarchical Clustering (AHC) was applied on the taste identification ability score, and liking for the different clusters were then compared. This was aimed to see if clusters based on taste recognition also differed according to liking. The relationship between the basic tastes reference (from the trained panel) for each unfamiliar food sample and children's liking was analysed by applying Principal Component Analysis (PCA) with liking included as a supplementary variable. This analysis aims to explain how liking relates to the actual product tastes, in a preference mapping principle. The average liking score for each basic taste were also calculated. The significant difference tests were calculated at a 95% confidence interval level ($p < 0.05$) for the univariate analysis and Tukey's test was applied for pairwise comparisons. All data was analysed using XLSTAT Sensory (version 2019.1.1, Addinsoft, France).

3. Results

3.1. Food variety background for schoolchildren participating in the study

There was no significant difference between the two participating schools regarding the children's FVB (*P-value* = 0.25) indicating that the children from these two schools had similar food variety backgrounds before they started the experiment. The FSQ scores also showed no significant differences before (*P-value* = 0.48) and after (*P-value* = 0.44) the intervention study or at week one and week five,

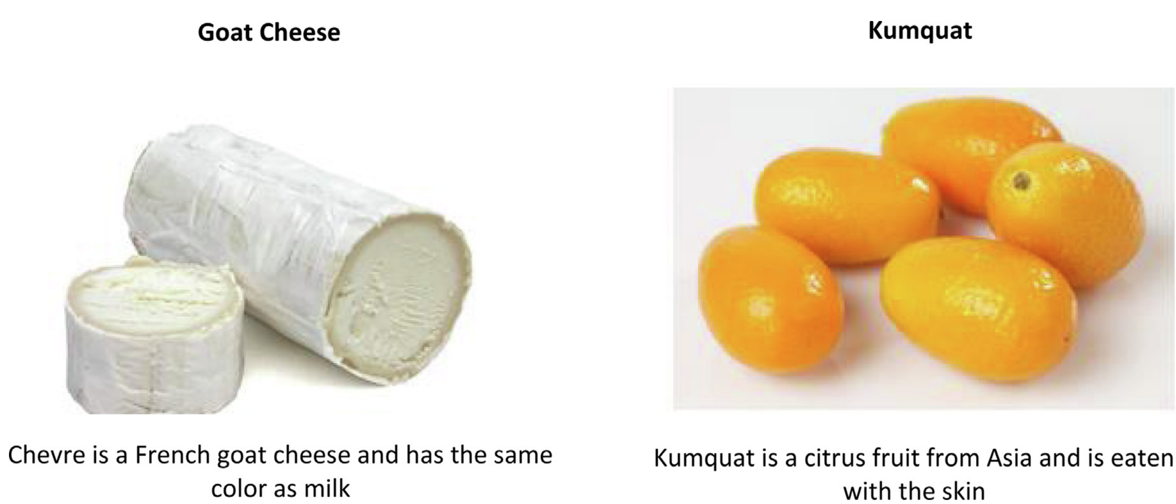

Fig. 1. Examples of the short information (name, photo, and non-taste-related sensory and non-hedonic information of the food sample).

respectively. This means that the children from these two schools had similar neophobic backgrounds and no significant effect of the intervention study occurred in the school that participated in the food exposure study that could affect children's perception on this experiment. Further results will consider the full sample of children as one data set.

3.2. Unfamiliarity and actual tasting of the food samples

The self-reported (un)familiarity revealed that on average, more than 80% of the children had never tasted the food samples prior to this experiment, which means most of the food samples were unfamiliar to them (Table 1). Artichoke heart (97.8%), kumquat (94.4%), and ginger candy (94.4%) had the highest unfamiliarity, while durum wheat semolina (65.2%) and root beer (65.9%) were the most previously tasted food samples by the children. Further, the data show a very high tasting rate of the test foods during the experiment, with a range between 88.9 and 100% of the children tasting the food samples in this study. The least tasted sample was crab stick (tasted by 88.9% of the children) while the most tasted samples were carrot juice and durum wheat semolina (tasted by 100% of the children, Table 1).

3.3. Children's basic tastes response

Fig. 2 presents the children's responses for the dominant taste of sweet, sour, salty and/or bitter for each food sample. It can be seen from the results that sweet taste was perceived as dominant in persimmon (0.87), followed by coconut cubes (0.79), and ginger candy (0.61), while sour taste was perceived as the most dominant in cucumber pickle (0.70), followed by kumquat (0.67), and grapefruit (0.61). Salty taste was perceived as dominant in chorizo (0.70), followed by cocktail salami (0.60), and beef jerky (0.55), while root beer (0.51), goat cheese (0.48), and grapefruit (0.45) were dominantly perceived as bitter.

CA was performed to create a basic taste identification mapping of the unfamiliar food samples in children and the trained panel (Fig. 3). The children's response of basic tastes showed a similar pattern to what was obtained with the description from the trained panel for sweet, salty, sour and bitter only with a clearer product differentiation by the panel on Factor 2. The RV coefficient between the configuration (with two factors) from the children's data and the panel description was 0.92, (p-value < 0.001). The high RV coefficient indicates a high similarity between the children and the trained panel in performing basic taste identification for the whole sample set of the unfamiliar foods.

3.4. Children's basic taste identification ability

The children's basic taste identification ability scores were calculated using the trained panel's responses as a reference. The average correctness scores for each basic taste were calculated based on the food samples that represented those tastes. The sour taste (9.4 ± 4.1 SD) and the salty taste (9.5 ± 4.0 SD) showed to have a significant higher correctness score compared to the sweet taste (4.4 ± 3.9 SD) and the bitter taste (5.1 ± 4.3 SD) (Fig. 4).

The children's ability to identify basic taste was then further investigated by calculating the percentage of children who correctly identified the dominant taste of sweet, sour, salty and bitter in each food sample (Fig. 5). Fig. 5 has also presented the dominant taste per each food samples and has adjusted to the number of children who performed the actual tasting. The highest correct taste identification rates were obtained with persimmon (86.7% correct) and coconut cubes (78.6%) which both are characterized by sweet taste. The lowest taste identification rates were obtained for root beer (28.7%, sweet) and goat cheese (33.3%, sour). The results indicate that children tended to have a higher identification ability for sweet taste, particularly when sweet taste was present as dominant single taste in the unfamiliar food.

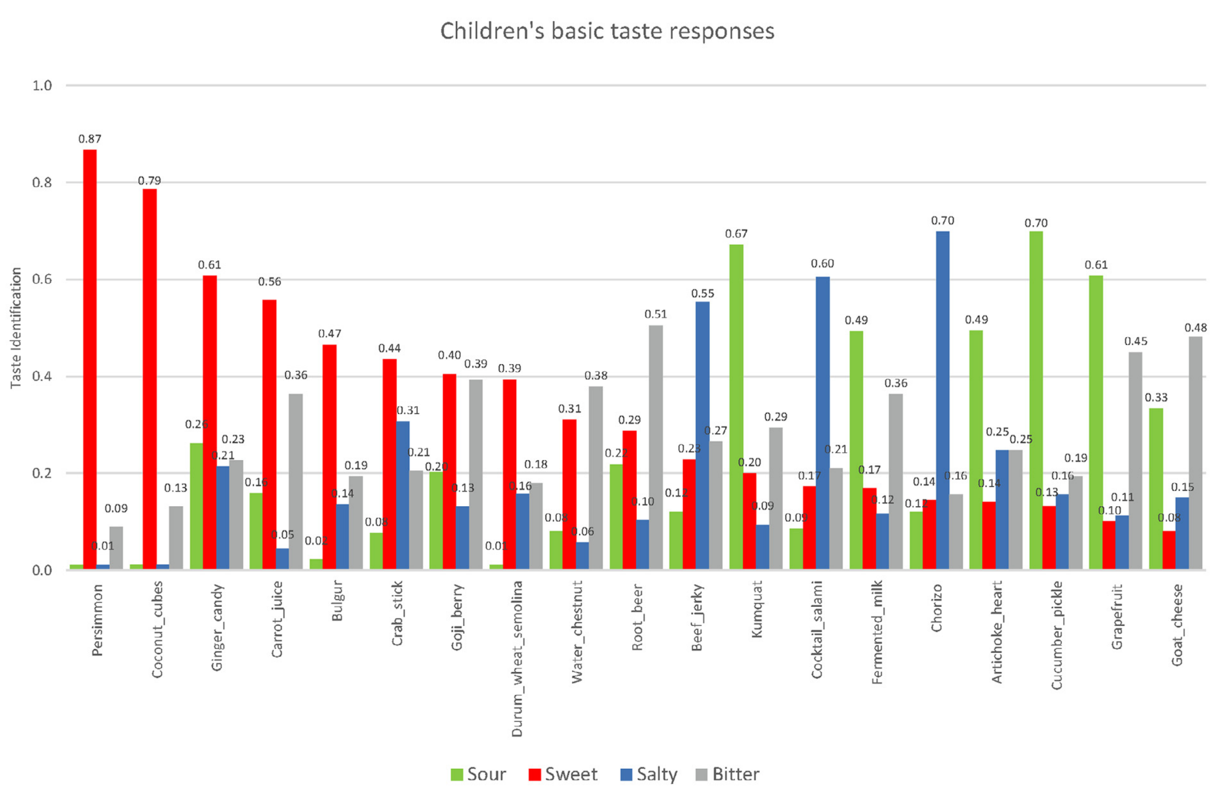

Fig. 2. Children's basic taste response per food sample, on average results (scale in binary 0–1, where 1, codes for dominance response of that taste).

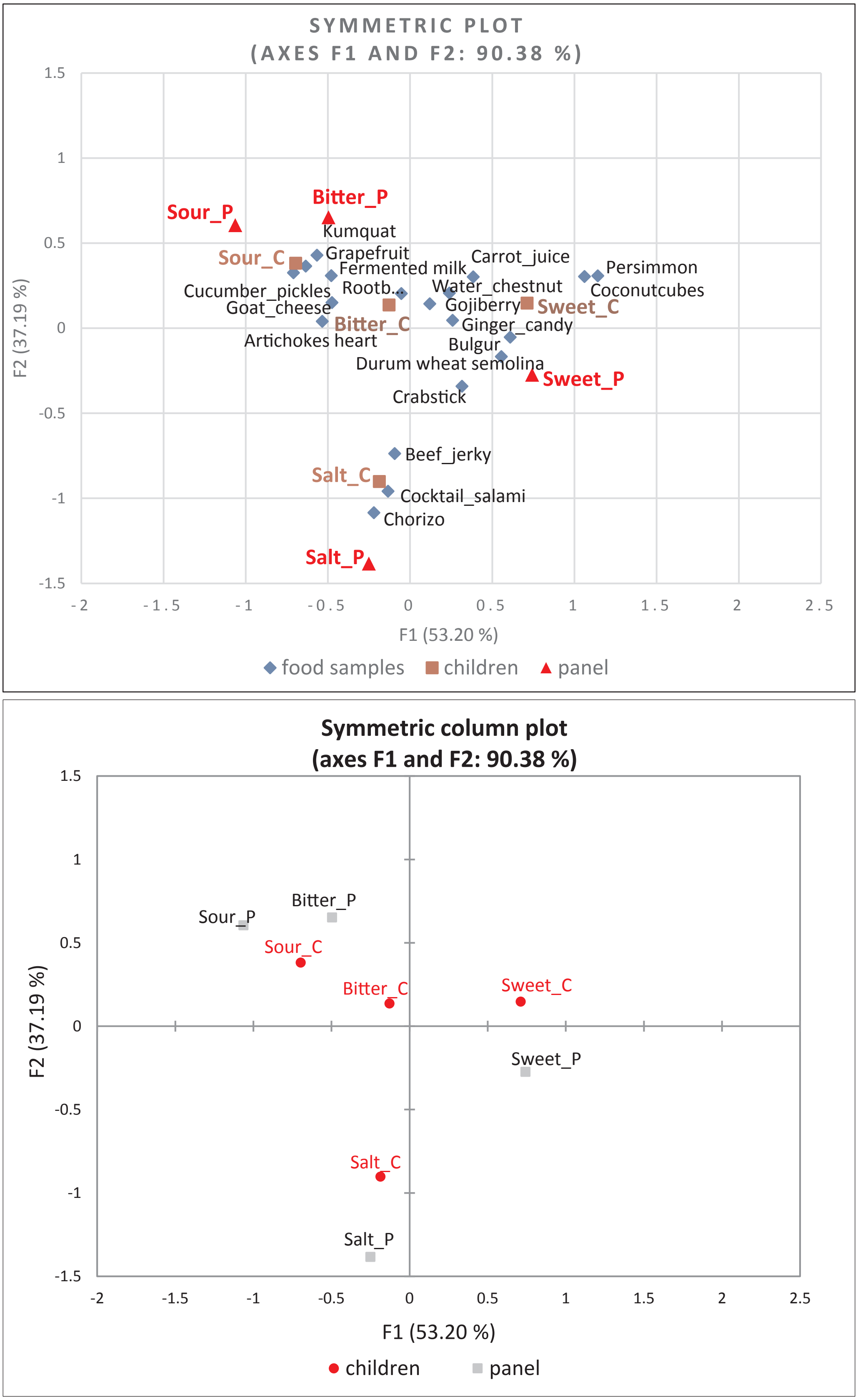

Fig. 3. Correspondence Analysis (CA) of taste identification between the children and the trained panel (P = panel, C = children).

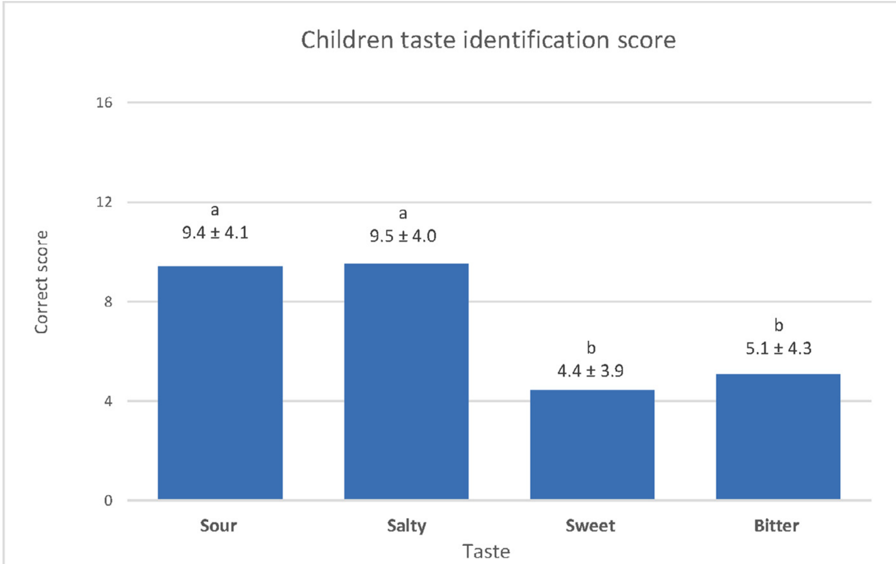

Fig. 4. Taste identification score. Different letters indicate significant differences in Tukey's pairwise comparison test ($p < 0.05$).

3.5. Children's liking

Fig. 6 presents the scatter plot of the basic taste identification of the children against liking for each food sample. Persimmon and coconut cubes were most often identified as sweet compared to other food samples and were most liked by the children. This is also supported by the results presented in Fig. 7 where the unfamiliar foods dominated by sweet taste were significantly the most liked (mean 4.9 ± 0.9 SD), while foods dominated by sour (mean 3.3 ± 1.2 SD) and bitter (mean 3.5 ± 1.3 SD) tastes were significantly least liked by the children.

The first two principal components of PCA analysis obtained from trained panel's response and children's liking explained 81.3% of the total variance (Fig. 8). The results showed a significant positive correlation to the liking for sweet taste (*Pearson* = 0.55, $p < 0.05$) and

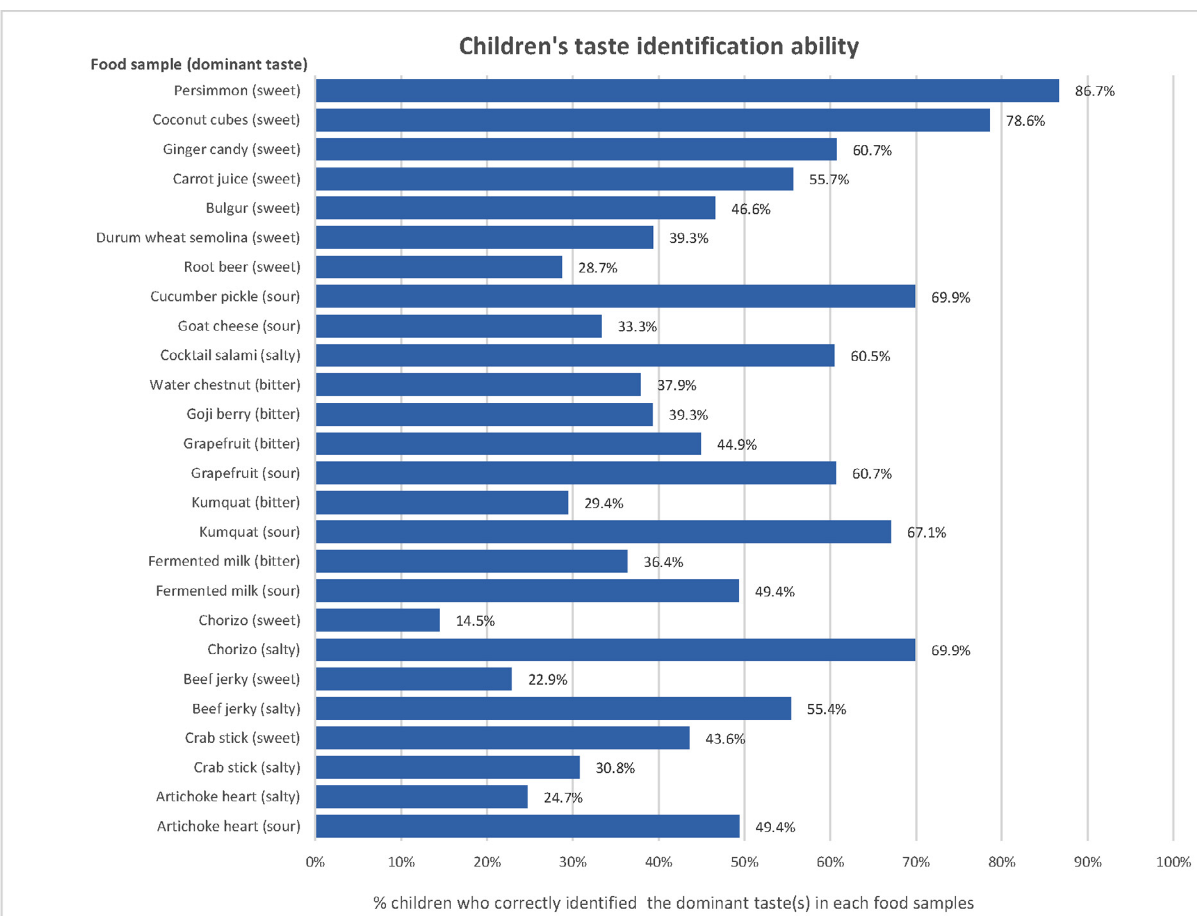

Fig. 5. Percentage of children who correctly identified basic taste(s) in each food samples.

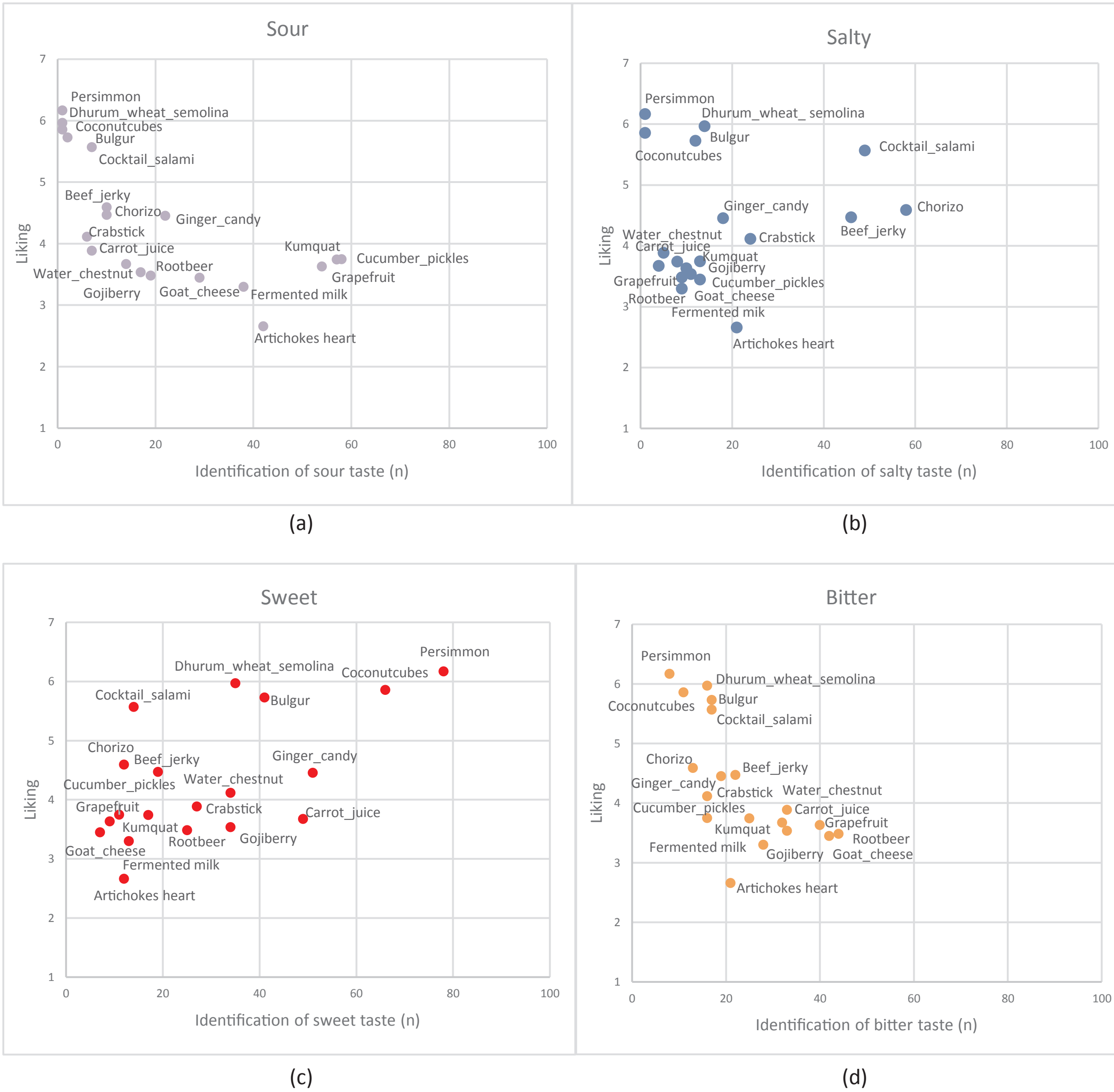

Fig. 6. The children's basic taste responses in relation to their liking of the food sample for sour (a), salty (b), sweet (c), and bitter (d) (n = number of children's responses).

significant negative correlation for sour taste (*Pearson* = -0.60, $p < 0.05$) and bitter taste (*Pearson* = -0.41, $p < 0.05$). Moreover, sweet taste also showed to have a strong negative correlation with sour (*Pearson* = -0.72, $p < 0.05$) and bitter (*Pearson* = -0.63, $p < 0.05$).

The exploration analysis conducted from the AHC method using children's taste identification score did not reveal any systematic patterns and correlations between the children's basic taste identification ability and their liking. This indicates that the children who correctly identified certain basic tastes did not consistently show higher or lower liking of that particular taste. Furthermore, there was no effect of gender on liking observed in this study (F = 0.31, *P-value* greater than 0.05).

4. Discussion

4.1. Children's taste identification ability

This study revealed that children were able to identify the basic tastes of sweet, salty, sour and bitter in unfamiliar foods with congruent results to a trained sensory panel as can be seen in the CA mapping. The basic taste responses of the children showed to be close to that of the trained panel for the whole sample set of unfamiliar foods. This relation was further highlighted through a significantly high RV coefficient between the children and the trained panel suggesting a high correlation and agreement in the basic taste identification between them. This result is aligned with the study from Laing et al. (2008) which reported that children were able to identify the four common tastes of salty, bitter, sour and sweet. Furthermore, results from James, Laing, Jinks, Oram, and Hutchinson (2004) also indicate that 8–9-year old children have the same response function of taste intensity as adults, particularly for sweet taste, concluding that children of this age had reached maturity for their suprathreshold perception of sweet stimuli. The taste identification study conducted by Mustonen et al. (2009) showed that sweet taste was the easiest and the most familiar taste to be identified by 7–11-year-old children, while bitter and umami was the most difficult to be identified by this age group. This corroborates our results where the taste identification ability of children was the highest for the sweet taste particularly when the sweet taste was shown to be the single dominant taste in the unfamiliar food sample and showed to be low in bitter taste.

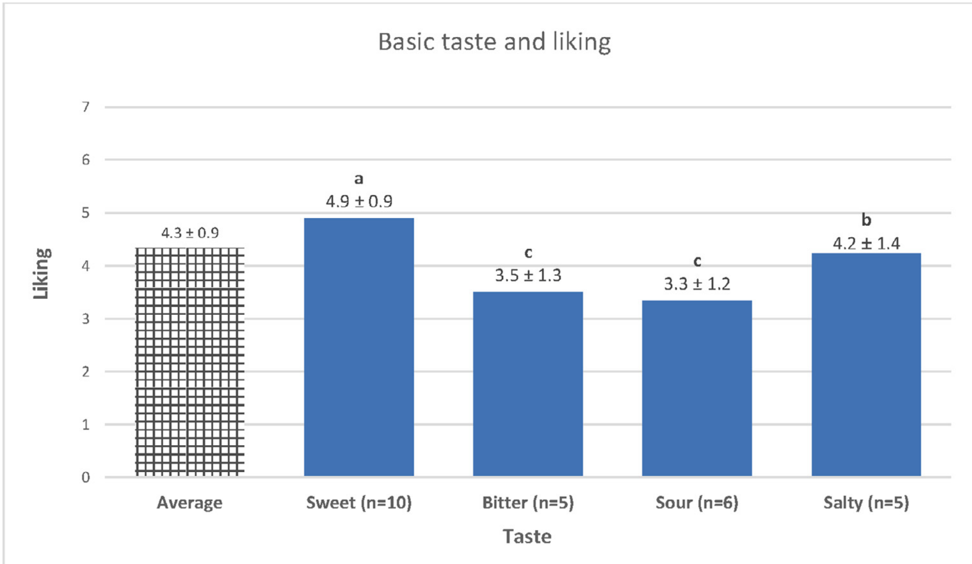

Fig. 7. Mean liking for food samples per dominant basic taste. Different letters indicate significant differences in Tukey's pairwise comparison test ($p < 0.05$), (n = number of actual dominant tastes occurred in food samples).

However, the children and trained panel seem to differ with regard to bitter taste as can be seen in Fig. 3. The children showed to have a lower average of taste identification score in food samples combining bitter and sweet dominance. They perceived root beer and goat cheese to be dominantly bitter whereas they should be sweet and sour, respectively. Root beer, known as vørterøl is a Norwegian traditional non-alcoholic malt beverage that has a sweet malty taste balanced with the fizzy sensation from the carbonation process of CO_2 (Carlsberg, 2019). The research by Lederer, Bodyfelt, and McDaniel (1991) suggested that the carbonation level generates a significant effect on bitterness and sourness perception. Moreover, another study by Hewson, Hollowood, Chandra, and Hort (2009) also revealed that the perception of bitter aftertaste was primarily driven by the CO_2 level. This perception was further enhanced with the presence of acid that is commonly added in carbonated beverages. The carbonation process was also reported to be able to supress sweet taste (Hewson et al., 2009) and this may have an effect on children's taste perception of the root beer.

As for the goat cheese, lactic acid has been reported as the main organic acid compound that contributes to the sour taste in this product (Gámbaro et al., 2017). However, in this study the children reported that the goat cheese tasted bitter rather than sour. Children reportedly have a heightened sensitivity and rejection response to bitter tastes biologically (Mennella et al., 2013). This might be one of the reasons why they perceived bitter taste to be stronger than sour taste. In addition, children's perception of the bitter taste can increase as the low to mild intensity of sour taste has an enhancing effect on the bitter taste (Breslin, 1996) particularly when both of these tastes appear in combination. Alternatively, it might have been difficult for the children to correctly name the acidic sensation of goat cheese as sourness. It has been reported that also adults commonly mistake bitterness for sourness and that the issue is even more frequent in children (Guinard, 2000).

Furthermore, the low identification of bitter taste might be due to the weak bitter taste intensity present in the food samples such as in goji berry and water chestnut. In this study, the goji berry was served as dried fruits and thus the bitter taste was not as strong as in the fresh berries, as the polysaccharides contributing to the sweet taste are more concentrated in the dried berry (Ma et al., 2019) possibly resulting in this food being identified as sweet by some of the children. As for the water chestnut, the canned version was used in this study and did not have a strong bitter taste which could be why they were not often identified as bitter by the children. In addition, most of the food that represented bitter taste had binary mixture with sour taste, such as in fermented milk, grapefruit and kumquat in which sourness was perceived more dominant in comparison to bitter (Fig. 5). This resulted in a higher correctness score for the sour taste (9.4 ± 4.1 SD) compared to the bitter taste (5.1 ± 4.3 SD), and explains the positive correlation between bitter and sour attributes in the PCA (*Pearson* = 0.36, $p < 0.05$). The low intensity may also affect the low identification score for the sweet taste in durum wheat semolina and bulgur. These foods are made from wheat (Elias, 1995) which mainly consist of carbohydrate content that makes them have an elicit sweet taste (Lim & Pullicin, 2019). However, the sweet taste in these products tend to have a low intensity which makes them popular to be cooked together with meat or vegetables to add more flavour and tastes (Rosentrater & Evers, 2018). This low intensity might contribute to lower the identification score ability of children for the sweet taste.

Oram and colleagues (2001) reported that children from the age of 8–9 year old have reliable sensitivity in identifying basic taste of single taste modality, however, the same study also revealed that they were not able to recognize the presence of binary taste combinations, resulting in them choosing the strongest or the most appealing taste based on their perception. In the two-component combination, each of the taste qualities is usually suppressed and perceived as less intense than when they are tasted separately (Bartoshuk, 1975). Sour taste is suppressed the least when other taste components are available in taste combination (Keast & Breslin, 2003). The combination of sour and bitter will enhance each other at low concentrations but at moderate concentrations the bitter taste will be suppressed, and sour taste enhanced (Bartoshuk, 1975). However, this depends on the concentration level (Breslin, 1996) and the taste compound (Keast & Breslin, 2003) used in the experiment. In this study, children identified sour taste more easily than bitter taste, because sour tends to be stronger in the taste mixture of the food samples. This conclusion is aligned with the previous study from James et al. (1999) who also stated that children might get distracted in taste modalities measurement when complex models are introduced. Considering the occurrence of basic taste combinations and the low intensity of dominant tastes in certain food samples, it would be important to also measure taste intensity in future studies.

This binary combination phenomenon was also observed in sweet taste. When sweet taste was present with other tastes such as salty in

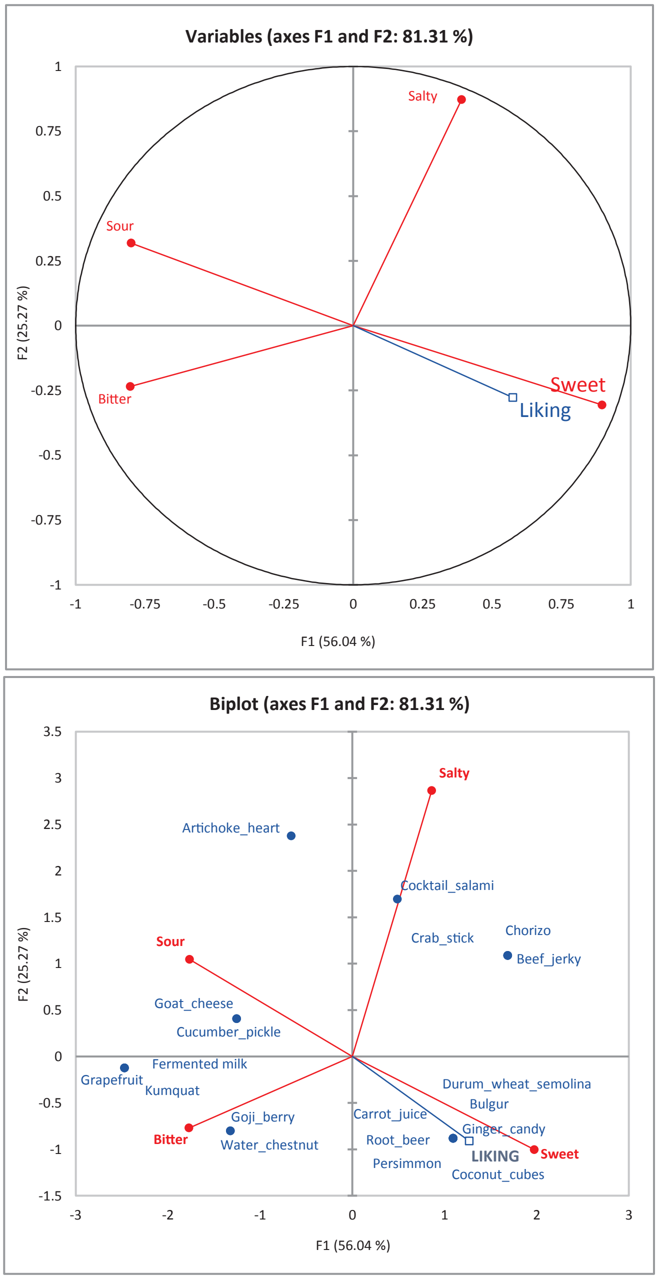

Fig. 8. PCA analysis showing the correlations between dominant basic tastes and children's liking for the food samples.

chorizo beef jerky, and crab stick, children's identification ability showed to be lower compared to when sweet taste was solely present such as in persimmon or in coconut cubes. In salty-sweet food samples, the children perceived the salty taste to be more dominant than the sweet taste, thus resulting in lower correctness scores for the sweet taste (4.4 ± 3.9 SD) than for salty taste (9.5 ± 4.0 SD). In addition, root beer was perceived to be more bitter than sweet and this contributes in lowering the general correctness score for sweet taste. This is in line with the conclusion from Oram et al. (2001) who suggested that children were able to identify single taste but not binary mixtures of tastes. Moreover, in the case of beef jerky, and chorizo, the salty taste was perceived to be more dominant than the sweet taste, while for crab stick there were several children who chose either sweet or salty as dominant, but not in combination. These meat-based products are salty due to the curing and aging process that helps prolong shelf life (Feiner, 2016). Furthermore, high liking scores were observed for the salty foods in this study. This is in line with a review study from Hoffman, Salgado, Dresler, Faller, and Bartlett (2016) on salt preferences, which suggested that young children and adolescents preferred higher concentrations of sodium chloride. In addition, a study involving 4–6 year-old children also showed that children have a good ability to identify salty taste in the model food of saltine crackers and cheese (Wendin et al., 2017).

4.2. Children's taste identification ability and liking

It has been reported that sweet taste is the most liked taste (Ahrens, 2015; Hoffman et al., 2016) and biologically preferred by children from infancy (Mennella & Bobowski, 2015). This is aligned with the results obtained from this study showing that the food samples that were dominantly characterized by sweet taste significantly had the highest liking scores (mean 4.9 ± 0.9 SD). According to the PCA, the presence of sweet taste showed to have a significant positive correlation with children's liking. On the contrary, the food samples that were dominantly characterized by sour taste led to the lowest liking scores. This supports previous results from Liem and de Graaf (2004) who suggested that children aged 6 to 11 years old did not prefer a higher level of sour taste orangeade even after repeated exposure of sour taste. Moreover, according to Hoffman et al. (2016), sour taste in general is also less preferred than sweet or salty tastes. The fact that sour and bitter tastes appeared in combination in several food samples in this study might also have affected children's acceptance (Oram et al., 2001; Keast & Breslin, 2003).

No correlation was found between basic taste identification ability of children and their liking, indicating that children who correctly identified a certain basic taste did not systematically show higher or lower liking for that specific taste. This corroborates previous studies from Vennerød et al. (2018) and Lanfer et al. (2013) suggesting that children's taste sensitivity does not solely determine their taste preferences. It has been extensively investigated that many other factors contribute to children's taste preferences and eating behaviour such as taste exposure (Nicklaus, 2016), demographics and family condition (DeCosta, Moller, Frost, & Olsen, 2017; Vennerød, Almli, Berget, & Lien, 2017), and socio-cultural environments (Lanfer et al., 2013). Moreover, basic taste sensitivity has also been reported to have a strong correlation with genetic factors (Mennella et al., 2005; Joseph, Reed, & Mennella, 2016) contributing to large differences of taste sensitivity between individuals (Hartvig et al., 2014). Further, there was no gender effect observed in this study, corroborating the previous study from James, Laing, and Oram (1997) reporting that taste sensitivity is not affected by gender in 8 to 9-year old children.

4.3. Methodological approach

To our knowledge, this is the first study measuring basic taste identification ability of preadolescent children in unfamiliar food samples. Food familiarity was reported to have influenced children's food perception (Laureati & Pagliarini, 2019). Removing the familiarity aspect will make the evaluation more difficult for the children as they did not have the memories to recall the taste of the foods (Higgs, 2011) and making them rely on their taste sensitivity only. In this study it was important to select unfamiliar foods that had distinct basic taste(s) dominance. However, the selection of the unfamiliar foods was challenging. It was difficult to select foods that fulfilled the unfamiliarity aspect as well as other aspects such as availability on the Norwegian market, the capacity to not trigger disgust, the practicality of being easily prepared and the possibility to be served at room temperature. The use of real food samples instead of model foods enhanced the relevancy of this sensory study by providing complex sensations of basic taste combinations in addition to odour, texture and aroma variations.

The limitation of the study is that only dominance, but not the intensities of the basic tastes were evaluated in the food samples. In addition, umami was not included in the measurement to the children which could be potentially present as a dominant sensation for the meat based food samples and might affect children's liking (Roininen, Lähteenmäki, & Tuorilla, 1996; Lanfer et al., 2013). The umami taste itself is not familiar in Europe (Cecchini et al., 2019). This taste is commonly labelled as salty even though umami has been accepted as the fifth basic taste and has a different receptor from salt (Kurihara, 2015). Inclusion of umami in future studies may however require a training session to ensure that the children are familiar with this taste and term.

5. Conclusion

This study aimed to investigate the ability of 10 to 11-year old children in identifying the basic tastes of sweet, salty, sour and bitter in unfamiliar food samples. In this study, the children relied solely on their taste perception as effects of context memories that may occur in familiar foods could not occur with unfamiliar foods. The results showed that children were able to identify the basic tastes of unfamiliar food samples with good congruency to a trained panel. This supports previous research which concluded that children have a good ability in perceiving taste stimuli in sensory testing. However, in our study, this ability was shown to be negatively affected by the co-presence of dominant tastes. Further, there was no association found between taste identification ability and children's liking. Future research may investigate the associations between basic taste identification ability and children's taste sensitivity thresholds. For future studies, it is recommended to consider the taste intensity in the food samples and to include umami, since umami contributes to the savoury taste of foods and might affect children's perception and liking. Finally, further studies are needed to better understand the role of basic taste perception abilities in children's food acceptance.

Credit authorship contribution statement

Ervina Ervina: Methodology, Formal analysis, Data curation, Investigation, Writing - original draft, Visualization. **Ingunn Berget:** Methodology, Supervision, Writing - review & editing. **Alexander Nilsen:** Conceptualization, Methodology, Investigation, Resources, Data curation. **Valerie L. Almli:** Conceptualization, Methodology, Data curation, Supervision, Writing - review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2020.103929.

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