



# Sweetness but not sourness enhancement increases acceptance of cucumber and green capsicum purees in children

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## ABSTRACT

For children it is important to consume enough vegetables to establish healthy dietary patterns. Taste acceptance is an important factor contributing to food choice and consumption. Sweetness and sourness enhancement can increase acceptance of specific foods in children. The aim of this study was to determine the effect of sweetness and sourness enhancement on acceptance of cucumber and green capsicum purees in 5–6-year-old children. Three concentrations of sucrose (2, 5 and 10%) and citric acid (0.05, 0.08 and 0.15%) were added to cucumber and green capsicum purees. Children ( $n = 70$ ,  $5.7 \pm 0.5$  yrs) assessed acceptance of the vegetable purees using a 5-point hedonic facial scale. Sweetness enhancement significantly increased acceptance of cucumber purees (5 and 10% sucrose) and green capsicum purees (2 and 10% sucrose) compared to unmodified purees. Sourness enhancement (0.05, 0.08 and 0.15% citric acid) did not significantly influence acceptance of cucumber and green capsicum purees compared to unmodified purees. Children differed in acceptance of vegetable purees with added sucrose and citric acid. Sweetness likers (cucumber 77.1%, green capsicum 58.6%) accepted sucrose concentrations better than sweetness non-likers in both vegetables. Sourness likers (cucumber 50.0%, green capsicum 44.3%) accepted medium and high concentrations of citric acid better than sourness non-likers in cucumber and all citric acid concentrations in green capsicum. We conclude that enhancement of sweetness increases acceptance of cucumber and green capsicum purees in most children whereas enhancement of sourness is better accepted by only a few children. This study highlights the challenge to get children to better accept vegetables, since only sweetness enhancement improved acceptance while addition of sucrose is undesirable. For a small subset of children enhancing sourness might be an alternative strategy to increase acceptance of vegetables.

## 1. Introduction

Consumption of vegetables by children is below recommended intake in multiple countries even though vegetables are an important part of a healthy diet (Alexy, Sichert-Hellert, & Kersting, 2002; Bowen, Klose, Syrette, & Noakes, 2009; CSIRO, 2008; Dennison, Rockwell, & Baker, 1998; Van Rossum, De Boer, & Ocke, 2009). Children form a key target group to increase vegetable consumption as vegetable consumption at a young age contributes to vegetable consumption later in life (Nicklaus, 2009).

Taste acceptance is an important factor contributing to food consumption, especially in children (Brug, Tak, te Velde, Bere, & de Bourdeaudhuij, 2008; Mennella, Finkbeiner, Lipchock, Hwang, & Reed, 2014). Recent studies showed that vegetables in general have low taste intensities compared to other foods (Poelman, Delahunty, & de Graaf,

2017; Van Stokkom et al., 2016). The low taste intensities of vegetables might contribute to low acceptance. Therefore, taste enhancement might be an effective approach to increase vegetable acceptance.

Several studies investigated the effect of taste enhancement of different taste modalities on food acceptance in children. Liem and de Graaf (2004) showed that enhancing sweetness but not sourness increased preference of orangeade and yoghurt in children. However, some children have a preference for extreme sourness intensities of foods (Liem, Westerbeek, Wolterink, Kok, & de Graaf, 2004). Enhancing sweetness of grapefruit juice, a more bitter food, by adding sucrose reduced initial dislike of grapefruit juice by children. An increased liking was even sustained when later on sucrose was removed (Capaldi & Privitera, 2008). In summary, children's acceptance of specific beverages and foods increased when taste intensities were enhanced and depends on taste modality and type of food.

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Limited research has been conducted to investigate the effect of taste enhancement on children's acceptance of vegetables. Bouhlal, Chabanet, Issanchou, and Nicklaus (2013) demonstrated that enhancing saltiness of green beans by adding sodium chloride increases children's acceptance of green beans. In adults, the effect of taste enhancement of different taste modalities on vegetable acceptance has been investigated more extensively. Sweetness enhancement increased acceptance of broccoli and cauliflower in adults (Capaldi & Privitera, 2008). A recent study by van Stokkom, de Graaf, van Kooten, & Stieger (2018) demonstrated that enhancing sweetness by adding sucrose to cucumber and green capsicum purees increases acceptance of these vegetable purees in adults. A relatively low sweetness enhancement (2% sucrose) was sufficient to increase acceptance of cucumber purees, while for green capsicum purees a higher sweetness enhancement was needed (5% sucrose). Sharafi, Hayes, and Duffy (2013) misted asparagus, Brussels sprouts and kale with solutions containing different concentrations of aspartame, sodium acetate and sodium chloride to determine the effect of sweetness, sourness and saltiness enhancement on bitterness suppression in adults. Aspartame was the most effective bitterness suppressor and increased liking for all vegetables in adults.

Taste perception and discriminatory abilities for taste often differ within children and between children and adults (De Graaf & Zandstra, 1999; James, Laing, & Oram, 1997), which might contribute to differences in acceptance. Children can prefer higher intensities of sweetness than adults in a variety of foods (Hoffman, Salgado, Dresler, Faller, & Bartlett, 2016). De Graaf and Zandstra (1999) demonstrated that children prefer higher sucrose concentrations in water and in lemonade than adults. Mennella et al. (2014) also showed that children prefer higher concentrations of sucrose in water than adults. In another study, children preferred higher sucrose concentrations in pudding compared to their mothers (Mennella, Finkbeiner, & Reed, 2012). Children might also prefer higher sourness than adults. Liem and Mennella (2003) showed that 35% of children preferred high levels of sourness in gelatine gels while for adults this was not the case. Vegetables such as cucumber and green capsicum do not have an inherent sour taste or might not have a flavour that is congruent with sourness. However, sour seasonings such as vinaigrettes or dressings are commonly used for the preparation of many vegetables (Martin, Visalli, Lange, Schlich, & Issanchou, 2014). Therefore, enhancing sourness of vegetables such as cucumber and green capsicum might increase acceptance in children.

To the best of our knowledge, the effect of sweetness and sourness enhancement on children's acceptance of cucumber and green capsicum has not been studied yet. The aim of this study was to investigate the effect of sweetness and sourness enhancement on acceptance of cucumber and green capsicum purees in 5-6-year-old children. We hypothesize that both sweetness and sourness enhancement increases acceptance for cucumber and green capsicum purees in children, but that sweetness enhancement has a stronger effect in most children than sourness enhancement. Additionally, we hypothesize that the higher the sucrose concentration, the larger the influence on acceptance. Knowledge about the effect of taste enhancements on acceptance of vegetables by children might help devise strategies to increase children's vegetable consumption.

## 2. Methods

### 2.1. Participants

A dedicated recruitment agency for consumer trials located in the Sydney metropolitan area (Australia) was used for the recruitment. Children aged 5 and 6 years were selected. Children were included if they were generally in good health and had consumed the target vegetables (cucumber and capsicum) at least once before participating in the study. Children were excluded when they had a strong dislike for either target vegetable, had any known food allergies or dietary intolerances or had any problems with chewing or swallowing (parental

reported). In total,  $n = 72$  children participated in the study. Two children refused most samples and were therefore excluded from data analysis. One child refused all capsicum purees. For the remaining children refusals were rare.  $N = 70$  children were included in the data analysis for cucumber purees and  $n = 69$  children for capsicum purees. The CSIRO Human Research Committee granted ethical approval for the study registered under number #25/2016. Participants received financial compensation for participation.

### 2.2. Vegetable purees

The study included cucumber (*Cucumis sativus*, variety Telegraph) and green bell capsicum, hereafter referred to as green capsicum (*Capsicum annuum*). Selection of vegetables was based on three criteria: first, one vegetable should display a relatively neutral taste profile whereas the other vegetable should display a slight bitter taste. In previous studies cucumber displayed a neutral taste profile while green capsicum was characterized by higher bitterness intensity compared to other vegetables (Poelman et al., 2017; Van Stokkom et al., 2016). Secondly, both vegetables should be commonly consumed in Australia (CSIRO, 2008). Thirdly, both vegetables should be consumable cold and without further preparation.

Vegetable purees were prepared at CSIRO in Sydney, North Ryde, Australia. Vegetables were collected in bulk to eliminate between batch variation. Vegetables were rinsed, cut in pieces and pureed with a mixer (NutriBullet, LLC. Los Angeles, United States). Three concentrations of sucrose (2, 5 and 10% w/w) and three concentrations of citric acid (0.05, 0.08 and 0.15% w/w) were added to the vegetable purees and are referred to as low, medium and high tastant concentrations. Tastant concentrations were based on reference solutions used in the modified Spectrum Method. In the modified Spectrum Method, three reference solutions with fixed intensities for each tastant are used to evaluate the intensity of the basic tastes (sweetness, sourness, bitterness, umami and saltiness) on an absolute scale (Martin et al., 2014). Using these concentrations ensured that purees had low, medium and high intensities. Tastants were mixed into the vegetable purees with a hand mixer until complete dissolution. Purees were poured into plastic food freezer bags. Samples were frozen immediately after production and stored at  $-20^{\circ}\text{C}$ . On each test day, one bag per sample was defrosted at  $4^{\circ}\text{C}$ . One hour prior to each session, the defrosted samples were removed from the refrigerator and kept at room temperature so that vegetable purees reached room temperature before the start of the session.

Cucumber and green capsicum purees used in this study were the same as vegetable purees used previously (van Stokkom et al., 2018). In the previous study, adult consumers ( $n = 66$ ,  $35.8 \pm 17.7$  yrs) rated the intensity of sweetness and sourness of vegetable purees using a 100 mm line scale. Sweetness and sourness intensities of vegetable purees assessed by adults increased significantly ( $p < 0.01$ ) with increasing tastant concentration (sucrose and citric acid). Sweetness intensity increased from unmodified (14 for cucumber; 14 for green capsicum) to low (35; 41), medium (71; 69) and high (84; 86) sucrose concentrations. Sourness intensity increased from unmodified (15 for cucumber; 28 for green capsicum) to low (40; 31), medium (55; 43) and high (76; 70) citric acid concentrations. All taste intensities significantly differed between vegetable purees with the exception of unmodified and low citric acid concentration for green capsicum.

### 2.3. Procedure

The acceptance test had a within subject design. Session typically took less than 30 min, only very few sessions lasted up to 45 min. Sessions were performed at the research facilities of CSIRO in Sydney, North Ryde, Australia. Each session included no more than four children. Sessions started with oral instructions after which the parent signed the informed consent form and children gave their assent by colouring in a happy smiley face. If children did not want to participate,

they had the option colouring in a sad smiley face. One child coloured in a sad smiley face and therefore did not participate. Children were placed in test rooms with no more than two children per test room. Research assistants helped each child one-on-one and recorded the results. Parents were seated nearby, but not in direct view of the child and were instructed not to communicate with the child during the test.

Serving order of vegetable type was balanced and alternated across sessions, so in one session all children started with cucumber and the next session with green capsicum. For each vegetable type, children tasted a small portion of each of the seven samples, one by one, using a randomized design across participants. Vegetable samples (~15 g per sample) were offered at room temperature in plastic containers (30 ml) covered with a lid until consumption. During tasting, children were instructed to sip a small amount of water between samples to cleanse their palate. Children received a tray containing seven samples of the first vegetable (unmodified; low, medium and high sucrose; low, medium and high citric acid). When children completed the assessment of the first vegetable type, there was a break of at least 1 min. The procedure was then repeated for the second vegetable. Acceptance was assessed using a 5-point hedonic facial scale and by preference ranking. First, children categorised each sample by placing the sample below the appropriate image of a 5-point hedonic facial scale. The five categories were visualized with smiley faces on an A3 page. Children's understanding of the scale was established during the oral instruction by asking children to explain the different categories in their own words. Additionally, the research assistant repeated that the faces represent 'really yucky', 'yucky', 'okay', 'yummy' and 'really yummy'. Next, the same seven samples were ranked for preference from most (rank number 1) to least liked (rank number 7). Samples were re-tasted whenever relevant. Previous studies with children used similar methods (De Graaf & Zandstra, 1999; Guthrie, Rapoport, & Wardle, 2000; Havermans & Jansen, 2007; Poelman & Delahunty, 2011; Poelman, Delahunty, & de Graaf, 2013).

#### 2.4. Parental questionnaire

During the session, parents completed a questionnaire to collect background information including demographics (gender and age of parent and child, parental educational level). Data was collected about the consumption frequency of vegetables (excluding potatoes) in general (servings per day for parent and child) and about the child's consumption frequency of the target vegetables (less than once a month; 1–3 times a month; once a week or more). Parents were also asked how they typically prepare cucumber and green capsicum and if they typically use any seasonings during the preparation. Parents assessed their child's food neophobia by the six-item version of the Child Food Neophobia Scale (CFNS) (Cooke, Carnell, & Wardle, 2006; Pliner, 1994).

#### 2.5. Statistical data analyses

Statistical data analyses were performed using SPSS (IBM, SPSS Statistics version 24). A *p* value of 0.05 was used as criterion for statistical significance. Descriptive data were generated for demographic and vegetable variables. Acceptance categorised by the 5-point hedonic facial scale and ranked preference were analysed separately. Acceptance categories were coded from –2 ('really yucky') to 2 ('really yummy') with 0 corresponding to 'okay'. Ranked preference was coded from 1 (most preferred) to 7 (least preferred). Refusals were coded as missing values. There was one refusal during preference ranking of cucumber purees and categorised acceptance of green capsicum purees. There were three refusals during preference ranking of green capsicum purees. Means and standard deviation of categorised acceptance, ranked preference and mean acceptance differences between samples and the unmodified sample were calculated. Differences in acceptance categories between cucumber and green capsicum vegetable purees

were analysed using dependent *t*-test. General Linear Model analysis including participant as random and sample as fixed factor was used to analyse differences in acceptance between unmodified vegetable purees and modified vegetable purees followed by LSD post-hoc testing. Spearman's Rho correlation coefficients were calculated to test for correlations between age, gender, CFNS and acceptance of cucumber and green capsicum purees. No significant correlations between these variables were found and therefore these variables were not included in results and discussions. Ranked preference was analysed with Friedman's test. When significant differences were found between samples, Wilcoxon signed-rank test was used with 20 comparisons per vegetable type corrected for number of comparisons resulting in an adjusted *p* value of 0.003 (Field, 2009). To assess individual differences in acceptance, children were divided based on their acceptance of sucrose and citric acid additions. Children were classified as 'sweetness likers' when they rated acceptance of samples containing medium and high concentrations of sucrose with either 1 or 2. All remaining children were assigned to the sweetness non-likers group. The same criteria for medium and high concentrations of citric acid addition were applied to classify children into sourness likers and sourness non-likers. Differences in acceptance within subgroups were analysed using the same GLM analyses as conducted for the overall group. Differences in acceptance between likers and non-likers were analysed using an independent *t*-test. Chi-square tests and independent *t*-tests were used to determine differences in age, gender and CFN score between 'likers' and 'non-likers'.

### 3. Results

#### 3.1. Characteristics of children and parents

Table 1 shows parent and child characteristics. The mean age of

**Table 1**

Characteristics of children and parents participating in the study which were self-reported by parent.

Parent characteristics (n = 70)		Mean ± SD or frequency (%)
Age (yrs)		37.8 ± 6.2
Gender (% female)		87.1
Education level		
Some high school		1.4%
Completed high school		2.9%
Tech, trade or TAFE qualification		25.7%
University		48.6%
Post graduate studies		21.4%
Use seasoning while preparing vegetables		
Cucumber (% yes)		11.4%
Capsicum (% yes)		44.3%
Vegetable consumption (serves/day)		2.71 ± 1.0
Child characteristics (n = 70)		Mean ± SD or frequency (%)
Age (yrs.)		5.7 ± 0.5
Gender (% girls)		54.3
Child food neophobia (CFN) score (range 6–42)		20.0 ± 7.7 (range 6–37)
Vegetable consumption (serves/day)		2.12 ± 1.1
Cucumber consumption frequency		
< once a month		1–3 times a month
4.3%	5.7%	Once a week or more
Capsicum consumption frequency		
< once a month		1–3 times a month
17.1%	40.0%	Once a week or more
Cucumber preparation method (multiple options possible)		
Raw with skin		Raw without skin
81.4%	35.6%	Other
Green capsicum preparation method (multiple options possible)		
Raw		Stir fry
60%	78.5%	Other
		25.8%

**Table 2**

Mean categorised acceptance assessed by children (5–6 yrs) for cucumber ( $n = 70$ ) and green capsicum purees ( $n = 69$ ) using a 5-point hedonic facial scale ranging from 'really yucky' ( $-2$ ) to 'really yummy' ( $+2$ ) and mean preference ranks assessed by children for cucumber ( $n = 69$ ) and green capsicum purees ( $n = 67$ ) ranging from most preferred (1) to least preferred (7). Letters a-c indicate significant differences in acceptance between vegetable purees belonging to the same type of vegetable.

Cucumber puree			Green capsicum puree		Significance of difference in acceptance between cucumber and green capsicum purees
Tastants and concentrations	Categorised acceptance ( $n = 70$ ) mean $\pm$ SD	Preference ranking ( $n = 69$ ) mean $\pm$ SD	Categorised acceptance ( $n = 69$ ) mean $\pm$ SD	Preference ranking ( $n = 67$ ) mean $\pm$ SD	
Unmodified	0.21 $\pm$ 1.45 <sup>bc</sup>	4.19 $\pm$ 1.94 <sup>ab</sup>	−0.41 $\pm$ 1.55 <sup>bc</sup>	4.27 $\pm$ 2.12 <sup>ab</sup>	$t(68) = 2.96, p < 0.01$
Sucrose					
Low	0.36 $\pm$ 1.47 <sup>ab</sup>	3.86 $\pm$ 1.78 <sup>a</sup>	0.09 $\pm$ 1.53 <sup>a</sup>	3.46 $\pm$ 1.91 <sup>a</sup>	$t(68) = 1.08, p = 0.29$
Medium	0.74 $\pm$ 1.38 <sup>a</sup>	3.30 $\pm$ 1.90 <sup>a</sup>	−0.06 $\pm$ 1.51 <sup>ab</sup>	3.61 $\pm$ 1.89 <sup>a</sup>	$t(68) = 3.58, p < 0.01$
High	0.70 $\pm$ 1.48 <sup>a</sup>	3.11 $\pm$ 2.04 <sup>a</sup>	0.14 $\pm$ 1.59 <sup>a</sup>	3.43 $\pm$ 2.13 <sup>a</sup>	$t(68) = 2.43, p < 0.05$
Citric acid					
Low	0.23 $\pm$ 1.49 <sup>bc</sup>	4.17 $\pm$ 1.96 <sup>ab</sup>	−0.39 $\pm$ 1.34 <sup>bc</sup>	4.19 $\pm$ 1.77 <sup>ab</sup>	$t(68) = 2.80, p < 0.01$
Medium	0.18 $\pm$ 1.37 <sup>bc</sup>	4.30 $\pm$ 1.95 <sup>ab</sup>	−0.62 $\pm$ 1.44 <sup>c</sup>	4.63 $\pm$ 1.75 <sup>b</sup>	$t(68) = 3.87, p < 0.01$
High	−0.15 $\pm$ 1.55 <sup>c</sup>	4.94 $\pm$ 1.96 <sup>b</sup>	−0.39 $\pm$ 1.56 <sup>bc</sup>	4.04 $\pm$ 2.16 <sup>ab</sup>	$t(68) = 1.01, p = 0.32$

children was  $5.7 \pm 0.5$  yrs and 54.3% were girls. Both parental and child vegetable consumption (2.71 and 2.12 serves/d) were below recommended intakes ( $> 5$  and 4.5 serves/d) (National Health and Medical Research Council, 2013). It should be noted that the Australian guidelines include potatoes while we excluded potatoes as this is common in WHO guidelines as well as guidelines of most other western countries. Cucumber was consumed more often than capsicum. Cucumber was most often consumed raw with skin (81.4%), green capsicum was most often consumed stir-fried (78.5%).

### 3.2. Acceptance of cucumber and green capsicum purees by children

Table 2 summarizes the mean acceptance scores assessed by children (5–6 yrs) for cucumber and green capsicum purees of categorised acceptance and preference ranking. For categorised acceptance, mean acceptance scores ranged from  $-0.15$  to  $0.74$  for cucumber purees and from  $-0.62$  to  $0.14$  for green capsicum purees. As a consequence of the taste intensity modifications, acceptance varied from 'yucky' to 'yummy'. Acceptance of 11 out of 14 vegetable purees (79% of samples) ranged between  $-0.5$  and  $0.5$  corresponding to 'okay'. Significant differences between acceptance of cucumber purees ( $F(6,427) = 4.30, p < 0.01$ ) and between acceptance of green capsicum purees ( $F(6,408) = 4.06, p < 0.01$ ) were found.

For cucumber purees, acceptance of purees with medium (5%) and high (10%) sucrose concentrations was significantly higher than acceptance of unmodified cucumber puree (mean difference  $+0.53$  and  $+0.49$ ). Acceptance of cucumber puree with low sucrose concentration (2%) was not significantly different from unmodified puree (mean difference  $+0.15$ ). Acceptance of cucumber purees with low (0.05%), medium (0.08%) and high (0.15%) citric acid concentrations did not significantly differ from unmodified cucumber puree (mean difference  $-0.03, -0.21$  and  $-0.37$ ). All cucumber purees with citric acid had a significantly lower acceptance than cucumber puree with medium (5%) and high (10%) concentrations of added sucrose (Table 2 and Fig. 1).

For green capsicum, acceptance of purees with low (2%) and high (10%) concentrations of added sucrose was significantly higher compared to unmodified green capsicum puree (mean difference  $+0.50$  and  $+0.55$ ). Acceptance of green capsicum puree with medium concentration of sucrose (5%, mean difference  $+0.35$ ) did not significantly differ from unmodified green capsicum puree, but acceptance tended to increase ( $p = 0.09$ ) in a similar direction as the other added sucrose concentrations. Low (0.05%), medium (0.08%) and high (0.15%) concentrations of citric acid (mean difference  $+0.02, -0.21$  and  $+0.02$ ) did not differ significantly from unmodified green capsicum puree. Green capsicum purees with low (2%) and high (10%) concentrations of sucrose were significantly better accepted than all green capsicum

purees with citric acid. Green capsicum puree with medium concentration of sucrose (5%) was significantly better accepted than puree with medium concentration of citric acid (0.08%) (Table 2 and Fig. 1).

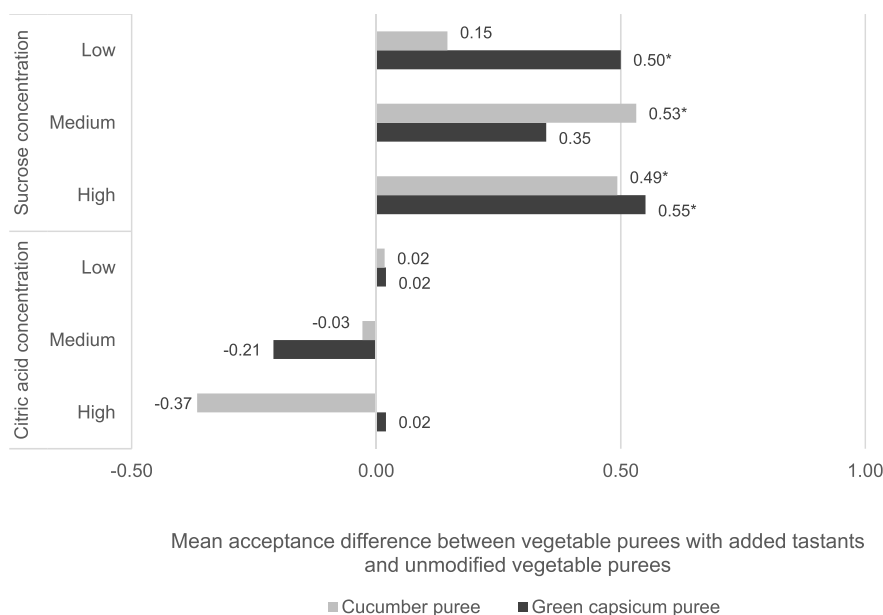
Unmodified cucumber puree was significantly better accepted than unmodified green capsicum puree. Medium (5%) and high (10%) sucrose concentrations and low and medium citric acid concentrations were better accepted in cucumber purees than in green capsicum purees. Acceptance did not differ significantly between cucumber purees and green capsicum purees for low sucrose (2%) and high citric acid concentration (0.15%) (Table 2 and Fig. 1).

For ranked preference, Friedman's test indicated that there were significant differences in acceptance between cucumber ( $\chi^2(6) = 35.6, p < 0.01$ ) and green capsicum purees ( $\chi^2(6) = 19.2, p < 0.05$ ). Rank of preference for cucumber with added sucrose and added citric acid did not significantly differ compared to unmodified cucumber puree. Cucumber puree with high concentration of citric acid (0.15%) was significantly higher ranked than cucumber puree with low (2%), medium (5%) and high (10%) concentration of sucrose ( $Z = -3.10, p = 0.02; Z = -4.04, p < 0.001$  and  $Z = -4.46, p < 0.01$ ). Rank of preference of green capsicum purees with added sucrose and added citric acid did not differ significantly compared to unmodified green capsicum puree. Rank of preference of green capsicum purees with medium concentration of citric acid (0.08%) was significantly higher than rank of preference of green capsicum purees with low (2%), medium (5%) and high (10%) concentrations of sucrose ( $Z = -3.15, p < 0.01; Z = -2.83, p < 0.01; Z = -2.86, p < 0.01$ ) (Table 2).

### 3.3. Sweetness and sourness likers versus non-likers

Table 3 shows categorised acceptance for sweetness likers versus sweetness non-likers and sourness likers versus non-likers in children (5–6 yrs). For cucumber, 54 children (77.1%) were classified as sweetness likers, and 35 children (50.0%) as sourness likers. For sweetness likers, medium (5%) and high (10%) sucrose concentrations increased acceptance significantly compared to unmodified cucumber puree. For sweetness non-likers, sucrose addition did not significantly increase nor decrease acceptance. Sweetness likers accepted unmodified cucumber puree and low (2%), medium (5%) and high (10%) sucrose concentrations significantly better than sweetness non-likers. For sourness likers, citric acid addition did not significantly increase nor decrease acceptance of cucumber. For sourness non-likers, high citric acid concentration (0.15%) significantly decreased acceptance compared to unmodified cucumber puree. Medium (0.08%) and high (0.15%) citric acid concentrations were significantly better accepted by sourness likers than sourness non-likers.

For cucumber, sweetness likers and sweetness non-likers and sourness likers and non-likers were not significantly different in age ( $t$



**Fig. 1.** Mean categorised acceptance difference between cucumber and green capsicum purees with added sucrose and citric acid and corresponding unmodified vegetable purees. Acceptance was measured on a 5-point hedonic facial scale ranging from 'really yucky' (−2) to 'really yummy' (+2). \* indicates significant differences ( $p < 0.05$ ) in acceptance compared to unmodified vegetable puree of the same type.

(68) = 0.070,  $p = 0.06$ ;  $t(68) = 0.236$ ,  $p = 0.55$ , gender ( $\chi(1) = 0.564$ ,  $p = 0.45$ ;  $\chi(1) = 0.230$ ,  $p = 0.63$ ) and CFN score ( $t(68) = 0.547$ ,  $p = 0.53$ ;  $t(68) = 1.693$ ,  $p = 0.41$ ).

For green capsicum, 41 children (58.6%) were classified as sweetness likers and 31 children (44.3%) as sourness likers. For sweetness

likers, acceptance increased by addition of low (2%), medium (5%) and high (10%) sucrose concentrations compared to unmodified green capsicum puree. For sweetness non-likers, a high concentration of sucrose (10%) significantly decreased acceptance compared to unmodified green capsicum puree. Sweetness likers accepted low (2%),

**Table 3**

Mean categorised acceptance assessed by children (5–6 yrs) using a 5-point hedonic facial scale ranging from 'really yucky' (−2) to 'really yummy' (+2) for sweetness likers versus sweetness non-likers (cucumber purees:  $n = 54$ ,  $n = 16$ , green capsicum purees:  $n = 41$ ,  $n = 28$ ) and for sourness likers versus non-likers (cucumber purees:  $n = 35$ ,  $n = 35$ ; green capsicum purees  $n = 31$ ,  $n = 38$ ).

Tastants and concentrations	Cucumber puree Categorised acceptance (mean $\pm$ SD)		Significance of difference in acceptance between likers and non-likers
	Sweetness likers ( $n = 54$ )	Sweetness non-likers ( $n = 16$ )	
Unmodified Sucrose	0.44 $\pm$ 1.34 <sup>b</sup>	−0.44 $\pm$ 1.59 <sup>a</sup>	$t(68) = 0.796$ , $p < 0.05$
Low	0.56 $\pm$ 1.44 <sup>b</sup>	−0.31 $\pm$ 1.40 <sup>a</sup>	$t(68) = 0.068$ , $p < 0.05$
Medium	1.17 $\pm$ 1.19 <sup>a</sup>	−0.69 $\pm$ 0.95 <sup>a</sup>	$t(68) = 0.095$ , $p < 0.01$
High	1.31 $\pm$ 1.04 <sup>a</sup>	−1.25 $\pm$ 0.86 <sup>a</sup>	$t(68) = 0.043$ , $p < 0.01$
	Sourness likers ( $n = 35$ )	Sourness non-likers ( $n = 35$ )	
Unmodified Citric acid	0.63 $\pm$ 1.37 <sup>a</sup>	−0.14 $\pm$ 1.42 <sup>a</sup>	$t(68) = 0.280$ , $p = 0.08$
Low	0.69 $\pm$ 1.35 <sup>a</sup>	−0.23 $\pm$ 1.50 <sup>a</sup>	$t(68) = 0.724$ , $p = 0.10$
Medium	1.23 $\pm$ 0.97 <sup>a</sup>	−0.80 $\pm$ 0.80 <sup>ab</sup>	$t(68) = 0.127$ , $p < 0.01$
High	0.89 $\pm$ 1.47 <sup>a</sup>	−1.20 $\pm$ 0.72 <sup>b</sup>	$t(68) = 3.238$ , $p < 0.01$
Tastants and concentrations	Green capsicum puree Categorised acceptance (mean $\pm$ SD)		Significance of difference in acceptance between likers and non-likers
	Sweetness likers ( $n = 41$ )	Sweetness non-likers ( $n = 28$ )	
Unmodified Sucrose	−0.15 $\pm$ 1.65 <sup>b</sup>	−0.79 $\pm$ 1.32 <sup>b</sup>	$t(67) = 4.174$ , $p = 0.09$
Low	0.66 $\pm$ 1.41 <sup>a</sup>	−0.75 $\pm$ 1.32 <sup>b</sup>	$t(67) = 0.695$ , $p < 0.01$
Medium	0.73 $\pm$ 1.38 <sup>a</sup>	−1.21 $\pm$ 0.79 <sup>ab</sup>	$t(67) = 8.638$ , $p < 0.01$
High	1.22 $\pm$ 1.01 <sup>a</sup>	−1.43 $\pm$ 0.74 <sup>a</sup>	$t(67) = 2.501$ , $p < 0.01$
	Sourness likers ( $n = 31$ )	Sourness non-likers ( $n = 38$ )	
Unmodified Citric acid	0.52 $\pm$ 1.39 <sup>ab</sup>	−1.16 $\pm$ 1.24 <sup>b</sup>	$t(67) = 1.880$ , $p < 0.01$
Low	−0.03 $\pm$ 1.40 <sup>b</sup>	−0.68 $\pm$ 1.23 <sup>a</sup>	$t(67) = 0.257$ , $p < 0.05$
Medium	0.52 $\pm$ 1.29 <sup>ab</sup>	−1.55 $\pm$ 0.69 <sup>b</sup>	$t(67) = 11.819$ , $p < 0.01$
High	0.84 $\pm$ 1.34 <sup>a</sup>	−1.39 $\pm$ 0.86 <sup>b</sup>	$t(67) = 6.623$ , $p < 0.01$



medium (5%) and high (10%) sucrose concentrations significantly better than sweetness non-likers. Addition of citric acid did not affect acceptance for sourness likers compared to unmodified green capsicum puree. Low citric acid concentration (0.05%) improved acceptance for sourness non-likers compared to unmodified green capsicum puree and medium (0.08%) and high (0.15%) citric acid concentrations. Sourness likers accepted unmodified green capsicum puree and low (0.05%), medium (0.08%) and high (0.15%) citric acid concentrations better than sourness non-likers.

For green capsicum, sweetness likers and sourness non-likers were not significantly different in age ( $t(67) = 0.434$ ,  $p = 0.14$ ), gender ( $\chi(1) = 0.606$ ,  $p = 0.44$ ) and CFN score ( $t(67) = 1.158$ ,  $p = 0.40$ ). Sourness likers and non-likers were not significantly different in gender ( $\chi(1) = 2.029$ ,  $p = 0.15$ ), CFN score ( $t(67) = 0.188$ ,  $p = 0.21$ ), but sourness likers were older than sourness non-likers ( $t(67) = 2.223$ ,  $p = 0.04$ ).

#### 4. Discussion

The aim of this study was to investigate the effect of sweetness and sourness enhancement on acceptance of cucumber and green capsicum purees in 5–6-year-old children. The main finding of this study is that sweetness enhancement by sucrose addition increased acceptance by children of an initially not well accepted vegetable puree, green capsicum puree, and a neutrally accepted vegetable puree, cucumber puree, but sourness enhancement by addition of citric acid addition did not.

##### 4.1. Influence of sucrose and citric acid addition on acceptance of vegetable purees by children

Unmodified cucumber puree, which has a more neutral taste profile, was better accepted by children (5–6 yrs) than unmodified green capsicum puree, which has a more bitter taste profile (Poelman et al., 2017; Van Stokkom et al., 2016). This difference in acceptance is probably caused by the bitterness of the green capsicum puree. Sucrose addition increased acceptance in both vegetables. Humans have an innate preference for sweetness (Birch, 1999; Drewnowski, 1997). Therefore, it was not surprising that children accepted cucumber and green capsicum purees with added sucrose better than the corresponding unmodified purees. However, the concentration that was needed to increase acceptance differed between cucumber and green capsicum purees. Medium and high concentrations of added sucrose increased acceptance in cucumber purees, while in green capsicum purees, low and high concentrations of added sucrose increased acceptance compared to unmodified vegetable purees. This difference between cucumber and green capsicum could be a result of differences in taste-flavour interactions between added sucrose and the flavour of the vegetables. Cucumber is fairly neutral tasting and therefore taste-flavour interactions might occur to a lower extent, while green capsicum is less neutral tasting and more bitter. In cucumber, sucrose addition probably increased acceptance due to higher sweetness intensity. In green capsicum, sucrose addition might also have increased acceptance due to bitterness suppression by sweetness (Keast & Breslin, 2003). Moreover, differences between the complexity of taste, flavour and texture of cucumber and green capsicum might have led to differences in perception and discrimination between concentrations of added tastants (James, Laing, Oram, & Hutchinson, 1999). We acknowledge that descriptive sensory profiling would be needed to quantify possible taste-taste and taste-flavour interactions. This was outside the scope of the current study. We recommend future studies to apply quantitative descriptive analysis to be able to investigate the effect of added tastants on taste-taste and taste-flavour interactions.

It is unknown whether an increase in acceptance leads to an increase in intake, nor whether the increase in acceptance is continued when sucrose is removed later on. The latter has been shown by Capaldi

and Privitera (2008) in grapefruit juice where increased acceptance after addition of sucrose persisted when sucrose was removed from the grapefruit juice later on.

In a study by Liem et al. (2004) 58% of the participating children preferred one of the two most sour gelatine gels (0.08 and 0.25 M or 1.5 and 4.8%), which is in contrast with the widely accepted idea that humans are pre-dispositioned to dislike sourness (Birch, 1999; Drewnowski, 1997). Our results showed that citric acid addition did not change acceptance significantly compared to unmodified vegetable purees. However, the lowest concentration used by Liem et al. (2004) (0.02 M or 0.38%) was higher than the highest concentration used in our study (0.15% w/w). Maybe the citric acid concentrations used in the current study were too low to increase acceptance for some children. It is also possible that sourness is not a taste associated and congruent with cucumber and green capsicum and therefore does not lead to clear rejection or acceptance. However, Martin et al. (2014) classified 47% of the vegetables as more intense in sourness, bitterness, umami and saltiness compared to other food classes. These vegetables were consumed cold with vinaigrette, indicating that sourness enhancement is commonly used for the preparation of vegetables. In our study, participants who indicated using seasonings for the preparation of cucumber and green capsicum mentioned that they typically add vinegar, lemon and yoghurt (next to salt and pepper) to vegetables (data not shown), which are sour. This indicates that the use of sour seasonings is not uncommon for the preparation of these vegetables.

Consumers often apply some form of preparation and seasoning before consumption of vegetables, as was also reported by parents in this study. These preparations lead to more complex taste alterations of vegetables than the enhancement of a single taste modality (sweetness or sourness) by addition of a single tastant. Adding a single tastant to a vegetable might not be congruent with expectations. Possibly more complex taste, flavour and texture combinations are needed to increase acceptance of vegetables further.

##### 4.2. Comparison of influence of taste enhancement on acceptance of vegetable purees in sweetness and sourness likers and non-likers

Of the participating children, a majority was classified as sweetness likers (cucumber 77.1%, green capsicum 58.6%). Acceptance of vegetable purees with added concentrations of sucrose was significantly higher for sweetness likers than for sourness non-likers in both vegetables. Although most children accepted sucrose addition in vegetables, this did not apply to all children.

For cucumber, 50.0% of the participating children were classified as sourness likers, while for green capsicum 44.3% were sourness likers. For children who were classified as sourness likers, adding citric acid did not increase acceptance compared to unmodified purees. Sourness likers did accept most citric acid additions better than sourness non-likers. Classification of the sourness likers group was based on positive acceptance scores for medium and high concentrations of added citric acid. However, results indicate that this group could better be called “sour indifferent”. Thus, sour addition had no positive effect on acceptance for a subset of children who liked sourness. However, it needs to be taken into account that the number of children in the segmentation analysis was small and may have been underpowered. Further research with a larger samples size would be recommended. In green capsicum, sourness non-likers accepted low citric acid concentration significantly better than the unmodified puree, which was unexpected and we cannot offer a suitable explanation.

##### 4.3. Comparison of influence of taste enhancement on acceptance of vegetable purees in children and adults

Van Stokkom et al. (2018) assessed the effect of taste enhancement on acceptance of vegetables by adults (18–65 yrs) using the same vegetable purees (cucumber and green capsicum), preparation methods

and tastant concentrations as in the current study with children (5–6 yrs). In adults, mean acceptance of unmodified green capsicum puree measured using a 9-point scale ( $-0.4 \pm 1.8$ ) was slightly lower than acceptance of unmodified cucumber ( $-0.1 \pm 1.5$ ). In the current study with children, using a 5-point category scale, there was a larger difference in acceptance of unmodified cucumber and green capsicum purees ( $-0.4 \pm 1.6$  vs.  $0.2 \pm 1.5$ ). This suggests that green capsicum was less accepted by children than adults.

Sucrose addition increased acceptance of vegetable purees significantly both in adults and children. However, there are some differences between adults and children. In adults, a low concentration of added sucrose increased acceptance of cucumber purees, whereas medium and high concentrations did not. In children, medium and high concentrations of added sucrose were needed to achieve significant increase of acceptance of cucumber purees. This means that for children higher concentrations of added sucrose were needed to increase acceptance of cucumber purees compared to adults which is in agreement with previous studies demonstrating that children prefer higher sucrose concentrations in non-bitter food products (water, lemonade, pudding) compared to adults (De Graaf & Zandstra, 1999; Mennella et al., 2012, 2014). For green capsicum purees, medium and high concentrations of added sucrose increased acceptance of green capsicum purees significantly in adults, whereas low concentration of added sucrose did not. While in the current study, children accepted green capsicum purees with low and high concentrations of added sucrose significantly better than unmodified purees. This means that for children lower concentrations of added sucrose already led to an increase in acceptance of green capsicum puree compared to adults. As children might have heightened bitterness sensitivity compared to adults (Mennella, Reiter, & Daniels, 2016), bitterness might have been suppressed at lower sucrose concentrations than in adults, leading to an increase in acceptance by addition of a low sucrose concentration in children but not in adults. The sensitivity for other taste modalities might also differ between children and adults. Vennerød, Nicklaus, Lien, and Almlil (2018) recently showed that between 4 and 6 yrs, sensitivity for sweetness decreases while sensitivity for sourness increases.

In adults, citric acid addition did not influence acceptance of cucumber and green capsicum purees (Van Stokkom et al., 2018). Liem and Mennella (2003) showed that a larger proportion of children prefer high sourness intensities of gelatine gels than adults. However, citric acid addition also did not increase acceptance compared to unmodified vegetable purees in the current study with children, also not for children classified as sourness likers. Enhancing sourness might be effective in increasing acceptance of gelatine gels in children but not in vegetables. Gelatine gels might be associated with candy, sweets or drops, so foods in which sourness is typical and common. While using sour seasonings such as vinaigrettes and dressings for the preparation of vegetables is common, citric acid addition did not increase acceptance of cucumber and green capsicum puree in adults and children.

Perception and discrimination of taste often differs between adults and children (De Graaf & Zandstra, 1999; James et al., 1997; Oram, Laing, Freeman, & Hutchinson, 2001). In van Stokkom et al. (2018) adults were able to discriminate between most concentrations of added tastants in cucumber and green capsicum purees. We did not quantify in the current study how children perceived the taste intensity of the different vegetable purees and how well children were able to discriminate between the three concentrations of both tastants as taste intensity of the vegetable purees was not quantified with children. Differences in perception and discrimination capability between adults and children might depend on the complexity of the stimulus. The latter has been suggested by James et al. (1999) where children could discriminate between different concentrations of sucrose in water similar as adults, but not between different concentrations of sucrose in orange drinks.

#### 4.4. Vegetable purees and use of sucrose

In the current study, we used vegetable purees to be able to control the concentration of added tastants. Presenting vegetables as a puree resulted in a different texture than in which the vegetables are commonly consumed. Although children had to have consumed cucumber and capsicum at least once to be included in this study, puree is not a common way to consume these vegetables. Preparation method and familiarity are important factors contributing to food preferences (Bongoni, Stieger, Dekker, Steenbekkers, & Verkerk, 2014; Bongoni, Verkerk, Steenbekkers, Dekker, & Stieger, 2014; Cooke & Wardle, 2005; Poelman & Delahunty, 2011; Poelman, Delahunty, & de Graaf, 2015; Poelman et al., 2013; Zeinstra, Koelen, Kok, & de Graaf, 2010). It is not known to what extent pureeing affected acceptance scores. However, all vegetables studied were pureed and compared to one another. We used raw vegetables to eliminate possible effects of preparation methods on taste. More importantly, by pureeing the vegetables, we ensured that each bite contained the same concentration of added tastant for all samples.

Children that have a strong dislike for vegetables are less likely to take part in a vegetable tasting study. Therefore, it is not surprising that children who participated in the study consumed more vegetables than the national average amongst 4–8 years olds which is 1.2 serves (CSIRO, 2008). It might be more difficult to increase acceptance in a population that already consumes and accepts vegetables. Hence, the effect of added tastants on acceptance might be larger for children that have a stronger dislike for vegetables. Future studies could attempt to include children with a stronger dislike for vegetables. For exploring differences in food consumption between children who do and who do not like sweetness or sourness, we recommend future studies to collect food consumption data.

Although acceptance of an initially not well accepted vegetable, green capsicum, increased by addition of sucrose, we stress that we do not wish to promote the use of sucrose in the preparation of vegetables. Current consumption patterns already exceed the recommended intakes of sugars. Only 29% of Australian children (4–8 yrs) do not exceed dietary guidelines for sugar consumption (CSIRO, 2008). Sweetness enhancement of vegetables by addition of sucrose should be avoided. Offering disliked vegetables in combination with other vegetables or foods with naturally sweet taste profiles might be a healthy means to enhance sweetness and increase acceptance of disliked vegetables.

#### 5. Conclusion

Sweetness enhancement by addition of sucrose can increase acceptance of vegetable purees in 5–6-year-old children, even for a vegetable that was initially not well accepted (green capsicum). The effect of tastant addition on acceptance of vegetable purees by children differed between concentrations of added tastants and vegetable type. For cucumber purees, at least 5% of added sucrose was necessary to increase acceptance by children while for green capsicum purees 2% of added sucrose was sufficient to increase acceptance. Sourness enhancement by addition of citric acid did not have a significant effect on acceptance in both vegetable purees in children. A majority of children have a higher acceptance of sucrose addition in vegetables (cucumber 77.1%, green capsicum 58.6%) and a smaller proportion of children accept citric acid addition better in vegetables (cucumber 50.0%, green capsicum 44.3%). This study highlights the challenge to get children to better accept vegetables. Although sucrose addition increased acceptance, acceptance was still not very high. It is possibly that more complex tastes, flavours and textures are needed to increase acceptance further. Adding sucrose to vegetables to increase acceptance should be avoided as from a health perspective extra sugar consumption should be discouraged. However, for a smaller subset of children enhancing sourness of vegetables might be an alternative strategy to increase acceptance.

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