

Sweet Difference Threshold of Strawberry-Flavored Carbonated Drink in 8-Year-Old Children in Khon Kaen

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Abstract

Carbonated drinks are the most popular sugar-contained beverages which might be one of the causes of excessive sugar consumption in Thai children. Stepwise sugar reduction technique, in which the sugar concentration no greater than a person's difference threshold is gradually reduced, is among one of the strategies used to assist people to reduce their sugar consumption. The objective of the present study was to determine the sweet difference threshold of a carbonated test drink in 8-year-old children. Paired-comparisons, forced-choice tests and survival analysis were used in determining the sweet difference threshold of 64 school children. Demographic data, sweet snack and beverage consumption were collected by a questionnaire. The results showed that the overall sweet difference threshold was 15 %. No significant difference in sweet difference threshold was found between gender, areas of school (municipal vs non-municipal), parents' education, family income, frequency of sweet snack and beverage consumption, frequency of strawberry-flavored-carbonated-drink consumption and frequency of adding sugar in their food. The threshold was greater than that obtained from a non-carbonated drink reported previously, indicating the possible effect of carbonation on sweet perception. The threshold value could be used to set the percentage sugar reduction steps in the stepwise sugar reduction program.

Keywords: Carbonated drink, Difference threshold, Sugar consumption, Sugar reduction

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Introduction

Excessive sugar consumption is a risk factor of non-communicable diseases (NCDs) and dental caries. World Health Organization (WHO) has recommended daily intake of free sugar below 10 % or 5 % of total

energy intake (i.e. 25 grams) per day for more benefits.¹ In Thailand, the Ministry of Public Health recommends less than 6 teaspoons (or 24 grams of sugar) per day. Despite these recommendations, Thai people have been

consuming sugar approximately 4 times higher than that suggested by WHO. Thai children aged below 5 years have daily sugar intake of 30.4 grams which is equivalent to 7.6 % of total energy intake.²

According to Food Consumption Data of Thailand, (2016) the most popular sugar-contained beverage was carbonated drink. The data showed 70.9 % of children aged between 6-12.9 years consumed 300 ml of carbonated drink per day on average.³ A regular size of carbonated drink (330 ml) contains approximately 30 grams of sugar, the amount of which already exceeds the daily recommendation. Stepwise sugar reduction technique is among one of the strategies used to assist people to reduce their sugar consumption.^{4,5} The technique employs the window of sugar concentration where a subject can 'just' distinguish the difference in sweetness, so called 'sweet difference threshold'. In order to gain the most benefit from this technique, the actual difference threshold should be used in the determination of concentration intervals to be gradually reduced. Using chocolate milk⁵ and fruit juice^{6,7}, it has been demonstrated that the average sweet difference threshold in children aged 6-12 years is 11.36 % which is significantly larger than that of adults⁶, indicating that children are less sensitive to changes in sugar concentration. On the other hand, the sweet difference threshold of carbonated drinks has never been studied but it is speculated that the carbonation could affect the perceived sweetness. The objective of the present study was to determine the sweet difference threshold of a carbonated test drink in 8-year-old children. The strawberry flavor was used since the color and taste can be easily controlled.

Materials and Methods

This cross-sectional study was approved by the Ethical Committee at Khon Kaen University (HE 612331)

and conducted between February–March 2019. Sixty-six children aged 8 years to 8 years 11 months on the date of data collection (February 1st, 2019) from the elementary schools in Muang district, Khon Kaen province participated in the study. The sample size was based on the minimum number of subjects conventionally employed during taste threshold studies, plus 10 % of subjects who might be excluded due to their taste insensitivity during the 50 % sugar difference test.⁸ The schools were selected using a stratified randomization method. Included subjects were healthy children who consumed any carbonated drink at least once a week. Excluded subjects were those who strongly disliked strawberry flavor, had diseases affecting taste and smell perception, were presently on sugar dietary control, were on continued medication during past 3 months, and could not distinguish the sweet difference between 2 concentrations of strawberry-flavored carbonated test drink with 50 % sugar difference. Assents were given by children and consents were given by their parents. Subjects were asked to fill a questionnaire, consisting of age, gender, family income, parents' education, frequency of sweet snack and beverage consumption, frequency of strawberry-flavored soft drink consumption and frequency of adding sugar in their food.

Preparation of test solutions

Seven sugar concentrations of strawberry-flavored carbonated test solutions were prepared from a fixed proportion of 3 ingredients: 80 %v/v of soda water (Rock Mountain[®], Thai Beverage Marketing, Bangkok, Thailand), 9 %v/v of concentrated artificial strawberry flavored syrup (Hale's Blue Boy, Hale's Trading, Thailand) (containing 78 %w/v of sucrose), and 11 %v/v of varying concentrations of sucrose solution (KBS First, Kornburi Sugar, Nakorn Ratchasima, Thailand). Details of sucrose concentration of prepared strawberry-flavored carbonated test solutions were shown in Table 1.

Table 1 Detailed concentrations of test solutions and the amount of added sugar.

No.	Sugar reduction percentage from the reference solution (%)	Sugar concentration in test solutions (%w/v)
0 (Reference)	0	14.00
1	9	12.74
2	12	12.32
3	15	11.90
4	18	11.48
5	21	11.06
6	24	10.64

The reference sugar concentration used in this study was 14 % similar to that contained in a commercial strawberry-flavored carbonated drink available in Thailand. The percent reduction of sucrose concentration relative to the reference solution was obtained by a pilot study and set as 9 %, 12 %, 15 %, 18 %, 21 % and 24 % respectively.

The syrup and sucrose solution were pre-mixed, stored in a refrigerator at $4\pm 1^{\circ}\text{C}$ and used within 24 hours. Before the test, 4 ml of the mixture was transferred to each plastic cup and 16 ml of soda water was added to give the final volume of 20 ml. A bottle of soda water was kept in 6°C iced water and used within 20 minutes after being opened in order to minimize the loss of carbon dioxide. All test solutions were served at 10°C in monadic sequence, in random order, to avoid carry-over effects. All temperatures were controlled using a thermometer.

Experimental procedure

Participants were tested one at a time, in a quiet room either in the morning or the afternoon, at least one hour before or after lunch. Each participant was seated face-to-face with the examiner and was instructed about the procedure before starting the experiment. To determine the sweet difference threshold, a paired-comparisons, forced-choice method was conducted. The procedure started with familiarization trials. First, the participants were requested to taste a pair of test solutions having the same sucrose concentration (14 %) and asked to choose the sweeter one, even they were not be able to detect the difference. Second, a pair of 14 % and 7 % sucrose solutions (50 % difference in concentration) was

tested and the participants were again asked to choose the sweeter one. Between each trial, participants rinsed their mouth with 20-ml of drinking water. Participants who were not cooperative or unable to detect the difference between the second pair of test solutions (50 % difference of sugar concentration) were excluded from the study.

After the familiarization test, participants assessed 6 pairs of test solutions. Each pair contained a cup of 20-ml reference concentration and a cup of 20-ml reduced-sugar solution. served in a random order. The participants were asked “which one is sweeter?”. The results were then recorded by the examiner. Between each trial, the participants rinsed their mouth with a cup of 20-ml drinking water, followed by a 30-s break. The next pair of test solutions was then evaluated in the same manner until all 6 pairs of solutions were finished. The correct answer (reference solution was sweeter) was recorded as ‘YES’ whereas the incorrect answer recorded as ‘NO’. The lowest sucrose concentration in which a participant consistently and correctly detected the difference were recorded as the sweet difference threshold of that individual.

Statistical analysis

The average age of participants was shown by mean and standard deviations. The other demographic data was described in frequency and the distribution between group were then compared by using Chi-square test (significance level = 0.05).

A survival analysis (Kaplan Meier estimate) was conducted to determine the overall sweet difference threshold of all participants and compared between groups of participants.^{6,7}

Results

Among 66 participants, 33 (17 boys, 16 girls) were students from the schools in the municipal area. The mean age of all participants was 8.43 ± 0.25 years. There were no significant differences in the distribution of age, gender, family income, parents' education, frequency of sweet snack and beverage consumption, frequency of strawberry-flavored soft drink consumption and frequency of adding sugar in their food between participants from municipal and non-municipal schools (Table 2).

Two of the 66 participants failed the 50 % sugar concentration difference test, resulting in 64 participants in the subsequent test for difference threshold. The overall sweet difference threshold was 15 %. The medians of sweet difference threshold were 15 % in boys and 18 % in girls. In addition, 10.6 %, 18.2 %, 21.2 %, 22.7 %, 21.2 % and 3.0 % of participants were able to correctly distinguish between the reference solution and 9 %, 12 %, 15 %, 18 %, 21 % and 24 % reduced-sugar solutions respectively (Table 3). No significant difference in the threshold was found between school area, gender, household income, parents' education, frequency of sweet snack and beverage consumption, frequency of strawberry-flavored soft drink consumption and frequency of adding sugar in their food (Table 4). The results of Kaplan Meier survival analyses were shown in Figure 1.

Discussion

The procedure used to determine the sweet difference threshold in this study was adapted from previous studies which used paired-comparisons, forced-choice technique to determine the taste perception in both children and adults.^{5-7,9} The technique has been claimed as a proper method for children.^{9,10} The familiarization test was performed prior to the actual experiment to allow the participants to be familiar with the method. Most participants were cooperative and able to follow the given instructions. Only 2 of 66 participants failed to detect the difference between

the reference and the 50 % reduced-sucrose solution.

In the present study, the sweet difference threshold of the carbonated drink was found to be 15 %, meaning that 50 % of participants were able to detect the difference of sweetness when sugar concentration was reduced up to 15 % from the reference concentration. Our value was larger than 10 % reported by Lima *et al.*,⁶ who tested the difference threshold of grape juice in children. Although the reference concentration used in Lima's study was lower (10 % compared to 14 % in the present study), our difference threshold would not be affected according to Weber's law which states that the ratio between the detectable difference and the initial stimulus intensity is constant.¹¹ The difference was probably due to the effect of carbonation. The fizziness of soda water might interfere with the sweet taste transduction mechanism and decrease taste sensitivity.¹² Another factor that might affect the threshold value was the cold temperature of our test solutions. However, both reference concentration and the serving temperature used imitated those in the commercially available carbonated drink.

The sweet detection threshold in Thai children has been studied and reported to be 25.9 mM or around 0.89 % (w/v).¹³ The detection threshold was not significantly different between boys and girls, and was not associated with sweet preference. It was speculated that sweet detection threshold was dependent of a child's innate capacity, in contrast to sweet preference which was likely to be a learned experience.¹⁴ The sweet difference threshold, on the other hand, has been less studied and was reported to be large in children and decreased in adults.⁶ We could not demonstrate any association sweet difference threshold and sweet consumption behavior. This could be because the ability to distinguish taste intensity was affected by multifactorial factors^{9,15-17} and probably was dependent of taste practice rather than its exposure. The inability to see any association could also be due to the small sample size of the present study.

In conclusion, under the limitation of the study, we have determined for the first time, the sweet difference threshold of carbonated drink in children. The threshold was greater than that tested with non-carbonated fruit juice.

The value could be used to determine the sugar reduction steps during a stepwise (gradual) sugar reduction program.

Table 2 Demographic data of the participants.

	Municipal schools	Non-municipal schools	Total	<i>p</i> -value
Gender				
Boys	17 (51.5 %)	16 (48.5 %)	33 (50 %)	1.000
Girls	16 (48.5 %)	17 (51.5 %)	33 (50 %)	
Parents' education				
<high school	15 (48.4 %)	23 (69.7 %)	38 (59.4 %)	0.126
≥high school	16 (51.6 %)	10 (30.3 %)	26 (40.6 %)	
Household income				
≤20,000 Baht/month	29 (87.9 %)	30 (90.9 %)	59 (89.4 %)	0.500
>20000 Baht/month	4 (12.1 %)	12 (9.1 %)	7 (10.6 %)	
Frequency of sweet snack and beverage consumption				
≤2 times/day	15 (45.5 %)	11 (33.3 %)	26 (39.4 %)	0.225
>2 times/day	18 (54.5 %)	22 (66.7 %)	40 (60.6 %)	
Frequency of strawberry-flavored soft drink consumption				
≤1time/week	15 (45.5 %)	12 (36.4 %)	27 (40.9 %)	0.617
>1time/week	18 (54.5 %)	21 (63.6 %)	39 (59.1 %)	
Frequency of adding sugar in food				
≤1time/week	21 (63.6 %)	23 (69.7 %)	44 (66.7 %)	0.794
>1time/week	12 (36.4 %)	10 (30.3 %)	22 (33.3 %)	

Table 3 Number and percentage of participants who were able to distinguish the difference in sugar reduction.

Percentage sugar reduction	Number of participants	% of participants	Valid %	Cumulative %
9 %	7	10.6	10.9	10.9
12 %	12	18.2	18.8	29.7
15 %	14	21.2	21.9	51.6
18 %	15	22.7	23.4	75.0
21 %	14	21.2	21.9	96.9
24 %	2	3.0	3.1	100.0
Excluded	2	3.0		
Total	66	100.0		

Table 4 Sweet difference threshold classified by demography and sweet consumption behaviors.

	N	Difference threshold	95 % confidence interval	p-value
Overall	64	15 %	13.379-16.621	-
School area				
Municipal	32	15 %	12.783-17.217	0.368
Non-municipal	32	15 %	12.629-17.371	
Gender				
Boys	32	15 %	12.700-17.300	0.230
Girls	32	18 %	16.504-19.496	
Parents' education				
<high school	37	18 %	16.279-19.721	0.375
≥high school	25	15 %	11.352-18.648	
Household income				
≤20,000 Baht/month	58	15 %	13.134-16.866	0.361
>20,000 Baht/month	6	15 %	12.737-17.263	
Frequency of sweet snack and beverage consumption				
≤2 times/day	24	15 %	12.950-17.050	0.647
>2 times/day	40	15 %	12.521-17.479	
Frequency of strawberry-flavored soft drink consumption				
≤1 time/week	26	18%	16.338-19.662	0.620
>1 time/week	38	15%	13.373-16.627	
Frequency of adding sugar in food				
≤1 time/week	42	15 %	13.276-16.724	0.250
>1 time/week	22	18 %	14.209-21.791	

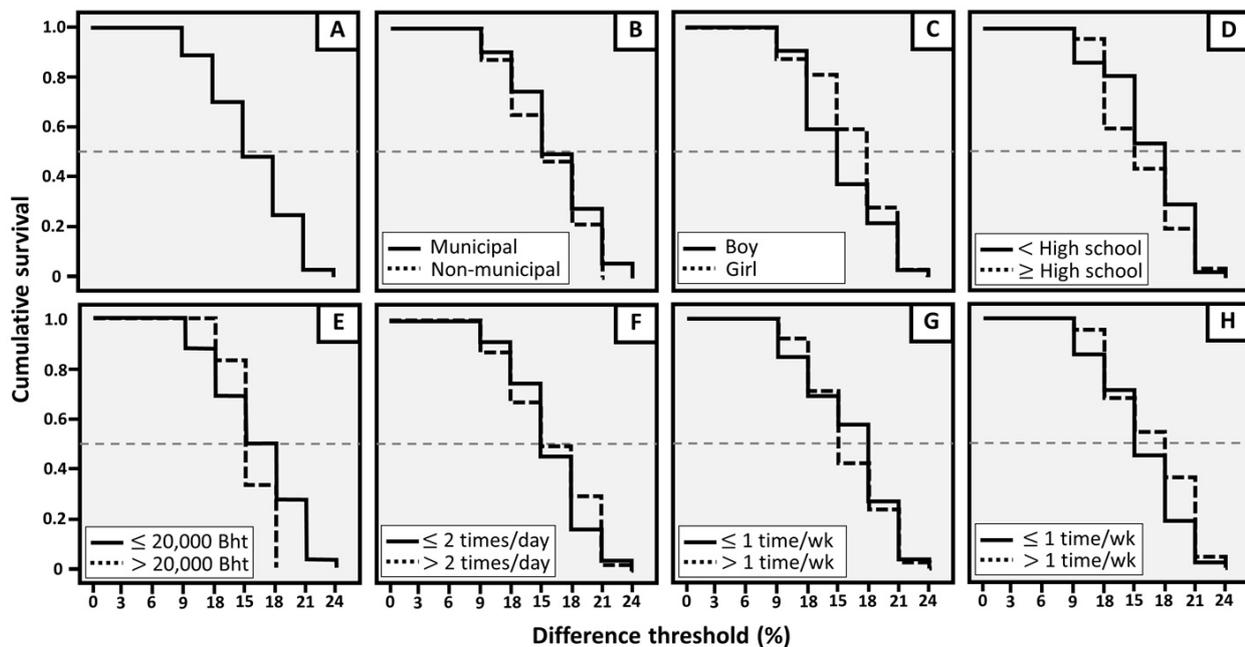


Figure 1 Meier survival analyses showing the difference threshold of all samples (A) by school area (B), gender (C), parents' education (D), household income (E), children's frequency of sweet consumption (F), frequency of strawberry-flavored soft drink consumption (G), and frequency of adding sugar in food (H).

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