

# Estimation of fluoride concentrations and pH values of commercially available vitamin water in Bangkok, Thailand

Sivaporn Horsophonphong<sup>1</sup>, Sirada Nuchit<sup>2</sup>, Nasibah Hayibueraheng<sup>2</sup>,  
Panthira Natkunanon<sup>2</sup>, Praewpan Tansiri<sup>2</sup>, Duangchewan Puengsurin<sup>3</sup>, Rudee Surarit<sup>3</sup>

<sup>1</sup> Department of Pediatric Dentistry, Faculty of Dentistry, Mahidol University, Bangkok, Thailand

<sup>2</sup> Dental Student, undergraduate program, Faculty of Dentistry, Mahidol University, Bangkok, Thailand

<sup>3</sup> Department of Oral Biology, Faculty of Dentistry, Mahidol University, Bangkok, Thailand

**Objective:** Over the last few years, the demand for vitamin water has grown. Water is the main source of fluoride intake, and the acidity of consumed water could contribute to tooth surface erosion. Therefore, the aim of this study was to investigate the fluoride concentrations and pH values of commercially available vitamin water in Bangkok, Thailand.

**Materials and methods:** Sixty vitamin water products that are commercially available in Bangkok, Thailand were purchased from supermarkets and convenience stores. The fluoride and pH of the vitamin water products were determined using a fluoride ion selective electrode and a pH meter with a glass electrode. Due to the sensitivity of the fluoride ion selective electrode, the fluoride concentrations that were less than 0.02 mg/L were considered 0 fluoride.

**Results:** The pH levels of the 60 vitamin water products ranged from 2.78–9.61 with a median and mean ( $\pm$ SD) of 3.61 and 4.11 ( $\pm$ 1.49), respectively. Most of the products (85%,  $n=51/60$ ) had pH values  $\leq$  5.5, and 15% ( $n=9/60$ ) had pH value above 5.5. The fluoride concentrations varied among products. The fluoride concentration in vitamin water ranged from 0–3.17 mg/L with a median of 0.046 mg/L and mean ( $\pm$ SD) of 0.243 ( $\pm$ 0.628) mg/L. Most of the products (92%,  $n=55/60$ ) contained undetectable or low fluoride levels. However, 8.3% of the products ( $n=5/60$ ) had high levels of fluoride ranging from 1.78–3.17 mg/L with a median of 1.98 mg/L and mean ( $\pm$ SD) of 2.242 ( $\pm$ 0.570) mg/L.

**Conclusion:** The vitamin water fluoride concentrations and pH values varied among products. Most of the products had pH levels lower than the critical pH value of enamel. The majority of the products contained low fluoride concentrations. However, 8.3% of the products contained high levels of fluoride that could increase the risk of dental fluorosis in young children.

**Keywords:** dental erosion, dental fluorosis, fluoride, pH, vitamin Water

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## Introduction

The COVID-19 pandemic has resulted in many people becoming interested in wellness and living healthy. People have begun to care more about the healthiness of their food and beverages. One healthy living trend that has become increasingly

popular over the last few years is drinking vitamin water. Vitamin water is water that is enriched with vitamins [1,2]. Vitamins are essential nutrients that play an important role in growth, development, body function, and the immune system [3,4]. Most vitamin water products contain few calories and are low in sugar, which is consistent with the

**Correspondence author:** Rudee Surarit

Department of Oral Biology, Faculty of Dentistry, Mahidol University

6 Yothi Road, Ratchathewi District, Bangkok 10400, Thailand.

Tel. +662 200 7849-50

E-mail: rudee.sur@mahidol.ac.th

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current living healthy trend [2]. Vitamin water has become an expanding new segment in the Thai consumer market. The popularity of vitamin water in the Thai market dramatically increased during the COVID-19 pandemic. The market share of vitamin water in Thailand has increased during the last few years and is expected to grow to 3.5 billion baht in 2021 and is predicted to reach 5 billion baht in 2022 [5].

Water and non-dairy beverages contain fluoride and are considered the main sources of daily fluoride intake, accounting for 66–80% of fluoride intake [6]. Fluoride in drinking water, when consumed at a minimum level, can prevent and reverse dental caries. However, higher fluoride concentrations or excess consumption can initiate dental fluorosis when consumed by infants and young children [7]. Many studies suggested that the optimal fluoride concentration in drinking water in a warm climate or tropical region should be 0.6–0.8 mg/L [8–10]. Moreover, the World Health Organization (WHO) suggests that the optimal level of fluoride for a temperate climate with a population that exhibited resistance to dental caries with minimal signs of dental fluorosis is ~1 mg/L [11]. Similarly, the U.S. Environmental Protection Agency reported that the recommended level of fluoride in the water in regions with warm and hot climates should be 0.9 mg/L and 0.7–0.8 mg/L, respectively [12]. In Thailand the fluoride concentration in bottled drinking water was reported to be 0.01–0.89 mg/L [13], while the fluoride concentration in beverages supplemented with collagen was between 0.015–0.334 mg/L [14]. Currently, there is no report concerning the relationship between the type of vitamins and fluoride concentration in bottled water.

The pH of beverages is a factor that can promote dental erosion and tooth decay. The acidic environment created when consuming beverages can initiate the demineralization process of dental hard tissue making the tooth vulnerable to dental caries and

increase the risk of dental erosion [15]. The WHO recommends that the standard pH levels of drinking water should range from 6.5–8.5 [16]. A previous study reported that the pH levels of the bottled drinking water commercially available in Bangkok, Thailand ranged from 6.61–8.2 [13].

Vitamin water has increased in popularity during the last few years. There are many brands and products of vitamin water in the Thai consumer market. Fluoride is one of the components normally found in water and fluoride in water is considered the main source of daily fluoride intake. Additionally, due to the corrosive effect of acidic water, the pH value of the drinking water should be monitored and reported. However, there is currently no report concerning fluoride and pH levels in bottled vitamin water sold in Bangkok, Thailand. Therefore, the objective of this study was to investigate the fluoride concentrations and pH values of vitamin water that are commercially available in Bangkok, Thailand.

## Material and Methods

Sixty commercially available vitamin water products from 20 brands were obtained from supermarkets and convenience stores in Bangkok, Thailand. Three bottles of each product with different batch numbers were selected and purchased. Each bottle was purchased before the expiration date indicated on the label. The products were kept in their original closed container and stored in the conditions recommended by the manufacturers until the pH value and fluoride concentration analysis. For each bottle, these analyses were performed before the expiration date on the label.

Prior to the measurement, the samples were left at room temperature and the vitamin water bottles were shaken before they were opened. The fluoride concentration and pH value of each bottle was measured in triplicate.

### pH measurement

The pH values of the vitamin water were measured using glass electrodes and a millivoltmeter (pH meter; 3-Star Benchtop pH Meter, Orion™, Expotech, Huston, Tx, USA). The pH meter was calibrated with pH standard solutions (pH 4, 7, and 10) (Orion™). The tip of the electrode was inserted in the water samples, and the pH values of the samples were determined.

### Fluoride measurement

The fluoride concentrations in the water were evaluated using a fluoride ion selective electrode (model 96-09BN, Orion™). A series of fluoride standard concentrations were prepared by 10-fold serial dilution of a 10 mg/L fluoride standard (Orion™) and were used to prepare a standard curve for calibrating the fluoride concentrations. Total ionic strength adjustment buffer (TISAB III, Orion™) (300 µL) was added into 3 mL of the water samples. The solution was mixed using a magnetic stirrer after that the electrode tip was inserted in the solution, and the fluoride concentration was determined. A fluoride concentration value less than 0.02 mg/L was considered an undetectable fluoride concentration due to the limitation of the ion selective electrode that has a detection limit of 0.02 mg/L for fluoride [17] and was recorded as 0 fluoride.

To determine the test-retest reliability of the detection method for fluoride concentrations and pH values, 10% of the bottles (n=18) were randomly selected and reanalyzed. The fluoride concentrations and pH values estimated from 3 batches of the same product were presented as the mean of the 3 batches and standard deviation (SD). Therefore, the data collected from one product of vitamin water was reported as mean ( $\pm$ SD). The fluoride concentrations and pH values in the 60 vitamin water products were reported as mean ( $\pm$ SD) and median (Min/Max).

## Results

The test-retest reliability of the fluoride estimation method was 100% and the reliability of the pH measurement was 99.3%, indicating excellent reliability of the detection method [18].

The fluoride concentration and pH value of each product of vitamin water are presented as mean and SD of the 3 batches obtained from a single product (Table 1). In addition, the pH values and fluoride concentrations based on the different types of supplemented vitamins are presented in Table 2.

**Table 1** Vitamin supplements, pH values, and fluoride concentrations among commercially available vitamin water products in Bangkok, Thailand

	Brand	Vitamins	pH value		Fluoride (mg/L)		Production sites
			Mean	SD	Mean	SD	
	TRUE®						
1	Vitamin water ALIVE exotic fruit flavor	B	3.21	0.057	0.201	0.006	Bang Phli Yai, Bang Phil,
2	Vitamin water CARE orange flavor	A, B, C, E	3.48	0.081	0.209	0.016	Samut Prakan

**Table 1** (continued). Vitamin supplements, pH values, and fluoride concentrations among commercially available vitamin water products in Bangkok, Thailand

Brand	Vitamins	pH value		Fluoride (mg/L)		Production sites	
		Mean	SD	Mean	SD		
<b>BLUE<sup>®</sup></b>							
1	Vitamin water peach flavor	B, C	3.17	0.062	0.031	0.004	Phuet Udom, Lum Luk Ka, Pathum thani
2	Vitamin water orange flavor	B, C	3.06	0.068	0.025	0.006	
3	Vitamin water green apple flavor	B, C	3.07	0.064	0.023	0.0013	
<b>PURRA<sup>®</sup></b>							
1	Vitamin water orange flavor	B, C	3.51	0.068	0.020	0.009	Ban Chang, Uthai, Ayutthaya
2	Vitamin water goji berries and ginkgo	B, C	3.55	0.108	0.024	0.002	
3	Vitamin water	B, C	5.53	0.111	0.023	0.004	
<b>AQUA•VITZ<sup>®</sup></b>							
1	Vitamin water honey lemon flavor	B, C	3.46	0.116	0.028	0.003	Om noi, Krathum Baen, Samut Sakhon
2	Vitamin mineral water	B	7.24	0.180	3.170	0.030	
3	Vitamin water lychee flavor	B, C	3.56	0.093	0.054	0.013	
<b>D.R. DRINK<sup>®</sup></b>							
1	Vitamin Water	B, C	5.88	0.308	0.021	0.003	Saphan Song, Wang Thong Lang, Bangkok
<b>CONCEPT<sup>®</sup></b>							
1	Water 0 Calorie Vitamin Recover Lemonade	B	3.83	0.021	0.047	0.005	Don Toom, Bang Len, Nakhon Pathom
2	Water 0 Calorie Vitamin Recover Orange	B	3.84	0.037	0.047	0.008	
3	Water 0 Calorie Vitamin Recover Lychee	B	3.43	0.041	0.046	0.003	
4	Water 0 Calorie Vitamin Recover Grape	B	3.36	0.063	0.045	0.002	
5	Water 0 Calorie Vitamin Recover Kiwi	A, B	3.79	0.016	0.046	0	

**Table 1** (continued). Vitamin supplements, pH values, and fluoride concentrations among commercially available vitamin water products in Bangkok, Thailand

Brand	Vitamins	pH value		Fluoride (mg/L)		Production sites
		Mean	SD	Mean	SD	
<b>YANHEE®</b>						
1 Vitamin water	B	7.73	0.156	2.40	0.176	Khlong Nok Krathung, Bang Len, Nakhon Pathom
2 Vitamin C water grass jelly	C	7.06	0.080	1.98	0.198	Nong Phrao Ngai, Sai Noi, Nonthaburi
3 Vitamin C water strawberry	C	6.76	0.142	1.88	0.182	
4 Vitamin C water lychee	C	6.81	0.102	1.78	0.085	
<b>MANSOME®</b>						
1 Vitamin water Beta-glucan, vitamin C and zinc	C	3.99	0.155	0.028	0.008	Bang Tan, Ban Sang, Prachin Buri
2 Vitamin water Vitamin B, high zinc and L-arginine	B	5.54	0.126	0.020	0.002	
3 L-glutathione	C, E	2.85	0.042	0.038	0.005	
<b>VITAMORES+®</b>						
1 Vitamin water Japanese peach flavor	A, D, E	3.62	0.124	0.026	0.004	Uthai, Uthai, Ayutthaya
2 Vitamin water lemonade flavor	B, C	3.91	0.077	0.032	0.004	
<b>ICHITAN®</b>						
1 Alkaline water PH plus with vitamin B complex	B	9.61	0.303	0.046	0.011	Uthai, Uthai, Ayutthaya
2 Alkaline water PH plus with Vitamin D and ginkgo leaf extract drink	D	8.23	0.680	0.051	0.003	

**Table 1** (continued). Vitamin supplements, pH values, and fluoride concentrations among commercially available vitamin water products in Bangkok, Thailand

	Brand	Vitamins	pH value		Fluoride (mg/L)		Production sites
			Mean	SD	Mean	SD	
<b>VITADAY+®</b>							
1	Vitamin water vitamin C plus collagen	C	4.28	0.187	0.035	0.004	Talad Jinda, Sam Pran, Nakhon Pathom
2	Vitamin water vitamin C 200% honey lemon flavor	C	3.68	0.115	0.032	0.003	
3	Vitamin water vitamin C 200% peach flavor	C	3.63	0.113	0.033	0.004	
4	Vitamin water vitamin B complex	B	6.27	0.339	0.025	0.003	
5	Vitamin A 150% mixed berries flavor	A	3.56	0.125	0.270	0.334	
6	Fe-Iron kyoho grape juice	C	3.75	0.038	0.087	0.072	Samrong, Phra Pradaeng, Samut Prakan
7	White krachai vitamin C 200%	C	3.22	0.082	0.135	0.030	
8	200% vitamin C lemon flavor	C	3.6	0.058	0.099	0.022	
9	200% vitamin C orange flavor	C	3.83	0.044	0.135	0.030	
<b>C-Vitt®</b>							
1	Vitamin pomegranate	C	3.77	0.044	0	0	Khleng Suan Phlu, Phra Nakhon Si Ayutthaya, Ayutthaya
2	Vitamin lemon	C	3.75	0.324	0.021	0.003	
3	Vitamin orange	C	3.82	0.060	0.023	0.001	
4	plus vitamin + collagen	C	3.65	0.051	0.034	0.008	Sansab, Minburi, Bangkok
5	plus vitamin + fiber	C	3.62	0.065	0.041	0.006	
<b>GEN C®</b>							
1	Gen C	C	3.82	0.035	0.133	0.072	Bang Kadi, Muang Pathumthani, Pathumthani
<b>CAMU C®</b>							
1	Camu C	B, C	3.18	0.042	0.055	0.017	Samrong, Phra Pradaeng, Samut Prakan

**Table 1** (continued). Vitamin supplements, pH values, and fluoride concentrations among commercially available vitamin water products in Bangkok, Thailand

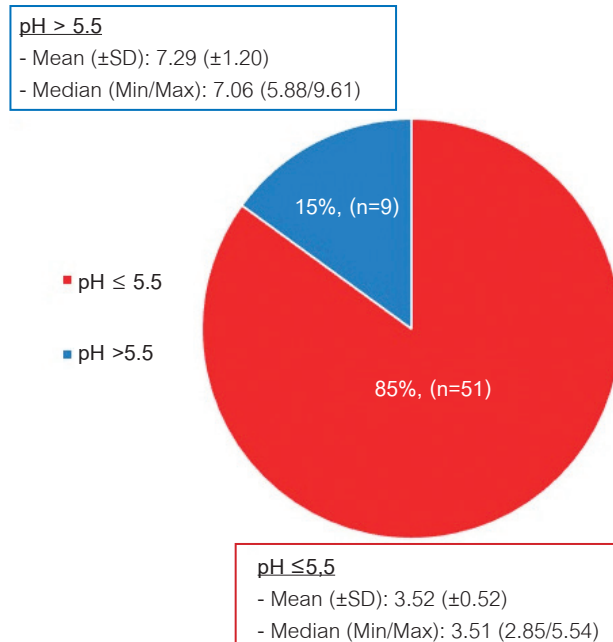
Brand	Vitamins	pH value		Fluoride (mg/L)		Production sites
		Mean	SD	Mean	SD	
WOODY C+ lock <sup>®</sup>						
1 Collagen mixed berry	C	3.66	0.062	0	0	Pimpa, Bang Pakong, Chachoengsao
2 Lemon	C	2.94	0.052	0	0	
3 Orange	C	2.94	0.045	0	0	
QminC <sup>®</sup>						
1 Curcumin	B, C	3.18	0.093	0	0	Pongdang, Khamtaleso, Nakhon Ratchasima
2 Manuka honey	A, B, C, E	3.38	0.090	0.063	0.022	
Hi! <sup>®</sup>						
1 Vitamin C 200% orange flavor	C	2.78	0.054	0.023	0.003	Bang Tan, Ban Sang, Prachin Buri
2 Vitamin C 200% mixed berry flavor	B, C	2.98	0.015	0.061	0.094	
SCOTH <sup>®</sup>						
1 ABC Drink Honey Lemon flavor	A, B, C	3.09	0.054	0.130	0.025	Lahan, Bang Bua Thong, Nonthaburi
2 ABC Drink Orange flavor	A, B, C	3.37	0.044	0.137	0.032	
VITA-ONE C+ <sup>®</sup>						
1 Spring orange flavor	A, B, C	3.51	0.087	0.127	0.054	Nonsee, Kabinburi, Prachinburi
2 Zesty lemon flavor	C	3.1	0.040	0.156	0.056	
Double C <sup>®</sup>						
1 Lemon & Lime flavor	C	3.4	0.030	0.031	0.038	Nong kom ko, Muang, Nong Khai
2 Orange & Lemon flavor	C	3.25	0.052	0.078	0.020	
3 Passion Fruit & Orange	C	3.33	0.063	0.084	0.006	
4 Fruit Punch flavor	C	3.65	0.013	0.072	0.006	
5 Peach & Lychee flavor	C	3.23	0.041	0.080	0.047	

**Table 2** The pH values and fluoride concentrations of the different types of supplemented vitamins

Supplemented vitamins	pH		Fluoride	
	Mean	SD	Mean	SD
A	3.560	0.125	0.270	0.334
B	5.406	2.237	0.605	1.164
C	3.938	1.1318	0.269	0.596
D	8.230	0.680	0.051	0.003
A, B	3.790	0.016	0.046	0
B, C	3.695	0.932	0.031	0.017
C, E	2.850	0.042	0.038	0.005
A, B, C	3.323	0.214	0.131	0.017
A, D, E	3.620	0.124	0.026	0.004
A, B, C, E	3.430	0.071	0.136	0.103

The pH values of the 60 vitamin water products ranged from 2.78–9.61 with a median of 3.61 and mean ( $\pm$ SD) of 4.11 ( $\pm$ 1.49). The pH of the products corresponding to the critical pH value (5.5) of enamel [19,20] are grouped and presented in Figure 1. Eighty-five percent of the

products (n=51) had a pH value  $\leq$  5.5, while 15% (n=9) had a pH value  $>$  5.5. Of the 60 products, Hi!<sup>®</sup> Vitamin C 200% orange flavor had the lowest pH value(2.78 ( $\pm$ 0.054)), whereas ICHITAN<sup>®</sup> PH Plus alkaline water with vitamin B complex displayed the highest pH (9.61 ( $\pm$ 0.303)).



**Figure 1** The number and percentage of vitamin water products with a critical pH value. SD: Standard Deviation, Min: Minimum, Max: Maximum.

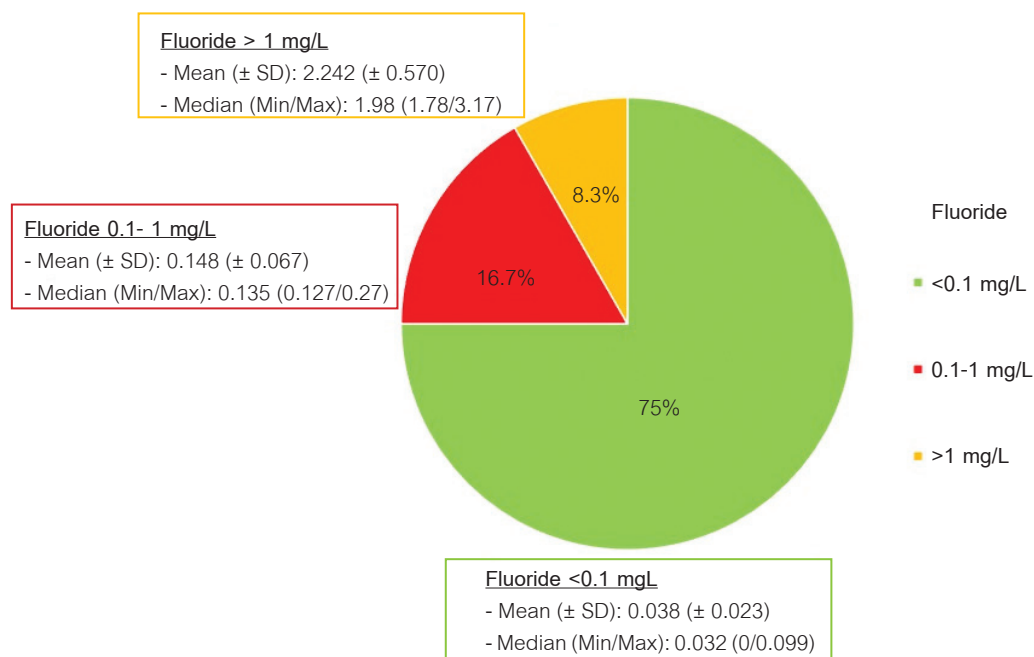


The fluoride concentrations detected in the 60 products of vitamin water ranged from 0–3.17 mg/L with a median of 0.046 mg/L and mean ( $\pm$ SD) of 0.243 ( $\pm$ 0.628) mg/L. The number of products based the ranges of fluoride concentration and their mean ( $\pm$ SD) and median (Min/Max) are presented in Figure 2. Of the 60 vitamin water products, 8.3% of the products tested in this study comprising 5 products from 2 brands; 1) YANHEE<sup>®</sup>; Vitamin water, Vitamin C water grass jelly, Vitamin C water strawberry, and Vitamin C water lychee (with fluoride levels between 2.40–1.78 mg/L) and 2) AQUA•VITZ<sup>®</sup> Vitamin mineral water (with a fluoride level of 3.170 mg/L), had fluoride concentrations higher than 1 mg/L with AQUA•VITZ<sup>®</sup> vitamin mineral water displaying the highest fluoride concentration. However, most of the vitamin water products (75%, n=45) contained a fluoride concentration less than 0.1 mg/L.

## Discussion

Dental erosion is a major concern in oral health. Dental erosion is characterized by the demineralization of dental hard tissue caused by the exposure of the tooth surface to an acidic environment, resulting in a permanent loss of tooth structure [19,20]. The critical pH value for enamel demineralization and tooth surface erosion is 5.5 [19,20]. Most of the vitamin water products in Thailand were acidic and had pH values below the critical level, increasing the risk of dental hard tissue demineralization and tooth erosion when consuming vitamin water on a regular basis.

A previous study reported that the pH of vitamin water products commercially available in the United State ranged from 2.86–3.65 with a mean of 3.19 and were considered erosive [21]. These findings are similar to the results of our study,



**Figure 2** The number and percentage of vitamin water products with different fluoride concentration levels. SD: Standard Deviation, Min: Minimum, Max: Maximum, < 0.1 mg/L fluoride is considered a very low level of fluoride in drinking water, while 1 mg/L fluoride is considered the optimal level of fluoride that exhibited resistance to dental caries with minimal signs of dental fluorosis [11].

which found that most of the vitamin water products (85%) commercially available in Bangkok, Thailand had an acidic pH. Several studies confirmed that acidic drinks and beverages caused dental erosion and the loss of tooth structure in both primary and permanent teeth [22-24].

Some of the vitamins that were added into the water are acidic, e.g., vitamin C is ascorbic acid [25] and retinoic acid is a vitamin A derivative (Retinol) [26]. Moreover, to enhance their fruity flavor, citric acid is also added in the drinks [27]. All of these components contribute to the acidity of vitamin water. Indeed, we found that most vitamin waters that were acidic contained vitamin A and/or vitamin C (Table 2). The only brand that added vitamin C in the water, but had a pH value in the neutral zone was YANHEE<sup>®</sup>. This could be because vitamin C is easily degradable and no trace of vitamin C was detected in the vitamin water product from YANHEE<sup>®</sup> [28].

The recommended pH value of drinking water ranges from 6.5–8.5 [16]. Of the 60 vitamin water products, there were only 4 products from YANHEE<sup>®</sup> that had pH values within the normal range. Moreover, the pH level of ICHITAN<sup>®</sup> PH Plus alkaline water with vitamin B complex (9.61) was higher than the normal recommended pH range and higher than the pH on the product label that indicated a pH of 8.5. Although drinking alkaline water is suggested to have a positive effect on human health [29], an *in vivo study* reported that drinking highly alkaline water could cause a delay in growth and development [30]. Therefore, the incorrect labeling of the pH of ICHITAN<sup>®</sup> PH Plus alkaline water with vitamin B complex product can result in consumers being unaware that the pH of this product is higher pH than the normal range.

The fluoride concentrations varied among the products with most of the products containing a fluoride concentration of less than 0.1 mg/L,

which is lower than the optimal recommended fluoride level in drinking water (1 mg/L) [11]. However, 5 products contained fluoride concentrations that exceeded the optimal recommended level, increasing the risk of dental fluorosis when consumed in large amounts by young children [7,31].

The fluoride concentration varied among the same type of supplemented vitamin water and we found no relationship between the type of vitamin and amount of fluoride detected. When investigating the water source based on the production sites, most of the production sites of vitamin water products had the same variation in fluoride concentration, except in Nakhon Pathom, Samut Sakhon, and Nonthaburi, which had a wide variation in fluoride concentration. Five products with a high fluoride concentration were manufactured from 3 production sites that had wide variations in fluoride concentration, AQUA•VITZ<sup>®</sup> mineral vitamin water from Samut Sakhon (1 out of 3 products) and 4 YANHEE<sup>®</sup> products from Nakhon Pathom (2 out of 13 products) and Nonthaburi (2 out of 4 products). Therefore, the high fluoride concentration caused the wide variation in those production sites. Furthermore, there was no difference in fluoride concentration in the products from the same company prepared from different production sites (YANHEE<sup>®</sup>). Therefore, there was no association between the fluoride concentration in vitamin water and the production site. This finding is similar to that of a previous study by Rirattanapong and Rirattanapong [32] that found no relationship between the production site and the amount of fluoride in rice milk products available in Bangkok, Thailand.

We observed that the highest fluoride concentration (3.17 mg/L), was found in mineral water by AQUA•VITZ<sup>®</sup>. This result corresponds to those of previous studies that found a greater

fluoride concentration in mineral water compared with plain water [13,33]. Furthermore, 4 out of 5 samples with a fluoride concentration above 1 mg/L were produced by the same company (YANHEE®). The Chemlab services (Thailand) limited reported that one of the components added into the water product is 0.1 g/L ash [34]. The added ash may contribute to the high fluoride concentration detected in vitamin water, based on a previous report that found that the concentration of fluoride in water contaminated with ash was directly proportional to the concentration of ash in the samples [35].

In contrast to our findings, vitamin water is promoted as a functional health beverage. The impact of vitamin water on oral health has never been investigated and discussed. Our study revealed that some of the products contained high levels of fluoride that could increase the risk of dental fluorosis in young children. Moreover, the acidity of the vitamin water could cause dental hard tissue demineralization and tooth erosion, which damages the tooth permanently.

## Conclusion

Most of the vitamin water products commercially available in Bangkok, Thailand were acidic and the pH levels were lower than the critical pH value for enamel demineralization. Moreover, the concentrations of fluoride varied among products with most products containing low levels of fluoride. In addition, 8.3% of the products contained high levels of fluoride, increasing the risk of dental fluorosis in young children. The data obtained from this study indicates that labeling the fluoride concentration and pH value on the vitamin water products is required.

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