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Assessment of Fluoride and pH Levels in a Range of Ready-to-Drink Children's Beverages Marketed in Malaysia

Aira Syazleen Ahmad[a,b], Nor Azlida Mohd Nor[b*], Nadia Afiqah Ahmad[b], Zamros Yuzadi Mohd Yusof[b], Ivor G. Chestnutt[c]

[a]*Oral Health Programme, Ministry of Health, Federal Government Administrative Centre, 62590 Putrajaya, Malaysia*

[b]*Department of Community Oral Health and Clinical Prevention, Faculty of Dentistry, Universiti Malaya, 50603 Kuala Lumpur, Malaysia*

[c]*Department of Applied Clinical Research and Dental Public Health, Cardiff University School of Dentistry, Heath Park, Cardiff CF14 4XY, United Kingdom*

*Corresponding author: azlida@um.edu.my

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ABSTRACT

This study aimed to determine the fluoride and pH levels of beverages likely to be consumed by children in Malaysia and to estimate daily fluoride intake from consumption of these beverages. A convenience sampling of 120 ready-to-drink beverages were purchased and categorised into 11 groups (UHT recombined milk, fresh milk [pasteurised], cultured milk [probiotic], yogurt beverages, fresh fruit juices, fruit flavoured beverages, soy-based beverages, malt-based beverages, tea, carbonated beverages and bottled waters). Fluoride concentration was measured using a fluoride ion-selective electrode while the pH level was measured using a pH meter. The fluoride concentration in the beverages ranged from 0.02±0.00 mg/L to 2.77±0.06 mg/L. Tea was found to have the highest fluoride concentration. The intake of fluoride from consumption of other types of beverages is below the lowest-observed-adverse-effect level (except tea). The pH of the beverages included in the study ranged from 2.20±0.01 to 7.76±0.00. Carbonated beverages (mean pH: 2.98±0.50) were found to be extremely acidic followed by fresh fruit juices (mean pH: 3.38±0.34) and fruit flavoured beverages (mean pH: 3.90±0.92). The correlation between fluoride and pH levels was weak, $\tau = 0.058$ and not statistically significant ($p < 0.35$). The majority of the beverages had a low fluoride level and their consumption is unlikely to cause fluorosis except for tea. Almost half of the beverages had a low pH level with carbonated beverages being the most acidic.

Keywords: *Beverages; dental erosion; dental fluorosis; fluoride; pH*

INTRODUCTION

The intake of beverages can influence a child's quality of diet in a positive or negative manner depending on the types and amount of beverages consumed. Over the past decades, trends in beverage consumption among children have changed where a decreasing trend in the consumption of water and dairy beverages and an increasing trend in the consumption of sugar-sweetened beverages and soft drinks were observed (Fulgoni & Quann, 2012). As far as dental health is concerned, high consumption of sugary drinks can lead to dental caries and high consumption of acidic drinks can lead to dental erosion (Chowdhury *et al.*, 2019). In addition, beverages may also contain fluoride depending on the sources of water used to manufacture the products. Beverages with fluoride levels between 0.5 mg/L to 1.5 mg/L could contribute to the "halo effect" of water fluoridation. This can happen when beverages manufactured in fluoridated areas are transported and consumed by populations in non-fluoridated areas (Victory *et al.*, 2017). As a result, the availability of fluoride in beverages could potentially benefit those living in non-fluoridated areas for the purpose of caries prevention. However, excessive ingestion of fluoride during tooth development in early childhood can lead to a defect in the enamel structure development known as dental fluorosis. This is represented by the appearance of white or brown lines, spots, or flecks on the surfaces of the teeth with weaker enamel structure in severe cases (Browne *et al.*, 2005).

Beverages with low pH levels (pH < 4.00) can exert a detrimental effect on the tooth structure through their erosive properties (Reddy *et al.*, 2016). Epidemiological data showed that there was a high prevalence of dental erosion, up to 79.0% among 2–5 years old children who consumed high amounts of acidic beverages such as carbonated drinks and fruit juices (Mantonanaki *et al.*, 2013). These beverages are sold widely in the market. Access to these products is made even easier by the availability of online shopping facilities (Ni Mhurchu *et al.*, 2013). Some of the beverages include certain types of acids, i.e., phosphoric acid, and citric acid and most of them are often sweetened with excess sugars. Thus, high intake of such beverages can lead to tooth erosion and dental caries (Reddy *et al.*, 2016; Chowdhury *et al.*, 2019).

Many previous studies have reported on the fluoride and pH levels contained in beverages (Reddy *et al.*, 2016; Zohoori & Maguire, 2018; Chowdhury *et al.*, 2019). These studies were done to provide the public with information on the fluoride and pH levels contained in the beverages whose information is missing from the labels. In the UK, researchers have urged beverage manufacturers to label their products with information on the fluoride and pH levels. However, many manufacturers have been reluctant to do so because of the extra financial cost incurred for measuring the fluoride and pH levels in their food and drink products (Zohoori & Maguire, 2018). Therefore, the only way to measure the fluoride and pH levels in beverages is by conducting separate laboratory tests. In response to the increasing trend of beverages consumption in children in Malaysia and the lack of information on the fluoride and pH levels in these beverages, this study aimed to determine the fluoride and pH levels in a broad selection of children beverages sold in Malaysia; and to estimate daily fluoride intake from consumption of these beverages. The findings will be useful to estimate the total daily fluoride intake among young children in Malaysia in order to prevent dental fluorosis. In addition, the information on fluoride and pH levels in different types of beverages will assist medical and dental health professionals to provide appropriate oral health education and dietary advice to mothers with small children with respect to beverage consumption and their effects on oral health.

MATERIALS AND METHODS

Sampling

In the present study, a convenience sample of 120 children's beverages were purchased from three major supermarkets; Giant, Tesco and AEON located in Nilai, Negeri Sembilan, Malaysia. The sampling frame consisted of popular supermarkets (n = 6) in Nilai. Of these, only three major retailers with supermarkets throughout Malaysia and their provision of online shopping facilities were selected. With the availability of online shopping platform, these products represent the majority of children beverages sold in the Malaysian market during the data collection period (January to March 2019).

Two methods were used to determine whether the beverages were marketed for children. First, children's beverages were identified based on their packaging. This included children-oriented packaging, i.e., with cartoon images or the manufacturers labelling the product as "children's product" or products with an age indication. The second method was based on the literature on popular beverages among children (Opydo-Szymaczek & Opydo, 2010; Zahid *et al.*, 2017; Rodríguez *et al.*, 2018). Only ready-to-drink children's beverages were included in this study. Alcoholic beverages, semi-solid beverages, energy boosters and caffeinated beverages were excluded.

The samples were grouped into 11 main groups of beverages: UHT recombined milk, fresh milk (pasteurised), cultured milk (probiotic), yogurt beverages, fresh fruit juice, fruit flavoured beverages, soy-based beverages, malt-based beverages, tea, carbonated beverages and bottled waters.

Sample Preparation and Analysis

The samples were kept in their original packaging at the same temperature as specified by the manufacturers (room or cold temperature) until before the fluoride analysis was undertaken. A blind measurement of fluoride and pH levels for each beverage was carried out by a single person who was unaware of which beverage was being tested in order to prevent assessment bias. First, the researcher placed a sample of each beverage in a beaker and labelled it with a code. Then, the beverage in the beaker was tested for fluoride and pH levels by a laboratory expert who was blinded to the types of beverages.

All samples were tested at room temperature (27°C) to minimise the effect of different surrounding temperatures on the readings. Beverages stored at room temperature were tested immediately after they were opened. However, cold beverages, i.e., fresh fruit juices and fresh milks were allowed to remain outside the refrigerator until the temperatures had risen to the room temperature before they were tested for fluoride and pH levels.

A direct method of fluoride ion selective electrode was used to measure fluoride levels in the beverages (Martínez-Mier *et al.*, 2011). A Thermo Scientific Orion 9609BNWP (Thermo Fisher Scientific Inc, US) fluoride ion selective electrode was used as the measurement tool. Prior to sample testing, the machine was calibrated for accuracy. Calibration was performed using 0.1 mg/L to 1.0 mg/L fluoride standards with total ionic strength adjustment buffer (TISAB) II. Only fresh standards were used for calibration in each session. To measure the fluoride concentration, 20 ml of TISAB II was added to 20 ml sample of each beverage. Samples were stirred for one minute using Eyela Magnetic Stirrer RC-2 (Eyela, US). The fluoride ion selective electrode was immersed into the solution to check for fluoride level using Orion Versa Star Advanced Electrochemistry Meter, (Thermo Fisher Scientific Inc, US) until a stable digital reading was obtained. The whole process took about five minutes per sample reading. The fluoride content of each sample was obtained from the average of triplicate readings.

To measure the pH levels, an Automatic Temperature Compensation (ATC) Probe, (Jenco Instruments Inc, US) was immersed into 40 ml of samples and the pH level was measured using a Jenco Vision Plus pH6175, (Jenco Instruments Inc, US). Dual point calibration was carried out using buffer solutions of pH 6.86 and pH 4.00 and only fresh standards were used for calibration before each session began. The pH level of each sample was obtained from the average of triplicate readings.

All instruments in the experiment were washed using deionised water and dried with a paper towel between measurements to prevent cross-contamination between samples or standards. To ensure the accuracy of readings, recalibration was done after every six measurements. Reproducibility of the method was assessed by re-analysis of 30% of the samples (n = 40). For re-analysis purpose, different packet beverages of the same types of beverages were tested. The measurements showed that the electrode readings were reproducible.

Data Analysis

All data were entered and analysed using IBM Statistical Package for Social Science (SPSS) version 24 software (24.0, IBM Corp, Armonk, NY). Descriptive statistics analysis was performed and data were presented using mean and standard deviation. For the purpose of data presentation, the values of 0.40 mg/L and 0.60 mg/L were used as cut-off points to establish categories that are consistent with the optimum fluoride levels in the public water supply in Malaysia (low level, F < 0.4 mg/L; optimum level, F = 0.4–0.6 mg/L; high level, F > 0.6 mg/L) (Malaysian Dental Council, 2009). The mean pH level in the beverages was further categorised based on their chemical erosive potentials; (1) extremely erosive (pH ≤ 2.99), (2) erosive (3.00 ≤ pH ≤ 3.99), and (3) minimally erosive (4.00 ≤ pH ≤ 6.99) (Reddy *et al.*, 2016). Test of normality showed that the outcome data were not normally distributed. As a result, Kendall's tau-b test was used to measure the association between fluoride concentration and pH levels in the samples. The p value < 0.05 was set as the level of statistical significance.

The equation used to calculate the estimated daily fluoride intake from beverages consumption was adapted from a previous study (Liu *et al.*, 2017). The estimated daily fluoride intake from beverages consumption (mg/day) was calculated using the mean fluoride level in the beverages, and the daily beverage consumption ranged from 253 ml/day (min) to 633 ml/day (max) as reported by the Institute of Medicine (Institute of Medicine, 2005). The estimated daily fluoride intake per kg body weight (mg/kg bw/day) was calculated using average child weights (≤4 years) from the Malaysian reference weight (Bong *et al.*, 2015) and the World Health Organization (WHO) reference weight (WHO Multicentre Growth Reference Study Group, 2006). The Institute of Medicine daily beverage consumption range was used as there is no local data available for young children in Malaysia. The minimum and maximum values of beverage consumption were used to reflect on the lowest and highest level of estimated fluoride ingestion from beverage consumption.

RESULTS

Of the 120 samples, 76.7% were locally manufactured and 23.3% were imported. The imported beverages were mainly from Thailand (n = 12), followed by Singapore (n = 3) and Australia (n = 3). Others were from Indonesia, Vietnam, South Africa, Bangladesh, Turkey, Cyprus, France, Italy, Austria and US; with one product each. None of the beverages stated the fluoride or acidity levels on their labels. In this study, the analysed samples were divided into 11 groups of beverages.

Fluoride Levels in Beverages

Table 1 shows the fluoride levels of the samples. The overall mean fluoride level (without differentiating the group of beverages) was 0.33±0.37 mg/L, and ranged from 0.02 to 2.77 mg/L. The majority of the samples had a low fluoride concentration. Only 10% had a fluoride level of more than 0.60 mg/L (Fig. 1). These were teas and malt-based beverages. Tea samples were found to have the highest variations in fluoride levels ranging from 0.11 to 2.77 mg/L (see Table 1). In terms of malt-based beverages, the mean fluoride level was 0.65±0.36 mg/L and the levels ranged from 0.05 to 0.96 mg/L (see Table 1). Only one bottled water had a high fluoride level (1.60±0.00 mg/L) with the remaining samples had a low fluoride level. There was a higher fluoride level in local beverages (mean = 0.38 mg/L, SD = 0.40) than imported beverages (mean = 0.16 mg/L, SD = 0.20) (see Table 2).

Estimated Fluoride Ingestion from Beverages

Table 3 shows the amount of fluoride ingested thorough consumption of the beverages. This was estimated at 0.006 mg/kg bw/day to 0.015 mg/kg bw/day using Malaysian children's body weight (14–15 kg). The amount was lower (0.005 mg/kg bw/day to 0.013 mg/kg bw/day) when calculated using global reference body weight from the WHO (16 kg).

Table 1 Mean fluoride level in different groups of beverages (*n* = 120)

Groups of beverages	Sample (*n*)	Fluoride range (mg/L)	Fluoride level (mg/L)	
			Mean	SD
UHT recombined milk	11	0.02–0.49	0.26	0.15
Fresh milk (pasteurised)	12	0.04–0.44	0.14	0.14
Cultured milk (probiotic)	7	0.05–0.59	0.34	0.21
Yogurt beverages	6	0.08–0.56	0.32	0.19
Fresh fruit juices	16	0.04–0.48	0.18	0.17
Fruit flavoured beverages	22	0.03–0.58	0.20	0.18
Soy-based beverages	13	0.04–0.69	0.38	0.19
Malt-based beverages	5	0.05–0.96	0.65	0.36
Teas	11	0.11–2.77	0.89	0.77
Carbonated beverages	9	0.03–0.45	0.10	0.14
Bottled water	8	0.07–1.60	0.52	0.49
Total	120	0.02–2.77	0.33	0.37

Table 2 Summary data of fluoride and pH levels in local and imported beverages (*n* = 120)

Value	Fluoride (mg/L)		pH	
	Local (*n* = 92)	Import (*n* = 28)	Local (*n* = 92)	Import (*n* = 28)
Min	0.02	0.04	2.20	2.70
Max	2.77	0.87	7.58	7.76
Mean	0.38	0.16	4.86	4.94
SD	0.40	0.20	1.69	1.51

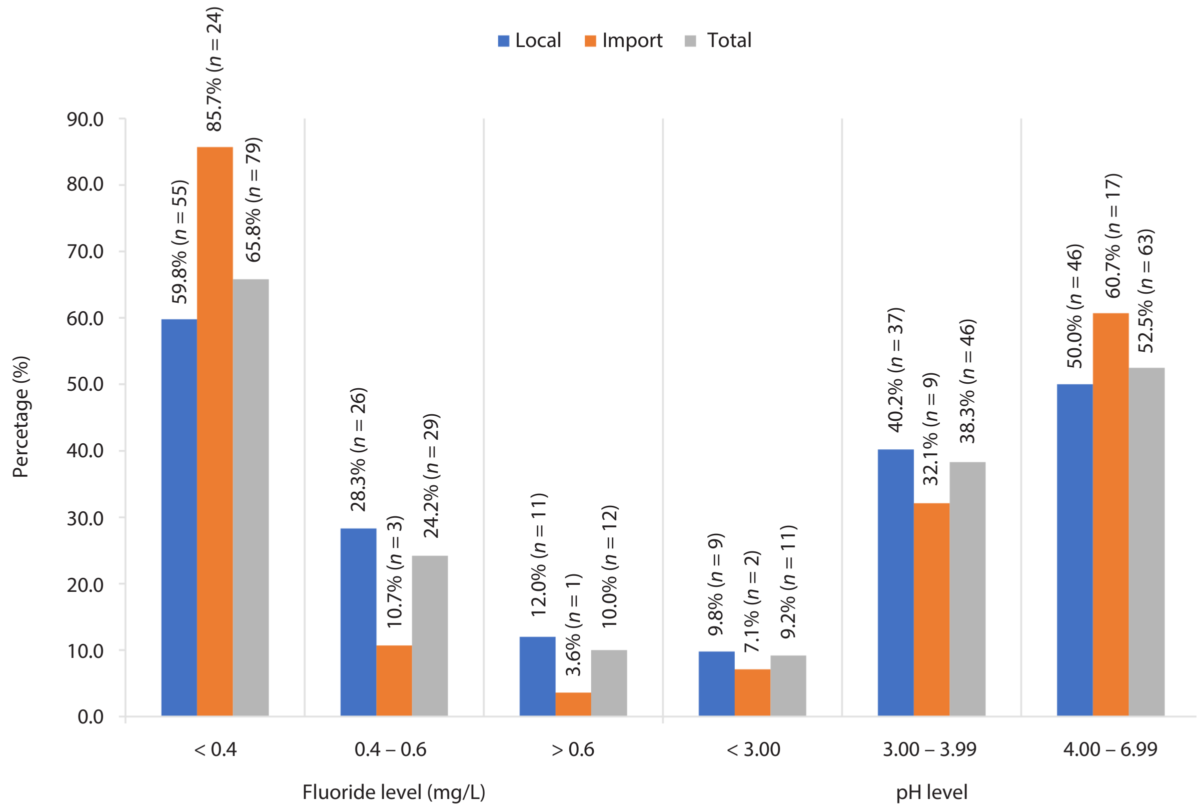

Fig. 1 Summary data of fluoride and pH levels in local and imported beverage samples.

Table 3 Estimated amount of fluoride ingested from beverages

Reference category	Children (1–4 years old) Boy	Children (1–4 years old) Girl
Body weight (kg)		
Malaysian growth reference[a]	15	14
WHO growth reference[b]	16	16
Range beverages consumption (ml/day)[c]	253–633	
Estimated maximum amount of fluoride ingested from beverages (total mean = 0.33 mg/L)		
mg/day	0.083	0.209
mg/kg bw/day	0.006[a] 0.005[b]	0.015[a] 0.013[b]

Notes:
[a] Calculation based on body weight from the Malaysian children growth reference (Bong *et al*., 2015).
[b] Calculation based on body weight from the WHO growth reference (WHO Multicentre Growth Reference Study Group, 2006).
[c] Recommended daily beverage consumption for children 1–4 years old (Institute of Medicine, 2005).

pH Levels in Beverages

There was a wide range of pH levels between and within the different groups of beverages with pH levels ranging from 2.20 to 7.76. Just under half of the beverages (47.5%) had a pH level lower than 4.00 (Fig. 1). Of these, carbonated beverages were found to be extremely erosive (mean pH: 2.98±0.50; range: 2.20 to 3.76), followed by fresh fruit juices (mean pH: 3.38±0.34; range: 2.70 to 3.97) and fruit flavoured beverages (mean pH: 3.90±0.92; range: 2.53 to 5.34) with some erosive potentials (Table 4). All milk-based beverages had pH levels approaching the neutral pH level (mean pH: 6.62±0.14; range: 6.24 to 6.89) except for cultured-milk (probiotic) beverages (mean pH: 3.62±0.14; range: 3.51 to 3.84) and yogurt beverages (mean pH: 4.11±0.15; range: 3.95 to 4.30) which were more acidic. There was little difference in pH levels between imported and local beverages (Table 2). Two groups of beverages were found to have the highest within-group variations in pH levels namely tea-based beverages and bottled waters.

Table 4 Mean pH level in different groups of beverages (n = 120)

Groups of beverages	Sample (n)	pH range	pH level	
			Mean	SD
UHT recombined milk	11	6.39–6.89	6.61	0.14
Fresh milk (pasteurised)	12	6.24–6.74	6.62	0.14
Cultured milk (probiotic)	7	3.51–3.84	3.62	0.14
Yogurt beverages	6	3.95–4.30	4.11	0.15
Fresh fruit juices	16	2.70–3.97	3.38	0.34
Fruit flavoured beverages	22	2.53–5.34	3.90	0.92
Soy-based beverages	13	6.24–7.05	6.62	0.24
Malt-based beverages	5	5.98–6.95	6.55	0.40
Teas	11	2.86–6.11	4.24	1.32
Carbonated beverages	9	2.20–3.76	2.98	0.50
Bottled water	8	2.87–7.76	6.38	2.05
Total	**120**	**2.20–7.76**	**4.88**	**1.64**

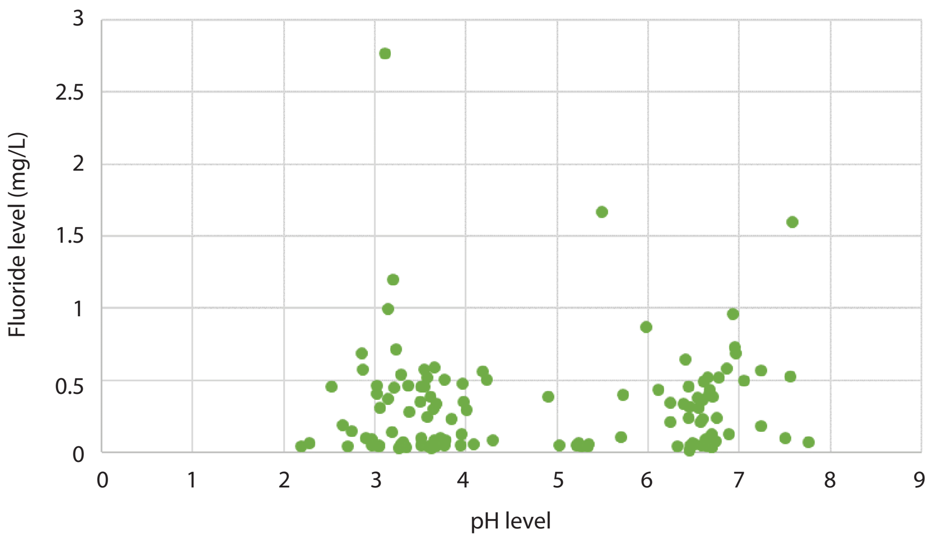

Fig. 2 Scatter plot of fluoride levels against pH levels of sampled beverages.

The mean pH levels in tea-based beverages ranged from 2.86±0.00 to 6.11±0.01 (Table 4). There were six tea brands (fruit flavour based such as lemon, peach and grape) that were found to have erosive to extremely erosive potentials (pH < 4.00). The range of pH levels in bottled waters was 2.87±0.01 to 7.76±0.00 (Table 4). Most of the bottled waters were alkaline except for the two lightly carbonated bottled waters (mean pH: 2.87±0.01 and 3.29±0.01). Fig. 2 shows the scatter plot of fluoride against pH levels of the beverages. There was a weak positive, but non-statistically significant ($p < 0.350$) correlation between fluoride and pH levels ($\tau = 0.058$).

DISCUSSION

This study aimed to assess the fluoride and pH levels in children's beverages available in the Malaysian market and to estimate the daily intake of fluoride from consumption of these drinks. The findings showed that there was a wide range of variations in the fluoride and pH levels in children's beverages sold in the Malaysian market.

Fluoride Levels in the Beverages and Implications for Oral Health

Despite variations in fluoride levels between and within the different groups of beverages, the majority of the beverages had low fluoride levels. Only tea and malt-based beverages were found to have higher fluoride levels than other groups of beverages in the study. High fluoride levels in tea drinks found in this study were similar to findings in other related studies conducted in other countries (Opydo-Szymaczek & Opydo, 2010; Fojo *et al.*, 2013; Rodríguez *et al.*, 2018). Tea drinks contain a high amount of fluoride mainly due to the fact that tea leaves accumulate fluoride from the soil. The mean fluoride level in tea drinks in the present study (0.89±0.77 mg/L) was similar to that found in a study in Thailand (0.81±0.51 mg/L) (Rirattanapong & Rirattanapong, 2017) but higher than fluoride levels found in tea drinks sold in Poland and Portugal (Opydo-Szymaczek & Opydo, 2010; Fojo *et al.*, 2013). In contrast, a higher mean fluoride level in tea drinks was also reported in a previous local study in 2014 (13.02±0.23 mg/L) (Rahim *et al.*, 2014). However, the difference in the findings between that and the present study could be due to the different types of tea drinks being tested and the different methods used in measuring fluoride levels where a photometer was used in the earlier study. Tea drinks included in the present study were ready-to-drink products targeted for children's consumption, and the fluoride levels were measured using the gold standard ion-selective electrode for fluoride analysis method established in the literature (Martínez-Mier *et al.*, 2011). In this method, errors in measurement were minimised as the fluoride electrode was linked directly to a digital fluoride reader.

In addition to tea, malt beverages were also found to have a higher mean fluoride level (mean: 0.65±0.36 mg/L) than the recommended national standard for fluoride level in the public water supply. Comparison of fluoride levels in malt beverages in this study with other published studies was limited due to the fact that past studies on the subject were mostly focused on juices and milk drinks and did not include malt-based beverages. By definition, malt drinks are malt-based foods manufactured by mixing malt with other cereal and legume flours with or without whole milk or milk powder and/or cocoa powder (Gan *et al.*, 2019). This type of beverage is popular among young children in Malaysia and is marketed as a nutritious beverage (Jan Mohamed *et al.*, 2015).

A potential reason for the wide variations in fluoride levels in the beverages could be due to the variations in fluoride levels in the water source used at the manufacturing sites. The water sources could come from artificially fluoridated areas, water with natural fluoride content and water coming from different types of water filters that may or may not remove fluoride (depending on the types of filtration system). Although the optimum level of fluoride in Malaysian public water supply is 0.5±0.1 mg/L, fluoride level in the water may not be consistent throughout the region and may vary by geographical areas (Shaharuddin *et al.*, 2009). As drink manufacturers may have multiple production sites, their water sources may come from different areas and therefore the beverages may contain different fluoride levels depending on the manufacturing sites where they were produced (Liu *et al.*, 2017; Townsend *et al.*, 2019). No clear patterns were observed between drinks produced inside or outside Malaysia. Most of the imported drinks had low fluoride levels, although they were imported from countries with a water fluoridation programme such as Thailand, Australia and Singapore. However, the results should be interpreted with caution as the samples of beverages produced outside Malaysia were relatively few in this study which reflected their availability in the local market during the data collection period. In addition, the variations in fluoride levels in the beverages could also be due to the different fluoride levels contained in fruits used to make fruit juice beverages. A study in Spain reported that certain types of fruit juices such as grape juice has a higher fluoride level (1.14 mg/L) than other juice products made from carrots (0.07 mg/L) or apricot (0.06 mg/L) (Rodríguez *et al.*, 2018). Meanwhile, a study in the UK reported that ready-to-feed infant juices contained fluoride ranging from 0.05 to 0.15 mg/L with the highest fluoride level found in pear and peach juices (Maguire *et al.*, 2012).

The estimated amount of ingested fluoride from beverages per body weight alone was low and did not exceed the lowest-observed-adverse-effect level of fluoride for young children (0.1 mg/L). Therefore, a potential association with dental fluorosis in the permanent dentition upon consumption of these beverages (except tea drinks) is highly unlikely. Similar results were reported from a study conducted in Heilongjiang Province, North-east China (Liu *et al.*, 2017). However, the present study found that certain types of tea-based beverages had high concentration of fluoride (2.77 mg/L) that exceeds the recommended level of fluoride in the water supply by local (0.4 to 0.6 mg/L) and the WHO guidelines (0.5 to 1.5 mg/L) (Malaysian Dental Council, 2009; World Health Organization, 2011). Excessive consumption of this type of beverages in addition to exposure to dietary and non-dietary sources of fluoride, i.e., toothpaste and/or fluoride varnish during childhood may increase the risk of dental fluorosis. The critical period for dental fluorosis development in the permanent teeth is in the first 2–3 years of life for upper central incisors and the first 6–8 years of life for posterior teeth (Buzalaf & Levy, 2011). It is known that a low level of fluoride in the oral cavity is beneficial for caries prevention. However too much exposure to fluoride may increase the risk of developing fluorosis. Therefore, continuous monitoring of fluoride intake during childhood is important to maximise the benefit of fluoride for caries prevention and minimise the risk of fluorosis.

pH Levels in the Beverages and Implications for Oral Health

In terms of pH level, the carbonated beverages were found to be the most acidic (extremely erosive) followed by the fresh fruit juices and probiotic beverages. The mean pH level of carbonated beverages in the present study (2.98±0.50) was in agreement with the findings in most studies on the erosive potential of carbonated beverages worldwide (Cochrane *et al.*, 2009; Idris *et al.*, 2016; Omid *et al.*, 2016). Carbonated beverages are acidic due to the formation of carbonic acid (H_2CO_3) in a reaction catalysed by carbonic anhydrase enzyme (Reddy *et al.*, 2016). The fizziness property of carbonated beverages was subject to the concentration of carbon dioxide dissolved and its ability to change from liquid phase to form bubbles (Descoins *et al.*, 2006). At the same time, a low pH level was also found in two of the lightly carbonated bottled waters also known as sparkling water. This may be due to the carbonation process in the making of the products which takes place at the manufacturing site and/or the naturally occurring mineral acids in spring waters from which they are made. Similar findings were also reported in studies conducted in the UK (Brown *et al.*, 2007) and Australia (Cochrane *et al.*, 2009).

Data on high acidity of fresh fruit juices and fruit flavoured beverages found in the present study support similar findings reported by other investigators in the US (Reddy *et al.*, 2016) and UK (Maguire *et al.*, 2012). This could be attributed to the acid ingredients which are added to the beverages at the manufacturing site in addition to the fruit's natural acids. Acids are added to beverages and compose a flavour profile giving the beverages a distinctive taste. For example, phosphoric acid and citric acid are added to beverages to impart a tangy flavour, act as a preservative, and enhance the intrinsic flavour. However, acids also occurred naturally in fruits. For example, citrus fruits such as lemon, orange, mango and grapes have both citric acid and ascorbic acid (vitamin C) (Reddy *et al.*, 2016). Other seasonal fruits such as apples, pears and cherries contain malic acids. Those additional acids on top of natural fruit acids have contributed to the decrease in pH level. As a result, high consumption of this type of beverage may increase the risk of dental erosion (Chowdhury *et al.*, 2019). Additionally, as far as dental health is concerned, both the carbonated and flavoured juices are often sweetened and contain high amount of sugars. The combination of high sugar levels and high acidity of carbonated drinks and fruit juices have made the products highly cariogenic which lead to dental caries over a short period of time if consumed in high quantities (Chowdhury *et al.*, 2019). In children, the consumption of these types of beverages should be limited to once daily preferably during one of the main meals when the saliva buffering capacity is at its peak (Moynihan, 2002). Sipping the drinks throughout the day is not recommended as this habit will expose the teeth to sugars and high acidity over a long period of time which may lead to severe early childhood caries (Moynihan, 2002).

The cultured milk (probiotic) beverages were also found to have low pH levels. One of the reasons is that these drinks often contain pieces of citrus fruits which are acidic in nature. In addition, cultured milk beverages are acidic because the starters used in the fermentation process of carbohydrates consist of homofermentative mesophilic lactic acid bacteria (Shiby & Mishra, 2013). Parents should be made aware of the low pH levels in cultured milk drinks as they tend to be quite popular among children and are often marketed as healthy products.

There was no significant association between fluoride and pH levels of the beverages in the present study. In view of the finding, the fluoride content in the beverages is unlikely to have a significant effect on the acidity of the beverages and vice versa. Similar findings were also reported by Larsen & Richards (2002) where fluoride was not able to reduce the erosive property of soft drinks for children.

Findings from the present study will be useful in assisting health professionals to educate parents with respect to the potential sources of fluoride intake in children especially at a young age. Knowledge on the acidity of different types of beverages is equally important in preventing dental erosion and managing patients with such a condition.

Study Strengths and Limitations

The strength of this study was that it included a wide variety of beverages tested for fluoride and pH levels. Furthermore, the respective test for each drink was conducted in triplicate to ensure the results obtained were precise and reliable. On the other hand, this study only included beverages purchased from one geographical area. However, efforts had been made to improve the external validity of the findings by selecting supermarkets that also provide online shopping, thus making the beverages accessible to a wider Malaysian population. The beverages were marketed in different types of packaging such as box cartridge, can, glass bottle and aluminium pouch. All these containers may potentially be a confounder for measuring fluoride level (Liu *et al*., 2017).

CONCLUSION

Beverages sold in the Malaysian market have a wide range of fluoride and pH levels. The majority had low fluoride levels except for tea and malt-based beverages while fewer types had low pH levels with carbonated beverages being the most acidic, followed by fruit-based beverages. There was a weak positive correlation between fluoride concentration and pH levels indicating fluoride content is unlikely to have an effect on the acidity of the beverages. The findings will be useful in dental health education and dietary advice for mothers with small children as well as patients with high intakes of certain types of beverages.

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