# EROSIVE POTENTIAL OF DRINKS CONSUMED IN DUBAI

**Ebraheem S. E. ALDeekan**
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# ABSTRACT

## Erosive potential of drinks consumed in Dubai.

**Ebraheem S. E. Aldeekan**

**Supervisor: Dr Haitham Elbishari**

**Background:** Most of the consumed soft drinks are acidic in nature, regular consumption of these drinks which contain the main source of extrinsic acid in diet may result in dental erosion. Although studies have tested drinks for chemical parameters internationally, limited studies have been conducted on drinks in Dubai. The aim of this in vitro study was to evaluate the erosive potential of different soft drinks in Dubai by determining the pH, titratable acidity and concentrations of phosphate, calcium, and fluoride in a variety of commercially available drinks in Dubai.

**Materials and methods:** twenty-four commercially available soft drinks in Dubai were selected for this in- vitro study. The drinks were divided based on their carbon dioxide ($CO_2$) contents into carbonated and non-carbonated drinks. All drinks were stored according to the manufacturers' recommendations prior of conducting the study. The properties of each product were analyzed to measure their Acidity (pH), Titratable Acidity (TA), Fluoride (F), Calcium (Ca) and Phosphate ($PO_4$). Inductively Coupled Plasma-Atomic Emission Spectrometers (SGIMADZU ICPE-9820) was used to calculate the mineral contents of tested juices at room temperature.

**Results:** The highest and lowest pH values were 4.38 & 2.79 which recorded for Orange juice (Rauch) and Sun cola (sun top) respectively. On the other hand, 3.6 and 0.11 were the highest and lowest titratable acidity values, which recorded for Mixed fruit lemon (Almarai) and Barbican- strawberry, respectively. Among both carbonated and non-carbonated drinks, the highest and lowest Ca values were 55.6 and 1.98 which were measured for orange juice (Rauch) and blue raspberry (Vimto) respectively. Both highest and lowest reading were among the non-carbonated drinks. In carbonated drinks, 7.83 was the highest Ca level measured for Power horse energy while 2.18 was the lowest value measured for Lemon Ice-Tea (Lipton). Among all carbonated drinks, phosphate was not detected apart from Barbican-apple juice which contains 39.55ppm phosphate. On the other hand, the values of phosphate among non-carbonated were ranged from 447.63 to 19.04 for orange juice (Rauch) and Berry mix (sun top) respectively. the mean and standard deviation of calcium levels for both carbonated and noncarbonated were 3.31(2.21) and 9.96(12.16) respectively. Mean (SD) for phosphate were 39.55(0) and 140.67(134.33) for carbonated and noncarbonated drinks correspondingly. pH means were 3.23(0.12) and 3.4(0.44), while means titratable acidity were 0.24 (0.19) and 0.52 (0.78) for carbonated and noncarbonated, respectively. Kruskal-Wallis test was used to compare the means of all variables between carbonated and noncarbonated drinks. only difference in calcium level was statistically significant ($p<0.05$). The means of pH and Calcium were compared with data of mineral waters and treated waters which revealed significant difference with all tested drinks at ($p<0.05$).

**Conclusion:** All drinks had erosive potential with fruit juices having the lowest mean pH and lowest mineral contents. The association between minerals and pH are high.

# DEDICATION

I dedicate this thesis to my lovely parent, whose support me and prays for me. And I would not be the person I am today if it was not for them. Second, I dedicate this to my brother and sisters for their unfaltering support.

To my faculty, colleagues and everyone who supported me during my residency.

# DECLARATION

I declare that all the content of the thesis is my own work. There is no conflict of interest with any other entity or organization.

Name:

Signature:

# ACKNOWLEDGMENTS

First and foremost, praises and thanks. To Allah, for his countless blessing throughout my postgraduate studies.

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# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

TSL: Tooth Surface Loss

NCTSL: Non-Caries Tooth Surface Loss

pH: Potential of Hydrogen

HA: Hydroxyapatite

TA: Titratable Acidity

Ka: dissociation constant

DS: degree of saturated

Ppm: parts per million

°C: Degrees Celsius

Ca: Calcium

F: Fluoride

H: Hydrogen

$CO_2$ : carbon dioxide

NaF: Sodium Fluoride

GERD: Gastroesophageal reflux disease

ED: Eating disorders

SIV: self-induced vomiting

MDC: microwave digestion system

SD:  Standard Deviation

# 1. INTRODUCTION

Tooth wear is defined as the loss of dental hard tissues from the surfaces of the teeth caused by factors other than dental caries, trauma, and developmental disorders (Litonjua et al., 2003). Tooth wear has other synonyms such as Tooth Surface Loss (TSL) and Non-Carious Tooth Surface Loss (NCTSL). It is classified according to the etiology into Mechanical cause, biomechanical cause, and chemical cause. Classification of tooth wear is illustrated in Fig 1.1. Mechanical wear could be due to tooth-tooth contact which is known as attrition or due to external cause which is known as abrasion. Attrition occurs in the occluding and proximal surfaces (Imfeld, 1996). Abrasion is a wear due to externally applied particles or objects such as toothbrush which affects the cervical areas of cuspid and bicuspid.

Biomechanical cause is known as abfraction (Grippo, 1992) which is due to due to tooth-tooth contact but away from occluding surfaces. Erosion is described as the chronic, gradual process of destruction hard tooth structure by non-bacterial acidic substances (Addy and Shellis, 2006). Tooth wear is a multifactorial and its severity is dependent on lifestyle, diet, type of acid, duration of the exposure. The transition from the past to the industrial revolution, led a change in human diets from eating raw unrefined foods to a much softer and easy to chew diet and this has resulted in a marked decrease in dental wear. Prehistoric humans had an average wear rate of 280-360 µm/year, while modern human teeth wear at an average rate of 15-20 µm/year in the post canine region (Addy and Shellis, 2006).

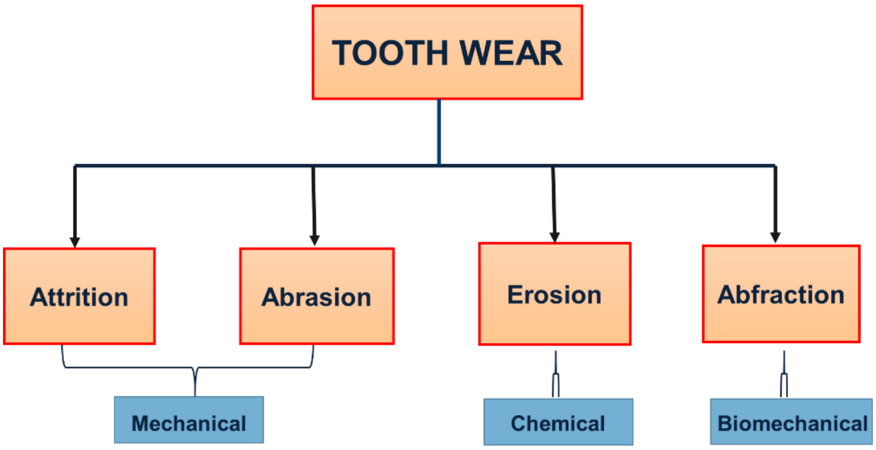


**Fig 1.1: Classification of tooth wear**

Dental enamel is composed of almost 96% mineral by weight. Our teeth have mineral composed of calcium deficient carbonate hydroxyapatite. When acid attacks the crystals of HA, hydrogen ions will extract carbonate and/or phosphate from the crystals (Featherstone and Lussi, 2006). The critical pH in respect to enamel demineralization ranges between 5.5 to 6.5 and is inversely related to the concentration of calcium and phosphate present in saliva (Ganss and Lussi, 2006). However, previous studies have shown that titratable acidity (TA) has important role in enamel demineralization. Titratable Acidity (TA) refers to the total concentration of free protons and undissociated acids in a solution (Benjakul and Chuenarrom, 2011a). Salivary composition and the mineral content of teeth are factors that affect the severity of dental erosion. It has been reported that erosive wear may increase in patients with lower salivary flow rate (Mulic et al., 2012). Electrolyte composition, buffer capacity and protein content of saliva influence wear, buffer acid attack the role of saliva capacity to balance from demineralization following an acid attack (Bashir and Lagerlöf, 1996). According to Amaechi, saliva can remineralize early enamel erosion, and the level of remineralization is different between sites within the same mouth (Amaechi and Higham, 2001). The diagnosis of dental erosion can be established by clinical examination and questioning the patient. The clinical presentation of erosion lesions in a patient's mouth who consumes erosive drinks include broad shiny concavities on smooth surfaces and wide buccal concavities in mandibular posteriors. Unique form of dental erosion of tooth wear which is proud of the existing fillings above the occlusal surface (Lutovac et al., 2017).

# 2. LITERATURE REVIEW

Dental erosion its defined as a demineralization of hard dental tissue by a chemical substance. Dental erosion is not only caused by extrinsic acid, but also is affected by intrinsic acids. Many drinks have been shown to be the cause of dental erosion including dilutable cordials, carbonated drinks, fruit juices, sports drinks and alcoholic drinks.

To determine the ability of erosive drinks to affect dental hard tissue, chemistry basics should be known and understood. Many different factors have huge roles in the potential of erosion, such as pH value which is the most widely used predictor of erosive potential and its defined as the concentration of free hydrogen ion, titratable acidity which means the total availability of the free ions within the drink, temperature and time of exposure of the drink to the dental surface.  Other factor that may reduce the potential of erosion such as buffering capacity and mineral content within the drink itself (Al-Majed et al., 2002).

Progression of erosion is related to different factors such as the chemical properties of the drink, biological factors and patient behavior. Drinking habit and unhealthy lifestyle are behaviors that corporate in increasing the extent of dental erosion. Preventive strategies such reducing the frequency and duration of acid exposure may act against the progression of acid erosion. Saliva and acquired pellicle are example of biological factors and they act as a barrier to prevent further demineralization (Magalhães et al., 2009).

## 2.1. Chemical properties:

### 2.1.1 Type of acid

Acid type and concentration of the acid within the drinks have important role in erosive potential. Many beverages contain basically different kind of organic acid. Citric acid ($C_6H_8O_7$) and malic acid ($C_4H_6O_5$) are the main acids in fruit drink and ready-made juices contain citric acid in different concentration and may reach 6% such as lemon juice. While fizzy drink and cola type drink contain phosphoric acid ($H_3PO_4$), ascorbic acid ($C_6H_8O_6$) and carbonic acid($H_2CO_3$). Lactobacillus bacteria in process called fermentation is produced lactic acid in some food types such dairy product and pickled vegetables. Wine and grapes are mainly containing tartaric acid ($C_4H_6O_6$) and Smaller amount of malic acid, citric acid and succinic acid ($C_4H_6O_4$) (Stefański and Postek-Stefańska, 2014).

In 2005, Hannig et al revealed that the highest erosive potential at pH 2.0 and 3.0 are lactic acid and acetic acid respectively when applied to bovine enamel (Hannig et al., 2005). On another study phosphoric, ascorbic and lactic acids were the most erosive while maleic, tartaric and citric acid were the least erosive acids (Beyer et al., 2011).

There are 3 main factors that determine the acidity of the solutions namely; pH, titratable acidity and acid dissociation constant (Ka) (Milosevic, 2004). pH is the amount of $H^+$ ion measured in a solution; titratable acidity is the amount of acid available.

### 2.1.2 The pH and Titratable acidity

The pH value resembles the equilibrium measure of the hydrogen ion concentration, but it does not indicate the overall acidic content of the drink, whereas TA gives a measure of all free $H^+$ available within the drink (Benjakul and Chuenarrom, 2011b). TA was claimed to be more effective parameter than pH value for determining the erosive potential of drinks (Benjakul and Chuenarrom, 2011b). Lussi and is colleagues, showed that the erosive potential of drinks is related to pH value, TA, phosphate and fluoride concentrations (Lussi et al., 1993).

On the same study, they showed that the influence of different minerals on enamel erosion and indicated that phosphorous was a better result on enamel demineralization than calcium (Lussi et al., 1993).

The erosive potential also depends on the ability of the beverages to hold out against pH changes by salivary buffering. Edwards et al in their study stated that fruit juices and fruit –

based carbonated drink showed high buffering capacity which may prolonged drop in oral pH (Edwards et al., 1999).

Baron et al, stated the critical pH of dental enamel dissolution is 5.5 but it is not a fixed value and it is different, because it is related to the concentration of minerals within solution (Barron et al., 2003). The critical pH is defined as the pH value at which a solution is just saturated with minerals such calcium or fluoride. Where the pH in a solution has value more than the critical pH then that solution is considered as super saturated with minerals. In contrast, if the pH within the solution is less than the critical ph then that means the solution is unsaturated and minerals will continue to dissolve until the solution becomes saturated (Dawes, 2003).

## 2.2. The Erosive potential

Three main stages of erosion process. In early stage, a demineralization will occur and softening of enamel structure without any loss. Then, material will be lost in microscopic level. At last, a visible lesion will be detected clinically. The chemical composition and physical properties of a drink are not the only dependent in erosive potential. But also, the nature of oral environment and the individual habits have their role. Three factors that influence the erosive potential of acidic beverages:

Chemical factors: pH and buffer capacity of the beverage, type of acid, adhesion of the product to the dental tissue, chelation properties, presence of calcium, presence of phosphorous and presence of Florine. Behavioral factors: Eating habits, lifestyle, high intake of fruit and vegetables, excessive consumption of acidic foods and drinks, the habit of plying children with acidic drinks at nighttime and oral hygiene practices. Biological factors: flow, composition and buffer capacity of the saliva, acquired pellicle, composition and dental structure, anatomy of the soft tissue in relation to the tooth (Lussi et al., 2004).

### 2.2.1. Methods for measuring erosive potential of drinks

Chemical parameters are one of the ways that determine the erosive potential of solutions and drinks. Most frequently used pH, titratable acidity and buffer capacity. Many authors claimed that titratable acidity is the most effectively to determine the erosive potential. However, others said that both pH and titratable acidy are well dependable to evaluate erosiveness. For example, when a large amount of a drink is consumed in short period of time and short contact with teeth surfaces, pH parameter is the choice in this case. On the other hand, titratable acidity is used in a small amount of beverage is mixed with saliva and stays in the oral cavity for a longer period (Stefański and Postek-Stefańska, 2014).

There are different methods to measure the erosive potential. One method is measuring of microhardness or nano hardness before and after exposure to the examined beverage is a basic quantitative method for examining tooth tissue softening. In this method measurements are done by a profilometer (optical or contact) or confocal laser scanning microscope to assess the surface roughness which would indicate the loss of tooth tissue in an erosive lesion (Stefański and Postek-Stefańska, 2014).

### 2.2.2. Methods for reducing the erosive potential

Erosive soft drink and juices are considered as the main etiology of dental erosion. Consumption of these drinks has increased significantly over last twenty years. A study done by British Soft Drinks Association in 2011 reported that consumption of erosive drinks have reached 235.3 liters per person per year (Association, 2012 ). So preventive measures such reduction in consuming acidic food and drinks are essential in lowering the dental erosion. However, it’s hard to achieve that especially in youth and kids. Therefore, a realistic way of lowering the danger of acidic beverages on teeth by modifying their chemical composition (Grenby, 1996).

Acid profile change is one of the methods for reducing the erosive potential by modifying the chemical composition. many acids within the drinks are behind of their refreshing affect and storage ability. Therefore. Getting rid of this ingredient is a challenge. citric acid and phosphoric acid are very erosive because complete dissociation of one molecule results in the formation of three hydrogen atoms. A study has shown that phosphoric acid is inferior in erosive potential than citric acid (Beyer et al., 2011, Wiegand et al., 2008). So many studies has been suggested to replace citric acid and phosphoric acid by malic acid which has less erosive effect on dental structure (Meurman et al., 1990, Bibby and Mundorff, 1975).

### 2.2.3. Acidity reduction by drink modification

Modification of beverages by increasing their pH (>3.8) and lowering of titratable acidity may result in a considerable reduction of erosive potential (Grenby et al., 1989). Hydroxy apatite dissolution was less in modified sport drinks with ph ranging from (5.5 to 5.6) in comparison with non-modified drinks with pH ranging from (3 to 4.2) (Meurman et al., 1990). However, modifying a drink by increasing pH value even to pH value of 7 does not make it absolute safe as some acid anions maintain the ability to bind calcium such as citrate, lactate and phosphate. The longer exposure time, the greater reduction of enamel microhardness. A study to evaluate the influence of a cola-type soft drink and a soy-based orange juice on the surface and subsurface erosion of primary enamel, as a function of the exposure time. Artificial saliva that contains calcium, phosphate and fluoride was used as a control because it exerts the same remineralizing effect as that of human saliva, as the control specimens showed gradual microhardness gain up to the 30th day and stabilization. And Its concluded that erosion of the surfaces exposed to the cola-type soft drink was more accentuated and directly proportional to the exposure time (Torres et al., 2010). Buffered drink defined as a salt of weak acid or base, added to a drink to hold out against changes in its acidity and maintain its pH. So, a well buffered drink has the ability to preserve large amount of hydrogen ion concentration (low ph) in the diffusion layer than a poorly buffered drink with equal ph. Therefore, the degree of saturation at the surface will be decreased and dissolution will be faster (Barbour et al., 2011). The buffering capacity can be assessed either by the total content of acid in the drink or by the slope of the titration curve at a predefined ph. The total content of acid and the buffering capacity are usually related. The initial pH value of the drink, however, gives no direct indication of the underlying buffering characteristics of the drink (Grobler and van der Horst, 1982, Lussi et al., 1993, Larsen and Nyvad, 1999).

## 2.3. Mineral Content

In addition of the pH, TA and acid type, the erosive potential of a drink also depend on certain Mineral content such as fluoride, calcium and phosphonate (Hannig et al., 2005). lussi et al revealed that phosphorous has better affect in demineralization of the enamel than calcium (Lussi et al., 1993). However, hara and zera found that calcium was better than phosphorous in prevention of the demineralization (Hara and Zero, 2008). This conflict is due to the differences in the type of drinks that has been examined. So, the conclusion of which mineral has the better effect is vary and difficult to predict. Attin et al concluded his study by confirming that modification of the drinks with low concentrations of calcium, phosphate and fluoride was able to lower the erosive potential. However, with these low concentrations enamel dissolution could not be completely prevented(Attin et al., 2005).

### 2.3.1. Calcium

The degree of saturation helps to determine whether dissolution is possible. If a solution is supersaturated, dissolution is not possible. Because the rate of dissolution of hydroxyapatite could be slowed if the solution contains calcium and phosphate ion. For example, diary product contain high concentration of calcium and phosphate and their erosive potential is too low despite the presence of lactic acid (pH4) (Lussi et al., 2004). Conversely, if a solution is undersaturated, it wouldn't be assumed that it will be erosive, since many factors, including low fluid movement and low temperature, can prevent or slow dissolution in an undersaturated solution.

A linear relationship between the degree of saturation and the dissolution(1988). In moderately undersaturated solutions, the rate of dissolution will intensify as the degree of saturation declines, but eventually the dissolution rate will come to a plateau and will not respond to additional declines in the degree of saturation. The degree of saturated of a drink with hydroxyapatite (DS ≥ 1.0) is not predicted to cause enamel dissolution. however, such changes in beverages may result in an undesirable flavor and be dangerous and it's not applicable in the food industry (hellis RP, 2013). Barbour et al. found an approximate threshold condition for citric acid (pH 3.3) defined by a calcium concentration of 120 mM and a phosphate concentration of 0.57 mM Despite being highly undersaturated (DS ~0.104), the solution showed no significant erosive potential with respect to enamel and using greater concentrations of calcium did not provide any additional benefit(Barbour et al., 2003). There is a risk when this modified drink has been consumed more than 520 ml. because taking more than recommended calcium level (2.5 gram per day) will result in several side effect such as nausea, vomiting, constipation, (zinc, magnesium and phosphates) absorption suppression in intestinal, and an increased risk of kidney stones (Stefański and Postek-Stefańska, 2014). According to a vitro study, a low concentration of 1 mM (0.04 g/L) of calcium decreases the erosiveness of 1% citric acid (Attin et al., 2003).

Calcium was found to be effective in reducing the erosive potential of most of the tested beverages (Calci-Cola, Calci-sports, Minute Maid Ca), while the effect of phosphorus and fluoride, in association with calcium, was less clear and should be investigated further (Hara and Zero, 2008). A series of investigations has demonstrated a Remarkable results in reducing the erosiveness of blackcurrant juices by different concentrations of calcium compared to non-modified juices (Hughes et al., 1999, West et al., 1999). Modification of orange juice with calcium 42.9 mmol and phosphate 31.2 mmol did not turn on enamel erosion after submerging for 7 days. Manifesting that even lower concentrations of calcium, phosphate together with fluoride were efficient to decrease enamel dissolution (Larsen and Nyvad, 1999). When selecting a modifier, solubility should be taken into consideration. The protective effect of a particular compound depends on the degree of ionization and saturation. So as to achieve effective investigation of the modifiers, it is advocated that the pH of the tested beverage should be modified in order to exclude the results from depending on hydrogen ion concentration (most modifiers increase pH) (Grenby, 1996). Erosion effect may be reduced by adding an effervescent tablet (calcium carbonate) to a juice. It has been confirmed by a study that one dissolving tablet that contain 500 mg of calcium has effective concentration of calcium when adding to 200 ml of juice (Wegehaupt et al., 2011).

A study has been done to evaluate the calcium pre rinse ability in increasing the effectiveness of fluoride rinse in protecting dental enamel, fifteen volunteers participated for 10 days by placing a palatal appliance that contain four sterilized bovine enamel slabs. Participants were divided to 3 groups and three phases. Each group followed a different protocol in each phase, and they crossed over all protocols. First protocol was to rinse their mouth by Ca lactate, followed by NaF. Second, to rinse their mouth by only NaF daily. third, to not use any kind of rinse. After removing the appliance from their mouth, .05 M citric acid were exposed every day to one side of the appliance for ninety seconds. The other side of the appliance served as control. After finishing all protocols and phases, Specimens were evaluated for surface loss using an optical profilometer. Study results showed that the CaL prerinse followed by NaF rinse significantly decreased surface loss of enamel when using it before erosive challenge in comparison with using NaF only (Turssi et al., 2014).

### 2.3.2. Phosphates

Adding one orthophosphate ions in the form of 0.21% monosodium orthophosphate has no effect in lowering the erosion of acidic drink as much as monocalcium phosphate as the latter has more effect (Reussner et al., 1975). While Grenby (Grenby and Saldanha, 1995) in his study shows that 1% of sodium dihydrogen phosphate was able to reduce the erosive potential of drinks. In other study by Hay et al, the significant effect on reducing erosion potential by phosphate ions alone or calcium ions alone is impossible, as the authors used compounds of calcium and phosphorus ($Ca_3PO_4$) or a mixture of calcium salts and compounds with a phosphate group (Hay DI, 1962). Application of polyphosphates and meta- phosphates before acid exposure, 20% to 50% reduction of erosive potential will occur (McGaughey and Stowell, 1977). Its revealed by several studies that phosphate group has the ability of binding with hydroxyapatite which will decrease the surface area for dissolution and replacing $HPO_4$ groups, hence inhibition detachment of further ions (Barbour et al., 2005, Schaad et al., 1994). Electrostatic and covalent effects of polyphosphate in adsorbing positively charged molecules on the solid surfaces explains the protective action from demineralization by a barrier layer (Schaad et al., 1994). Polyphosphate has weaker protective action on enamel than dentine, as the enamel has more minerals content (Scaramucci et al., 2011). Chain length of polyphosphates is determining the effectiveness and persistence of the action and that why sodium tripolyphosphate and sodium pirophosphate tetrabasic are weak in protection against erosion (Scaramucci et al., 2011, Barbour et al., 2005). All previous study on the effectiveness of phosphate in protective action were in situ and in vitro condition. Therefore, the role of saliva in this action is absence. In oral cavity conditions, the adsorption of phosphates is disturbed by some saliva ingredients, which also have affinity for hydroxyapatite surface (Barbour et al., 2005).

### 2.3.3. Fluoride

Comparison experiments between with and without fluoride in erosive potential of drinks show that each solution at each time point was always less with fluoride. These experiments show no significant difference between drinks with or without fluoride except for orange juice. The reduction in erosion by modifying drinks by fluoride was incomprehensible, particularly as it had no effect on pH or TA. Its assumed that the effect must have been due to an alteration in ion exchange at the surface (Hughes et al., 2004). Larsen reported that adding 4 to 6 ppm fluoride to soft drinks was not significant in reducing erosion (Larsen, 2001). Other study reported that adding 6 to 15 ppm to non-carbonated soft drink with ph higher than 3 was significant in reduction of erosion (Larsen and Richards, 2002). Hughes conclude in his study that the addition of fluoride to drinks offered protection against erosion by citric acid and soft drinks. However, the addition of fluoride to soft drinks is probably not a manufacturing possibility. He also reported that Pre-treatment of enamel with fluoride products having more effectiveness than adding fluoride to the acid solution (Hughes et al., 2004).

Topical treatment with Prevident 5000 (contains 5000 ppm fluoride in the form of 1.1% NaF in a dental cream. Significantly increased enamel resistance to erosion by orange juice and should be considered as a treatment choice in patients susceptible to acidic dental erosion (Ren et al., 2009).

### 2.3.4 Iron

Ferrous sulphate is other form of iron that used in drinks such coca cola to reduce erosive potential. In coca cola high concentration must be used such 30mM and 60mM (Buzalaf et al., 2006, Kato et al., 2007). Because even addition of fluoride to low concentration (1mM) is in effective(Kato et al., 2007). The optimal erosion-protective concentration of iron was found to be 15 mM (Buzalaf et al., 2006). The mechanism of iron in erosion protection is by participating of ferric phosphate(Kato et al., 2007)or hydrous iron oxides (Buzalaf et al., 2006).

## 2.4. Patient-related factors

### 2.4.1. Drinking Habits

Frequency of dietary acid intake is hypothesized to be the most important risk factor in extrinsic tooth wear progression (Moazzez et al., 2000). The first step regarding preventive measures for this condition is to identify the frequency, amount and time of the day when erosive products are consumed using dietary and behavior records over four days. Interesting patterns emerged when dietary acid intake was separated by timing in relation to meals. The consumption of acidic drinks both with and between meals was independently associated with erosive tooth wear (O'Toole et al., 2017). Patients must avoid the retention of dietary acid in the mouth before swallowing, and not swish them around the teeth or even sip the erosive dinks over an extended period. The use of straws positioned toward the back of the mouth is also recommended when drinking any potentially erosive drink (Torres et al., 2010).

### 2.4.2. Lifestyle

Unhealthy lifestyles such as use of alcohol and drugs, are often linked to an increase the risk of erosion. It is also linked to individual diets, whether vegetarian or omnivores. most of studies show that no association was found between consumption of erosive foods and drinks with the prevalence of erosive tooth wear in vegetarian or vegan persons (Linkosalo et al., 1988, al-Dlaigan et al., 2001, Herman et al., 2011). On the other hand, other studies found that a vegetarian diet increases dental erosion (Rafeek et al., 2006, Smith et al., 2008). Studies reported that oral hygiene habit may show a relationship between brushing after erosive challenges and abrasion, so it advocated that to increase waiting period before brushing, due to surface remineralization.

### 2.4.3. Reflux

Gastroesophageal reflux disease (GERD) is a condition that affect the direction movement of stomach acids which is retrograde to esophagus due to failure of lower esophagus sphincter. Failure of this coordination may lead to this chronic condition (GERD) (Marsicano et al., 2013). Dental erosions, burning sensation, mucosal ulceration, loss of taste, xerostomia and sometimes increased salivary flow are manifestations of GERD(Di Fede et al., 2008). Its reported that increased dental erosion is the most common manifestation among them (Firouzei et al., 2011). The prevalence of GERD in Western countries is between 20-40% among adults (Spechler, 1992, Dent et al., 2005) and it considerably increases after 40 years of age(Marsicano et al., 2013). GERD can instigate the dental erosion since they may reduce the saliva pH to the levels below the critical pH (pH=5.5) in which hydroxyapatite crystals in the dental enamel dissolves. With a pH of less than 2.0; gastric reflux is potentially capable of causing dental erosion(Marsicano et al., 2013, Poddar, 2013). Refluxes and subsequent GERD should be considered during taking the medical history of the patient. Collaboration of medical specialists in gastroenterology and dentists in the diagnosis and management of patients with GERD would inevitably improve the patients' medical and dental health (Lazarchik and Filler, 1997). A study on the prevalence of dental erosion in young Icelandic adults (19–22 years old) and patients with gastroesophageal reflux disease (GERD), in relation to their soft drink consumption used a detailed frequency questionnaire of soft drink consumption followed by a clinical examination. Erosion was scored for incisor and molar teeth separately. No significant difference was observed in the prevalence of dental erosion between young adults and GERD patients. However, by combining the two study groups a three-fold higher risk of having erosion in molars or incisors was found for subjects drinking Coca-Cola three times a week or more often. Additionally, significantly higher erosion scores were found in molars among subjects drinking more than 1 liter of carbonated drinks (all brands) per week. It was concluded that the frequency of soft drink consumption is a strong risk factor in the development of dental erosion (Jensdottir et al., 2004).

### 2.4.4. Vomiting

Eating disorders (ED) are defined as conditions which known by restricted food intake and by self-induced vomiting (SIV). These conditions may lead to impairment of both general and dental health. Dental erosion is one of oral manifestation that caused by stomach acid(association). The prevalence of ED has been studied in united states of America and Norway. Its reported that the prevalence of ED among adolescents .3-.9% and 12.5% respectively(Swanson et al., 2011) (Hudson et al., 2007). Vomiting can also occur during the first trimester of pregnancy, but can be only considered a risk factor for developing erosion when it is frequent over an extended period of time (Buzalaf et al., 2018).

### 2.4.5. Saliva

Saliva is one of the most protective factors against dental erosion due many reasons. First, its confirmed that saliva has important role in formation of acquired pellicle. Second, diluting, clearing and buffering the acids. Third, saliva has the ability of reducing demineralization and enhance remineralization through its content such calcium, phosphate and many types of protein (Buzalaf et al., 2012).

In addition of the mineral content, salivary flow rate is also important in the protective ability of the saliva. Higher salivary flow accelerates the clearing of the acids and also increases organic and inorganic components of saliva, thus creating a favourable environment for the prevention of initial erosive attacks. The salivary flow can be enhanced both mechanically (by mastication) (Yeh et al., 2000) and chemically (for example, by dripping citric acid droplets to the tongue (Engelen et al., 2003). Moreover, the proteomic profile of saliva changes following stimulation by different tastes (Neyraud et al., 2006).

Hyposalivation is decreasing in saliva flow rate. Therapeutic drugs (Miranda-Rius et al., 2015), Sjogren's syndrome (Both et al., 2017) and radiation therapy are the main cusses of this condition (Lieshout and Bots, 2014).

Many clinical trials show a correlation between hyposalivation and the high prevalence of dental erosion (Frese et al., 2015). In hyposalivation and dry mouth, its suggested that chewing gum give the ability to increase salivary flow rate

For patient with reduced salivary floor and high risk of dental erosion, some preventive measures are able to increase saliva flow rate such chewing gums and to support saliva by minerals such chewing hard cheese (Gedalia et al., 1991). Mouth rinsing (with water or commercial mouthwashes) after consuming acidic drinks or food has the ability to increase salivary pH and decrease dental erosion (Dehghan et al., 2017). In more compromised cases such radiation therapy and Sjogren syndrome, pilocarpine is still the best performing sialogogue (Gil-Montoya et al., 2016). More Clinical trials are necessary for these preventive measures to give them more confidence while recommending it (Buzalaf et al., 2018).

### 2.4.6. Acquired pellicle

The acquired pellicle is composed mainly by proteins which have salivary glands origin and other components such as lipids and glycoproteins. These components accumulate and form a thin layer on the tooth surface and give a physical barrier that act as a permeable membrane, preventing the direct contact between the acids and the tooth surface, thus reducing the dissolution of hydroxyapatite and protecting the tooth against erosive challenge (Vukosavljevic et al., 2014). Due to the high affinity of the precursor proteins by hydroxyapatite (mucins, amylase, cystatins, lysozyme and lactoferrin), a protein layer 10–20 nm thick will be formed at the first to the tooth surface. This process takes only few seconds of enamel exposure to saliva(Hannig and Balz, 1999). Then, the thickness will rapidly increase (100–1000 nm) due to the adsorption of protein aggregates (Hannig et al., 2001). The thickness of the acquired pellicle varies around the mouth such that the thickest pellicle occurred on the lower lingual surface, and the thinnest pellicle occurred on the upper anterior palatal surface. In the lower arch, pellicle was significantly thicker in the anterior lingual surface compared with the anterior labial surface at a ratio of 2:1, while the posterior lingual surface had a significantly thicker pellicle than the posterior buccal surface, also at a ratio of approximately 2:1(Amaechi et al., 1999b).

2.4.7. Occupation

The nature of individual work may increase the risk of erosion. The risk for teeth wear and the severity of erosion increases with increasing concentration of the acid or the acidic fumes, increasing exposure time and duration of employment and shortening the distance between the worker and the acid source (Buzalaf et al., 2018). Workers must follow safety instruction and they should use personal protective equipment (respiratory masks) and the factories must adhere to the threshold limit values recommended by occupational health legislations (Wiegand and Attin, 2007). A study by Buczkowska shows that the occurrence of erosion in competitive swimmers is high (Buczkowska-Radlińska et al., 2013). This issue can be easily prevented by well-buffered and pH-controlled chlorinated swimming pool water (Schlueter and Tveit, 2014)

## 2.5. Diet related factors

2.5.1. Acids within the diet

It’s important that erosive potential of drinks, food and medication should be identified. Most of fruits are acidic in nature. A study reported that two times a day of eating fruits was 37 times more likely to have erosive tooth wear (Järvinen et al., 1991). One study investigated the erosive potential of combination of chilies and tomatoes , observing a low pH in a basic north Indian masala sauce (Ghai and Burke, 2012).

The addition of fruit or fruit flavorings to drinks has also increased(Association, 2016), which can have equivalent erosive potential to that of cola drinks(Lussi et al., 2012). It has been shown that adding fresh lemon or lime to the drink has a citric acid concentration greater than six times the amount of lemonade formulations or lemon dilutables (Penniston et al., 2008). Fruit-flavored teas such as (ginger, lemon tea and berry tea) and Fruit-flavored sweets, lozenges or medications have also large erosive potential when consumed regularly(Lussi et al., 2012).

379 commercial drinks were examined to determine the erosive potential, 39% were extremely erosive (pH <3), 54% were considered erosive (pH = 3–3.99) and only 7% were identified as minimally erosive (pH ≥4), the lowest ph (2.2) was the lemon juice, followed by cola drinks (2.32–2.39)(Reddy et al., 2016). Sugar free drinks are as much as their sugar sweetened drinks in erosive potential. And although plain sparkling mineral water has a low ph du to carbonation content, it has a low erosive potential because the low titratable acidity(Reddy et al., 2016). Vinegars and pickles are also having strong effect on dental erosion and should not be underestimated. Jarvenin *et al.* observed those who consumed apple cider vinegar weekly were 10 times more likely to have severe erosive wear (Järvinen et al., 1991).

### 2.5.2. Frequency of dietary acid intake

Patterns of consumption are important to be observed as the erosive potential of specific dietary acids are linked strongly with these patterns. The frequency of dietary acid intake has been recognized as one of the primary risk factors for erosive tooth wear progression (O'Toole et al., 2017). Its reported that dental erosion was influenced by whether they were consumed with meals or between meals, particularly for acidic drinks. Those who consumed acidic drinks twice a day between meals were over 11 times more likely to have moderate or severe erosive tooth wear. This was the half when drinks were consumed with meals (patients who drank two acidic drinks per day with meals were 6.8 times more likely to have tooth wear compared to those who did not drink acidic drinks daily) (O'Toole et al., 2017). High acidic drinks consumptions are very risky for dental erosion whenever the time of consumptions, between or with meals. On the other hand, fruit consumption with meals was not linked with dental erosion and fruit consumption between meals did increased (O'Toole et al., 2017).

2.5.3. Quantity of dietary acid intake

Quantity of dietary acid intake is relatively difficult to assess as portion size is often sub- jective and difficult to measure (Andersen et al., 2004). However, Sovik et al. in his study used a self-administered questionnaire to assess the quantity of acidic consumption. And he categorized into low (0–0.24 L/day) moderate (0.25–0.74 L/ day) and high (0.75–5 L/day) consumption (Søvik et al., 2015). A higher prevalence of erosion was observed in those with increased quantity consumption.

Other study to investigate the relation of the quantity of fruit intake and erosive wear. The intake quantity of fruit was assessed by self-administered questionnaire with picture accompaniments providing guidance as to portion size. and its reported that high prevalence of erosion was observed in those with a median fruit intake of 9.5 kg per week (Ganss et al., 1999). Conclusively, the evidence for an association between quantity of acidic foods and drinks and erosive tooth wear is not as strong as the frequently intake (O'Toole and Mullan, 2018).

## 2.6. Physical Factors

2.6.1. Temperature

The mouth has normal temperature of around 36.8 °C. When hot or cold drinks are consumed, there is a considerable change in intra-oral temperature that depends on the temperature of the fluid and the area in the mouth. A study has been made for 18 areas within the mouth to determine temperature value after consuming one draught of tea at 60.8 °C, temperatures jumped up to between 51.0 and 57.48 °C at different areas in the mouth, with the highest value detected at the upper anterior region (Airoldi et al., 1997). The pH of a weak acid decreases with increasing in temperature, as dissociation of the acid is more thermodynamically favoured. therefore, soft drinks to cause dental erosion is decreased at lower temperatures and increased at higher temperatures. One study of enamel and dentine surface loss, when the orange juice heated up, the erosive lesion depths in enamel increased by a factor of 2 after 12 hours of exposure (Amaechi et al., 1999a). A study has been made by Barbour et al using Atomic force microscopy nanoindentation and non-contact optical profilometry to assess changes in enamel nanomechanical properties of two different non-carbonated soft drinks exposure at different temperatures. Its concluded that material loss was increased, and nano hardness was decreased, approximately linearly with temperature (Barbour et al., 2006). Different drinks showed different softening and virtually no material loss, and temperature had statistically significant difference on erosion. The difference between the drinks can be explained by their composition but generally for the erosive drink, material loss increased, and Nano hardness decreased, linearly with temperatures (Barbour et al., 2006).

## 2.7. Types of Drinks

### 2.7.1. Soft Drinks

The highest increase in soft drink consumption has happened in children and adolescents; approximately 40% of preschool children drink more than 250 mL of soft drinks per day (Harnack et al., 1999). In recent years, diet drinks have increased in relation to their regular beverage counterparts. In 1997, artificially-sweetened diet sodas accounted for 24% of soft-drink sales, an increase of 16% since 1970 (Putnam and Allshouse, 1993). And there also has been an increase in the consumption of sports drinks, although these may have a sugar content as high as 20% (Shenkin et al., 2003). Different carbonated soft drinks (both regular and diet versions) were placed in 5.0 mL screw-cap plastic containers and the specimens were weighed at 24–48 hour intervals for a total of 14 days (336 hours). The enamel dissolution was two to five times greater ($p < 0.05$) among non-cola drinks than among cola beverages. In addition, enamel dissolution in canned iced tea was some 30 times greater than that produced by brewed black tea and coffee. The amount of enamel dissolution from coffee and brewed black tea was seven times greater than that of both water and root beer, while cola drinks dissolved enamel 55–65 times more than both water and root beer. Enamel dissolution from non-cola drinks was 90–180 times greater than dissolution from water. Reducing the length of time of beverages are in the mouth by would be beneficial (von Fraunhofer and Rogers, 2004). The difference between regular and light Coca-Cola drinks influences the wear of enamel subjected to erosion followed by brushing abrasion. Regarding chemical characteristics, light cola had a pH of 3.0, 13.7 mg Ca/L, 15.5 mg P/L, and 0.31 mg F/L, while regular cola had pH 2.6, 32.1 mg Ca/L, 18.1 mg P/L, and 0.26 mg F/L. The light cola promoted less enamel loss than its regular counterpart. There was not a significant difference between erosion and erosion plus abrasion for light cola. However, for regular cola, erosion plus abrasion resulted in higher enamel loss than erosion alone (Bseptp BM, 2011).

Soft drinks with high calcium contents have significantly lower erosive potential. Low pH and high citrate content may cause more surface enamel loss. Although pH was believed to be a better predictor, the titratable acidity to pH 7 may be a predictor of the erosive potential for acidic soft drinks. The erosive potential of the soft drinks may be predicted based on the types of acid content, pH value, titratable acidity, and ion concentration(Wang et al., 2014).

### 2.7.2. Sparkling Water

Bottled waters appears less erosive and may provide a safe alternative to more erosive acidic drinks (Parry et al., 2001). As manufacturers try for a greater share of the market, the sparkling fruit-flavored water drinks are now extensively available in Europe and all over the world. The flavoring for these drinks usually includes citric and other fruit-derived acids. thus, it is important to assess these drinks in dental erosion potential. A study by Catriona to determine the pH, titratable acidity and erosive potential of a selection of these drinks from the UK market to identify what dietary advice would be appropriate in relation to their consumption. the flavored waters tested showed appreciable titratable acidity (0.344 – 0.663 mmol) and low pH (2.74–3.34) and all of the waters demonstrated erosive potential (89–143%) similar to or greater than that of pure orange juice. In conclusion the author stated that Flavored sparkling waters should be considered as potentially erosive, and preventive advice on their consumption should recognize them as potentially acidic drinks rather than water with flavouring (Brown et al., 2007).Dental erosion is an increasingly prevalent problem in Australian schools. The composition and erosive potential of beverages exhibited erosive potential but found no significant differences in erosivity between sugar and non-sugar-containing carbonated beverages (Cochrane et al., 2009)

2.7.3. Fruit Juices and Smoothies

Three different of grape juice were used to exam the roughness of primary enamel after immersing it for 2 min, 3 times per day, for 9 days. Storing in artificial saliva between immersing was done. Roughness of the enamel, ph and titratable acidity of the grape juices were measured. No roughness differences were found among groups. The pH had a weak correlation with the acidity values and the juice with highest acidity showed greater erosive (Tocolini et al., 2018). Other study assessed ph and titratable acidity, four commercially available fruit smoothie drinks, orange juice was used as a positive control. Baseline pH and titratable acidity were measured, until pH 7 and pH 10 were reached. Each of the fruit smoothies assessed, showed a low baseline pH and had comparatively high titratable acidity. Because of both their low pH and high titratable acidity, the author concluded that the consumption of such fruit smoothies to mealtimes should be reduced(Blacker and Chadwick, 2013).

### 2.7.4. Mouthwash

The majority of mouthwashes were slightly acidic, therefor the erosive potential of mouthwashes has been investigated. it has been shown that Listerine had the lowest pH similar to Nestle orange juice. Only two of the mouthwashes had pH above 5.5. Although this study did not find significant association between mouthwash use and erosion; dental care products that come in contact with teeth should be formulated at safer pH instead of acidic pH. Studies concluded better efficacy of Fluoride at neutral pH in causing remineralization and inhibiting demineralization than acidic ph (Haq et al., 2012a).

# 3. AIM

The current invitro study aims to determine the erosive potential of drinks consumed in Dubai.

## 3.1. Objectives:

1. To measure the pH and titratable acidity of drinks available in Dubai.
2. To measure calcium, phosphate and fluoride concentration
3. To compare the acidity of different types of drinks with treated and mineral water.

# 4. MATERIALS AND METHODS

## 4.1 Study Design

The current in-vitro study was conducted to analyze erosive potential of commercially available drinks in the UAE. The total number of studied drinks were twenty-four drinks. The drinks were divided based on their carbon dioxide ($CO_2$) contents into carbonated and non-carbonated drinks. All tested drinks are illustrated in Table 3.1 All juices were stored according to the manufacturers' recommendations prior of conducting the study. Five different variables were measured. The measured variables were Acidity (pH), Titratable Acidity (TA), Fluoride (F), Calcium (Ca) and Phosphate ($PO_4$).

## 4.2 Measurement of variables

4.2.1 Measurement of Calcium (Ca)

Inductively Coupled Plasma-Atomic Emission Spectrometers (SGIMADZU ICPE-9820) (Fig 1) was used to calculate the mineral contents of tested juices. Inductively Coupled Plasma-Atomic Emission Spectrometers (ICP-AES) has an optic source (plasma) to split the light into its various wavelengths, and a detector to measure each specific wavelength and its intensity. The position of the light on the detector determines its wavelength and the intensity is proportional to concentration.

Sample prepared by adding 100 ML of 50$^{o}$C heated ionized water to 10 +/- 0.1 ML of tested juice into Erlenmeyer flask and the mixture was well mixed. The sample was heated at 200°C with nitric acid (HNO3), in a closed-vessel microwave digestion system (MDS). The sample was then aspirated into the nebulizer before getting into the plasma. Nebulization creates very small droplets that are carried by the argon carrier gas into the plasma. It enters a spray chamber that removes the largest droplets. Only a fine mist containing about 1% of the aspirated sample reached into the plasma. 99% of the sample aspirated went down the drain.

(0.50 +/- 0.01g) of sample mass transferred on a dry weight basis in the prepared slurry to MDC vessel (1.00 +/- 0.01 g into a 100 ml. volumetric flask for MDO). The MDS vessel walls, or Pasteur pipet was lined with weighing paper during sample transfer to keep sample from adhering to sides of vessel or use a Pasteur pipet to transfer liquid samples. Carefully add 5.0 +/- 0.1 ml $HNO_3$ into MDC vessel and then 5ml $H_2O$ only into MDS vessel. Loosely cap MDS vessel without sealing.

The concentration of calcium (ppm) is calculated by the following formula.

$$\text{Concentration of Ca (ppm)} = \frac{\text{(Concentration from ICP-AES) X (Dilution)}}{\text{Volume of Sample}}$$

4.2.2 Measurement of phosphate (PO4)

The method used to determine the measurement of phosphate was the same method used to measure the calcium. The method is thoroughly described in section 3.2.1.

The calculation of phosphate ($PO_4$) was done by measuring the phosphorus (P) using the following formula.

$$\text{Phosphorus (ppm)} = \frac{\text{(Concentration from ICP-AES) X (Dilution)}}{\text{Volume of Sample}}$$

Then converting the phosphorus to phosphate by factor of 3.066

4.2.3 Measurement of Fluoride

Fluoride was measured using a sophisticated Ultraviolet Spectrophotometer (Fluoride meter HACH (DR 6000 UV-VIS SPECTROPHOTOMETER) (Fig2).

60 mL of deionized water was added into a 250mL glass Erlenmeyer flask. 120 mL of concentrated sulfuric acid was added into the flask. The flask was put in an ice bath to decrease the temperature of the solution. The water was turned on and adjusted to maintain a

steady flow through the condenser. 100-mL of sample was added into the distillation flask using 100 mL graduated cylinder. the thermometer inserted, to control the heat. 9. When the temperature is 180 °C. the solution was diluted to a volume of 100mL.

**Calculation:**

$$\text{Fluoride (ppm)} = \frac{\text{Concentration from uv spectrophotometer X Dilution}}{\text{Volume or Weight of Sample}}$$

4.2.4 Measurement of pH

pH meter (BIOBASE) (Fig 3.3) was used to measure ph. An accurate volume of 50 ml tested sample was collected, and temperature accurately sat at 25°C. The electrode of pH meter immersed into the tested sample for measurement and pH was recorded.

4.2.5 Measurement of titratable acidity (T.A)

The same 50 ml of the sample drink was placed on the magnetic stirrer, with the pH electrode placed in the sample. Incremental addition of NaOH 0.1M with a pipette was done while monitoring the pH until it reached 7.0 and recorded it.

The T.A percentage was calculated by the following formula.

$$\text{\% of Titrable Acidity} = \frac{\text{(Titre Value) X (Normality) X (Acid Factor) X 100}}{\text{Sample Volume X 1000}}$$

## Table 3.1: Samples tested in the study

| | Criteria | Drink name | Brand | origin | Expiry |
|---|---|---|---|---|---|
| Study drinks | carbonated | Power horse | Power horse energy drinks GmbH | Linz (Austria) | 02/07/2022 |
| | | Vitaene C | Vitaene | Japanese drinks maker - Pokka | 06/07/2021 |
| | | lemon ice tea | Lipton | PepsiCo | 15/07/2021 |
| | | Barbican malt drink-strawberry | Barbican | Aujan Coca-Cola Beverages Company (ACCBC) (Saudi Arabia) | 15/08/2021 |
| | | Barbican malt drink- apple | Barbican | Aujan Coca-Cola Beverages Company (ACCBC) (Saudi Arabia) | 13/09/2021 |
| | | Barbican malt drink- pineapple | Barbican | Aujan Coca-Cola Beverages Company (ACCBC) (Saudi Arabia) | 13/09/2021 |
| | non-carbonated | Mixed fruit lemon | Almarai | Saudi Arabia | 21/11/2021 |
| | | Cranberry classic | Ocean spray | American | 05/05/2021 |
| | | Kiwi and strawberry | Snapple | Dr Pepper (USA) | 19/09/2021 |
| | | Orange pineapple | Del monte | USA | 05/10/2021 |
| | | Pomegranate | Rawabi | UAE | 25/03/2021 |
| | | Berry cocktail | Rawabi | UAE | 07/03/2021 |
| | | Original vimto | Vimto | Nichols plc (England) | 08/09/2021 |
| | | Blue raspberry vimto | Vimto | Nichols plc (England) | 16/10/2021 |
| | | Strawberry vimto | Vimto | Nichols plc (England) | |
| | | apple green tea | (c2) | Philippines | 27/07/2021 |
| | | Orange rani | Rani | Aujan Coca-Cola Beverages Company (ACCBC) (Saudi Arabia) | 05/05/2021 |
| | | Fabulous cocktail | Rauch | Rauch Fruchtsäfte GmbH & Co OG (Austria) | 27/07/2021 |
| | | Berry mix | Sun top | CORO FOODS (Saudi Arabia) | 27/08/2021 |
| | | Pineapple juice | Rauch | Rauch Fruchtsäfte GmbH & Co OG (Austria) | 22/12/2021 |
| | | Orange juice | Rauch | Rauch Fruchtsäfte GmbH & Co OG (Austria) | 26/07/2021 |
| | | Apple juice | Masafi | UAE | 22/9/2021 |
| | | Sun cola | Sun top | CORO FOODS (Saudi Arabia) | 27/07/2021 |
| | | Kiwi lime juice | Rawabi | UAE | 01/03/2021 |

**Table 3.4: List of instruments used in the study.**

| Type | brand |
|---|---|
| 1- Ph meter | Biobased meihua<br>Benchtop ph meter |
| 2- Fluoride meter | DR 6000 UV-VIS<br>spectrophotometer |
| 3- Calcium meter | 1-Ethos Lean<br>Compact microwave digestion<br>2- ICP-AES<br>(plasma atomic emission spectrometer) |
| 4- Phosphate meter | 1-Ethos Lean<br>Compact microwave digestion<br>2- ICP-AES<br>(plasma atomic emission spectrometer) |
| 5- Magnetic stirrer, heater | Stuart Heat stir – UC152 |
| 6- Beakers, pipette | Tefal beaker, Gilson pipettes (1ml, 0.1ml) |

**Figure 3.1: SGIMADZU ICPE-9820**


**Figure 3.2: Fluoride meter HACH (DR 6000 UV-VIS SPECTROPHOTOMETER**


**Figure 3.3: Ph meter (BIOBASE)**

### 4.3. Statistical Analysis

Data was entered into the computer using IBM-SPSS for Windows version 25.0 (SPSS Inc., Chicago, IL). Kolmogorov-Smirnov was used to test the normality of continuous variables (Calcium, Phosphate, Ph and table acidity). The measurements were described by means and standard deviation. When comparing the means between more than two groups the Kruskal-Wallis test was used. The Spearman correlation coefficient was used to test the associations between measurements. A P-value of less than 0.05 will be considered significant in all statistical analyses.

# 5. RESULTS

A total of 24 labelled as carbonated and Non-carbonated drinks were tested at room temperature excluding two controls (treated water and Mineral water, read on average from different type of waters). Data of continuous variables (Calcium, Phosphate, pH and titratable acidity) is illustrated in Table 4.1.

### 5.1 Minerals contents

Among both carbonated and non-carbonated drinks, the highest and lowest Ca values were 55.6 and 1.98 which were measured for orange juice (Rauch) and blue raspberry (Vimto) respectively. Both highest and lowest reading were among the non-carbonated drinks. In carbonated drinks, 7.83 was the highest Ca level measured for Power horse energy while 2.18 was the lowest value measured for Lemon Ice-Tea (Lipton). All Ca levels are illustrated in Fig 4.1. Among all carbonated drinks, phosphate was not detected apart from Barbican-apple juice which contains 39.55ppm phosphate. On the other hand, phosphate was measured in almost all the noncarbonated drinks. The values were ranged from 447.63 to 19.04 for orange juice (Rauch) and Berry mix (sun top) respectively. Distribution of phosphate levels is illustrated in Fig 4.2. Fluoride was not detected in all the tested drinks.

### 5.2 pH and Titratable acidity

The highest and lowest pH values were 4.38 & 2.79 which recorded for Orange juice (Rauch) and Sun cola (sun top) respectively. On the other hand, 3.6 and 0.11 were the highest and lowest titratable acidity values, which recorded for Mixed fruit lemon (Almarai) and Barbican-strawberry, respectively. Levels of pH and Titratable acidity for all tested drinks are illustrated in Fig 4.3 and Fig 4.4.

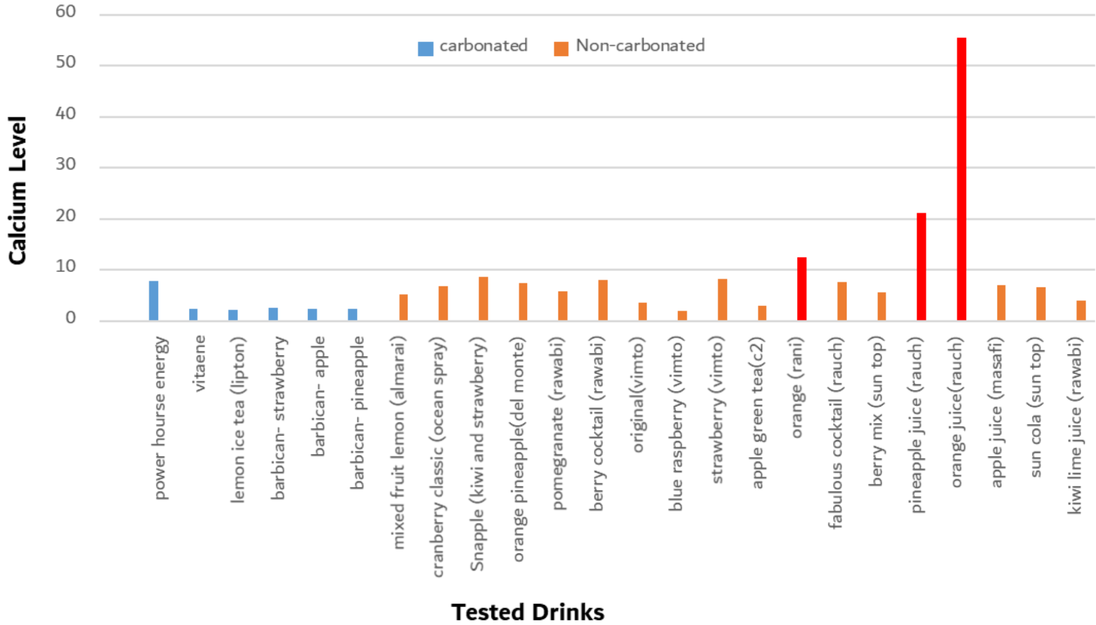


**Figure 4.1: Distribution of calcium per carbonated and Non-carbonated drinks**

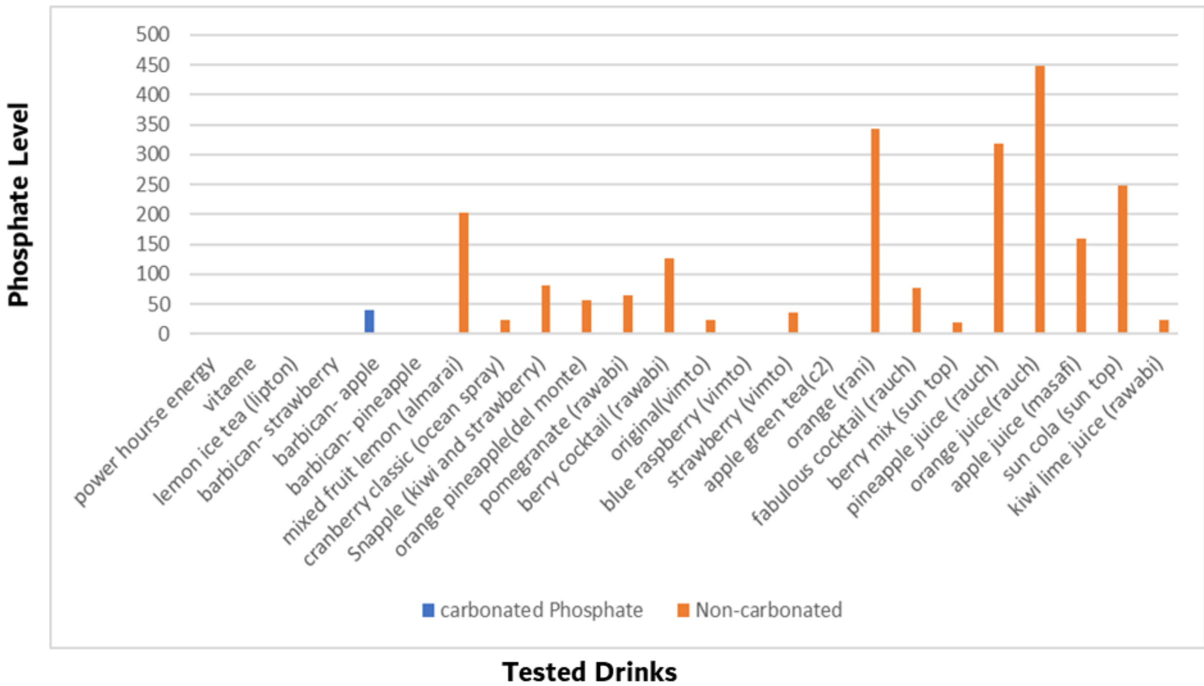


**Figure 4.2: Distribution of phosphate per carbonated and Non-carbonated drinks**

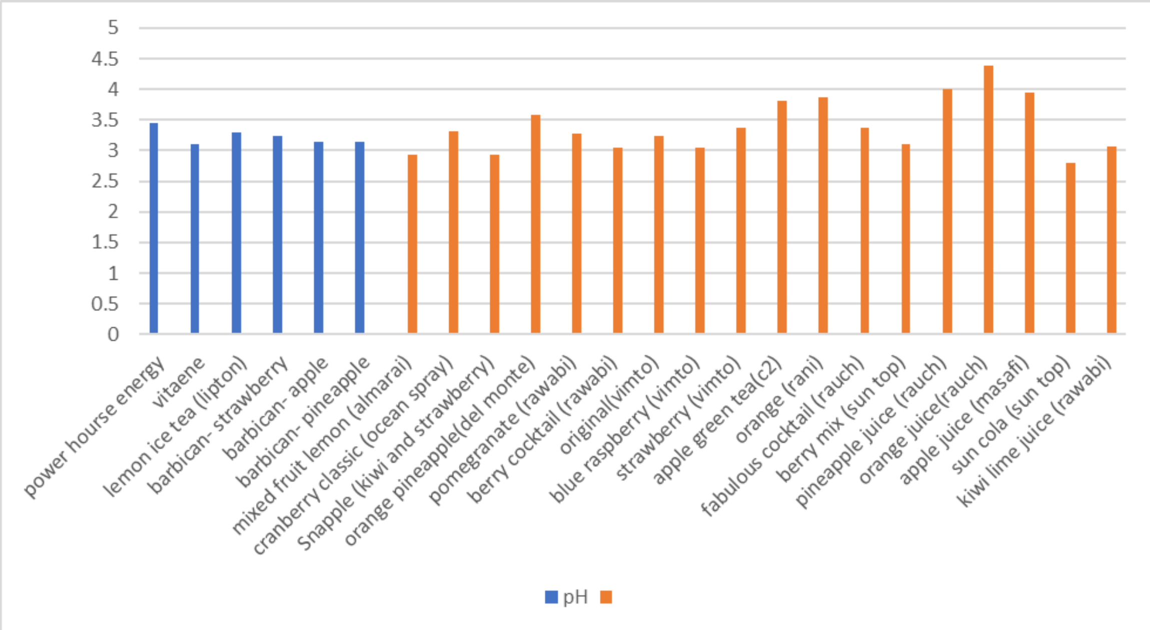


**Fig 4.3: Distribution of pH per carbonated and non-carbonated drinks**

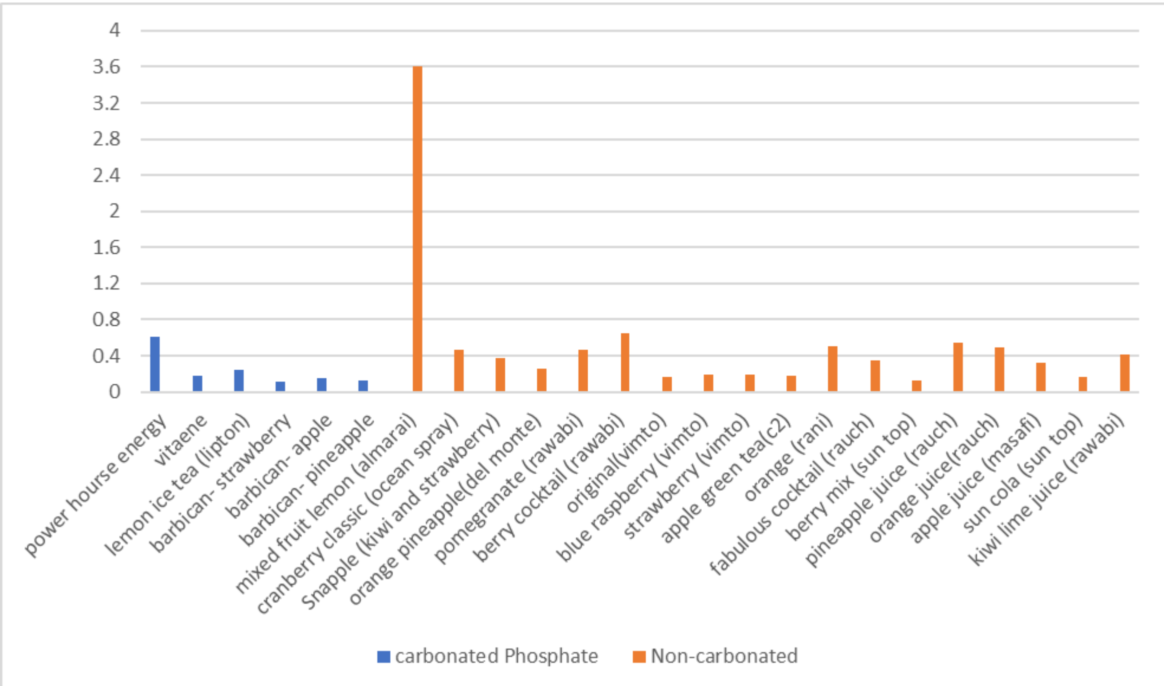


**Fig 4.4: Distribution of Titratable Acidity per carbonated and non-carbonated drinks**

**Table 4.1: Levels of Calcium, phosphate, pH and table acidity of tested drink**

| Drink | sample | Calcium | Phosphate | Fluoride | pH | Titratable Acidity |
|---|---|---|---|---|---|---|
| Carbonated Drinks | Power hourse energy | 7.83 | ND | ND | 3.44 | 0.61 |
| | Vitaene | 2.39 | ND | ND | 3.11 | 0.18 |
| | Lemon Ice-Tea (lipton) | 2.18 | ND | ND | 3.3 | 0.24 |
| | Barbican- strawberry | 2.54 | ND | ND | 3.23 | 0.11 |
| | Barbican- apple | 2.51 | 39.55 | ND | 3.15 | 0.15 |
| | Barbican- pineapple | 2.42 | ND | ND | 3.15 | 0.12 |
| | | | | | | |
| Non-Carbonated Drinks | Mixed fruit lemon (almarai) | 5.34 | 202.96 | ND | 2.94 | 3.6 |
| | Cranberry classic (ocean spray) | 6.77 | 23.88 | ND | 3.32 | 0.47 |
| | Snapple (kiwi and strawberry) | 8.62 | 82.16 | ND | 2.94 | 0.37 |
| | Orange pineapple (del monte) | 7.46 | 55.49 | ND | 3.58 | 0.26 |
| | Pomegranate (rawabi) | 5.79 | 64.99 | ND | 3.27 | 0.47 |
| | Berry cocktail (rawabi) | 8.04 | 125.7 | ND | 3.05 | 0.65 |
| | Original(vimto) | 3.64 | 22.74 | ND | 3.23 | 0.16 |
| | Blue raspberry (vimto) | 1.98 | ND | ND | 3.04 | 0.19 |
| | Strawberry (vimto) | 8.32 | 36.79 | ND | 3.37 | 0.19 |
| | Apple green tea(c2) | 3.11 | ND | ND | 3.82 | 0.18 |
| | Orange (rani) | 12.6 | 343.4 | ND | 3.87 | 0.5 |
| | Fabulous cocktail (rauch) | 7.59 | 76.65 | ND | 3.38 | 0.35 |
| | Berry mix (sun top) | 5.68 | 19.04 | ND | 3.1 | 0.12 |
| | Pineapple juice (rauch) | 21.3 | 318.86 | ND | 4.01 | 0.54 |
| | Orange juice(rauch) | 55.6 | 447.63 | ND | 4.38 | 0.49 |
| | apple juice (masafi) | 6.97 | 159.43 | ND | 3.95 | 0.32 |
| | Sun cola (sun top) | 6.57 | 248.34 | ND | 2.79 | 0.17 |
| | Kiwi lime juice (rawabi) | 3.98 | 22.71 | ND | 3.07 | 0.41 |

The distribution normality was assessed by Kolmogorov-Smirnov test and revealed that data was not normally distributed.

Mean and standard deviation (SD) of each variable was calculated. the mean and standard deviation of calcium levels for both carbonated and noncarbonated were 3.31(2.21) and 9.96(12.16) respectively. Mean (SD) for phosphate were 39.55(0) and 140.67(134.33) for carbonated and noncarbonated drinks correspondingly. pH means were 3.23(0.12) and 3.4(0.44), while means titratable acidity were 0.24 (0.19) and 0.52 (0.78) for carbonated and noncarbonated respectively. Kruskal-Wallis test was used to compare the means of more than two groups. Among all variables, only difference in calcium level between carbonated and noncarbonated was statistically significant ($p<0.05$). Table 4.2 illustrates comparison of mean (SD) of all variables.

**Table 4.2: Comparison of calcium, phosphate, pH and table acidity by carbonated and Noncarbonated drink**

| | | calcium | phosphate | PH | table acidity |
|---|---|---|---|---|---|
| **Type** | **No** | **Mean (SD)** | | | |
| **Carbonated** | 6 | 3.31 (2.21) | 39.55 (0) | 3.23 (0.12) | 0.24 (0.19) |
| **Non-Carbonated** | 18 | 9.96 (12.16) | 140.67 (134.33) | 3.4 (0.44) | 0.52 (0.78) |
| **P-value** | | 0.012* | NA | 0.770 | 0.077 |

Superscript Asterisk (*) indicates significant difference ($p<0.05$)

Furthermore, the means of calcium were compared with commercially available data of mineral waters and treated waters (Fig 4.5). Additionally, means of pH were also compared with data of mineral waters and treated waters (Fig 4.6). Table 4.3 demonstrates the comparison and revealed significant difference at ($p<0.05$).

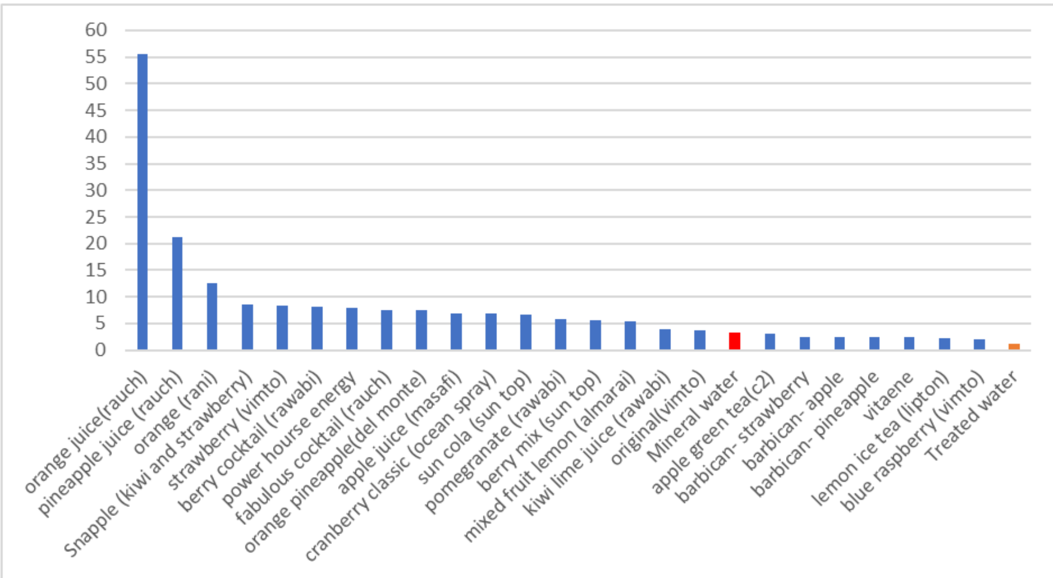


**Figure 4.5: Distribution of calcium comparing with two controls: treated water & mineral**

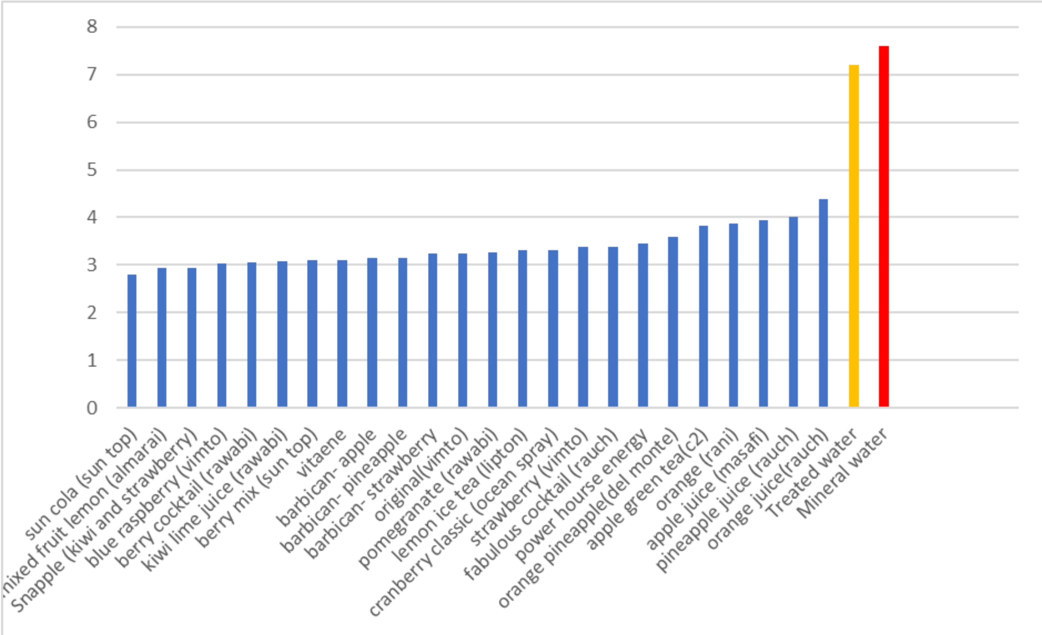


**Figure 4.6: Distribution of pH comparing with two controls: mineral and treated water.**

**Table 4.3 Comparison of calcium and pH of tested drink with mineral and treated water**

| **Name of drink** | **Calcium** | **pH** | **type** |
|---|---|---|---|
| power horse energy | 7.83 | 3.44* | carbonated |
| Vitaene | 2.39 | 3.11* | ------------ |
| lemon ice tea (Lipton) | 2.18 | 3.3* | ------------ |
| barbican- strawberry | 2.54 | 3.23* | ------------ |
| barbican- apple | 2.51 | 3.15* | ------------- |
| barbican- pineapple | 2.42 | 3.15* | ------------- |
| mixed fruit lemon (Almarai) | 5.34 | 2.94* | Non-carbonated |
| cranberry classic (ocean spray) | 6.77* | 3.32* | ---------------- |
| Snapple (kiwi and strawberry) | 8.62* | 2.94* | --------- |
| orange pineapple(del monte) | 7.46* | 3.58* | ------------ |
| pomegranate (rawabi) | 5.79* | 3.27* | -------------- |
| berry cocktail (rawabi) | 8.04* | 3.05* | ------------ |
| original(vimto) | 3.64 | 3.23* | ---------------- |
| blue raspberry (vimto) | 1.98 | 3.04* | ----------------- |
| strawberry (vimto) | 8.32* | 3.37* | ------------- |
| apple green tea(c2) | 3.11 | 3.82* | ------------- |
| orange (Rani) | 12.6* | 3.87* | ---------------- |
| fabulous cocktail (Rauch) | 7.59* | 3.38* | --------------- |
| berry mix (Sun top) | 5.68* | 3.1* | ----------------- |
| pineapple juice (Rauch) | 21.3* | 4.01* | ----------------- |
| orange juice (Rauch) | 55.6* | 4.38* | ------------------ |
| apple juice (Masafi) | 6.97* | 3.95* | ------------------- |
| sun cola (Sun top) | 6.57* | 2.79* | ------------------- |
| kiwi lime juice (Rawabi) | 3.98 | 3.07* | ------------------- |
| Treated water<br>95% CI | 1.1<br>2.24-1.9 | 7.2<br>7.01-7.4 | Control1 |
| Mineral water<br>95% CI | 3.3<br>-2-5.7 | 7.6<br>6.4-8.1 | Control2 |

*indicate statistically significant from the water

The correlation between mineral contents and titratable acidity were checked. The association between calcium and other variables namely, Phosphate, pH and titratable acidity was revealed. On the other hand, pH was neither associated with titratable acidity nor with phosphate. The association is summarized in table 4.4

**Table 4.4: Matrix of association between the measurements**

| | **Calcium** | **Phosphate** | **pH** | **Titratable acidity** |
|---|---|---|---|---|
| **Calcium** | 1 | 0.635** | 0.443* | 0.626** |
| **Phosphate** | | 1 | 0.293 | .586* |
| **pH** | | | 1 | 0.23 |
| **Titratable acidity** | | | | 1 |

## 6. DISCUSSION

The main aim of the current study was to determine the erosive potential of commercially available drinks in the UAE local market. The variable measured were the mineral contents (Calcium, Phosphate and Fluoride), pH and titratable acidity. Furthermore, the Calcium content and pH were compared with commercially available mineral and treated water.Dental erosion occurs due to the chemical properties of the drinks that includes pH, titratable acidity and the mineral content of the solution (Omid et al., 2016, Haq et al., 2012b) In the current study the heights pH among the tested drinks was revealed for Orange juice (Rauch) at 4.38. Moreover, the lowest pH at 2.79 was recorded for Sun cola (sun top). It is well believed that the critical pH for enamel demineralization is 5.5(Lussi and Ganss, 2012, Dawes, 2003). All recorded pH readings in the current study were below the critical pH 5.5 which indicates that all tested drink have a high erosive potential. This result supports a study in Sudanese school children that revealed that carbonated drinks were erosive drinks (El Karim et al., 2007).

Reddy et al in 2016 classified drinks and beverages according to their erosive potential into extremely erosive (pH < 3.0), erosive (pH 3.0 to 3.99), and minimally erosive (pH ≥ 4.0)(Reddy et al., 2016). Based on, n this classification, most tested drinks (79.2%) were erosive (pH 3.0 to 3.99), 12.5 % were extremely erosive (pH < 3.0) and only 8.3% of tested drinks were minimally erosive (pH ≥ 4.0).

When the pH of tested drink compared to that of mineral water (7.6) and treated water (7.2), the difference was statistically significant.

Titratable acidity is the amount of alkali needed to neutralize an acid within a given aqueous solution. In this study, the percentage of titratabe acidity was measured for all tested samples. In order to relate the amount of acid within the solution by neutralizing it with 0.1M NaOH in a 50 ml volume of the drink. It is believed that the total acid available (titratable acid) of dietary substances is considered more important than their pH, because it will determine the actual Hydrogen ions ($H^+$) available to interact with the tooth surface(Zero, 1996).

The height titratable acidity was recoded for Mixed fruit lemon (Almarai) at 3.6% this indicates it has high acidic content and erosive potential. On the other hand, the lowest percentage was recorded for Barbican-strawberry at 0.11%. this result supports a pervious result which stated that lemon and lime juices contain more citric acid than other ready-made juices (Penniston et al., 2008).

The association between pH and titratable acidity in this study was checked by matrix association and revealed there is no association between them. This result is in agreement with previous invitro studies (Cairns et al., 2002). The difference between carbonated and non-carbonated drinks, the difference in pH and titratable acidity was not statistically significant. The other variables measured in the current study were fluoride, calcium and phosphate. Fluoride was not detected in any if tested drinks. This could be since none of the tested drinks contains fluoride or the content is less than the detection limit of fluoride which believed to be less than 0.025ppm.

Previous invitro studies have shown that the addition of 1 ppm of fluoride reduced erosiveness of drinks even at lower pH (Stefański and Postek-Stefańska, 2014, Attin et al., 2005). When fluoride is present in oral fluids, fluorapatite is formed during the remineralization process. Fluoride ions ($F^-$) replace hydroxyl groups ($OH^-$) to form the apatite crystal lattice. In fact, the presence of fluoride increases the rate of remineralization. Fluorapatite is less soluble than hydroxyapatite, even under acidic conditions (Jensdottir et al., 2004).When hydroxyapatite dissolves under acidic conditions if fluoride is present fluorapatite will form. And because fluorapatite is less soluble than hydroxyapatite, it is also more resistant to subsequent demineralization when acid challenged. Australian Water Quality Guidelines recommend levels up to 1 mg/L (1ppm) to protect against dental caries.

The other minerals tested in the current study were calcium and phosphate. The highest and lowest calcium values were 55.6 orange juice (Rauch) and 1.98 for blue raspberry (Vimto). While phosphate values were ranged from 447.63 to 19.04 for orange juice (Rauch) and Berry mix (sun top). Among the carbonated drinks, phosphate only detected in Barbican-apple juice which contains 39.55ppm phosphate. The correlation between calcium and phosphate revealed to be very high (0.635**). The association of calcium with pH and titratable acidity is also revealed to be high. Which means the less calcium and pH high titratable acidity the more erosive potential will be the drinks. This result is in agreement with previous study(Saxena, 2010).

When the pH on the tooth surface becomes acidic, phosphate in oral fluids combines with hydrogen ions (H+) to form hydrogen phosphate species, phosphate is then "pulled" from tooth enamel to restore phosphate levels in the saliva, and the hydroxyapatite dissolves. As pH returns to normal, the calcium and phosphate in saliva can remineralise the enamel. Either 1.0 mmol (equivalent to 40.1 ppm) calcium or a combination of 0.5 mmol (20.05 ppm) calcium plus 0.5 mmol phosphate plus 0.031 mmol fluoride (0.6 ppm) was added to the beverages. Modification of the test beverages with low concentrations of Calcium, Phosphate and Fluoride was able to reduce the erosive potential of the drinks.[28] Supplementation of orange juice with Calcium 42.9 mmol (1719.4 ppm) and Phosphate 31.2 mmol did not erode enamel after immersion for 7 days. showing that even lower concentrations of Calcium, Phosphatetogether with Fluoride were able to reduce enamel dissolution and demineralization.[32]

### 6.1. Study Limitations

The study had the following limitation:

- The study did not study the effect of drinks on enamel or dental restorations.
- Knoop hardness test and profilometry on enamel slabs can be more indicative.

# 7. CONCLUSION

With the limitation of the current study, it can be concluded that:

1- All tested drinks had a pH of less than 5.5, ranging from 2.79 for Sun cola (sun top) & 4.38 for Orange juice (Rauch).

2- 12.5 % of tested drinks were extremely erosive (pH < 3.0).

3- Titratable acidity ranged from 3.6 and 0.11%.

4- Fluoride was less than the detection limit of 0.025 ppm for all tested drinks

5- Tested drinks with higher level of calcium and phosphate may have less erosive potential than other

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