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Evaluation of Various Carbonated Soft Drinks to Assess their Effects on Human Health

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ABSTRACT

Sugar, citric acid, phosphoric acid, and caffeine are extensively present in soft drinks. The high concentrations of these elements have harmful effects on human health. A series of nine carbonated drinks namely Pepsi, Mountain Dew, 7-up, Mirinda, Coca cola, Sprite, Fanta, Amrat cola, and Amrat lemon were collected from the open market of Peshawar, Pakistan. Various physicochemical parameters were measured to evaluate the quality of the collected drinks. Brix (Total dissolved solids) were found to be 11.40, 11.90, 10.70, 12.90, 10.37, 10.0, 13.00, 10.6, and 10.20% in Pepsi, Mountain Dew, 7-up, Mirinda, Coca-cola, Sprite, Fanta, Amrat cola, and Amrat lemon, respectively. CO_2 gas volume (G. V) was found to be 3.60, 3.20, 3.70, 1.80, 3.80, 3.80, 1.80, 3.80, and 3.70 G.V in Pepsi, Mountain Dew, 7-up, Mirinda, Coca-cola Sprite Fanta, Amrat cola, and Amrat lemon, respectively. Caffeine was found only in Pepsi, Coca cola, Amrat cola, and Mountain Dew, having a concentration of 103, 105, 109, and 146 mg/L, respectively. Pepsi, Coca cola, and Amrat cola were free of citric acid. The citric acid amounts were 1337.6, 1459.2, 1816.32, 1196.8, 1664, and 1216 mg/L in Mountain Dew, 7-up, Mirinda, Sprite, Fanta, and Amrat lemon, respectively. Phosphoric acid was found only in Pepsi, Coca cola, and Amrat cola, in the amounts of 583.1, 490, and 588 mg/L, respectively. It is concluded that the frequent use of carbonated soft drinks (CSD) could cause serious health damage.

Keywords: brix, Carbonated Soft Drinks (CSD), cola, caffeine, CO_2 contents

INTRODUCTION

A beverage free from alcohol is known as a soft drink. At the same time, the term hard drinks define a beverage that contains alcoholic content. Almost all carbonated soft drinks are available in varieties with sugared or

low caloric sweeteners [1], [2]. Soft drinks are excessively used due to their flavors and nutrients. Moreover, manufacturers promote and market them efficiently everywhere. Owing to high calories, quick energy source, and their sweetness commends them to sweet food lovers [3].

The fruit-flavored drinks lead to the origin of soft drinks. Carbonated water was first discovered by imparting water with carbon dioxide by an Englishman Joseph Priestley, in 1767. Therefore, his contribution is a substantial component in the discovery of carbonated soft drinks [4, 5]. The global beverages industry surpassed $1 trillion [6]. Since the beverages industry is expanding and demanding increased CSD, its quality should be maintained during the manufacturing process. According to other accredited authorities, brix and inverted brix (IB) must be under routine inspection.[7].

Total dissolved solids in a sugar liquor are called ‘brix’. A molecule of sucrose produces glucose and fructose, consuming one molecule of water. This sugar reversal is enhanced by the presence of certain acids and high temperatures. Through this inversion process, the density of the sugar solution was enhanced. Consequently, the brix value changed from 10.40 brix-11.98 inverted brix [8]. The use of carbonated soft drinks with a high brix percentage causes weight gain. To improve the taste by balancing the sweetness, acidity regulators or acidulants are used in carbonated soft drinks. The acidulants arouse saliva flow in the mouth due to their thirst-appeasing properties. Citric acid acts as an acid regulator in most carbonated soft drinks except cola flavored carbonated soft drinks Phosphoric acid is a strong acid commonly used to provide taste in cola flavored drinks [9].

In the 19th century, American pharmacists started selling mineral water with added herbs to improve the taste. In the 20th century, the trade of CSD enhanced exponentially and became an important market share [10]. A study conducted in America on the consumption of beverages that included data from 1977-2002 revealed the increased obesity and associated changes in body mass index (BMI) as the outcomes of higher consumption of soft drinks [11]. Dentists often advise using a drinking straw to avoid as much contact as the drink with the teeth. It has also been recommended to avoid brushing teeth just after drinking carbonated soft drinks as it may cause further erosion to the teeth having acid [12].

An analysis of 88 studies showed that drinking soda is associated with reduced milk ingestion and vitamins and other micronutrients. Phosphorus, a micronutrient found in cola-type beverages may cause risk by consuming too much. Researches suggested that consuming carbonated beverages decreases bone mineral density by increasing the fracture risk in the future [13]. High fructose corn syrup (HFCS) was used as a sweetener in the United States, until 2010, due to its low cost. HFCS has been criticized for its numerous harmful effects on human health like diabetes, hyperactivity, and hypertension [14].

Due to the harmful effects of various dietary sugars, cancer occurrence was observed in several people. It was found that added sugars in the diet risk twenty-four malignancies. Proportional hazard regression was used to determine risk ratios and 95% confidence intervals in variable models accustomed to confounding factors relevant to individual cancers. In gender-combined analyses, added fructose was linked with a risk of intestinal cancer, and all examined sugars were linked with a high risk of pleural cancer [15].

A study was conducted to assess drinking water's physico-chemical constraints and pollution. Most of the water samples were found unsuitable for drinking purposes. Therefore, the quality of water used in cold drinks matters a lot [16]. The United States Food and Drug Administration released its data after testing several drinks having benzoates and ascorbic or erythorbic acid. Five tested drinks comprised benzene levels above the EPA's suggested limit of 5 ppb. Despite these findings, as of 2006, the FDA stated that benzene levels found in soft drinks and other beverages do not pose a safety concern for consumers [17]. Various brands of orange products were used to determine most amines' physicochemical characteristics and levels. Approximately less than 10% of orange juice might have been used in soft drinks, as suggested by the level of amines that varies between 5.0-7.6% of the mean levels in orange juice [18].

The risk factors of kidney stone formation by consuming the cola beverage was assessed. It was based on urinary biochemical data that was published previously, indicating greater calcium oxalate crystallization in those who regularly consume cola [19]. A study was also conducted to determine the dentine loss caused by consuming soft drinks. Dentine loss

was reported to be reduced by fluoride toothpaste brushing. That might provide some protection against erosion [20].

Organophosphate, carbamate, and pyrethroid pesticides are the most common insecticides used worldwide [21]. These are poisonous and their small amount causes severe illness or death if ingested via any means [22]. Pesticides are also found in fruit-based soft drinks as evaluated under a monitoring program conducted in Morocco. Post-harvest fungicides are found in the peels of citrus fruits used in soft drinks. Therefore, exposure to these chemicals through drinks is a serious health risk [23].

However, the venom of various scorpion species is rich in neurotoxins, enzymes, enzyme inhibitors, histamine, lipids, and different salts from which peptides demonstrate great potential against various diseases. Thus, used for the treatment of cancer, cardiovascular diseases, influenza, paralysis, epilepsy, malaria, measles, severe combined immunodeficiency, fever blisters, and diabetes [24]. Research in the Clinical Journal of the American Society of Nephrology in 2013 determined that drinking CSD is a greater risk of increasing 23% of kidney stones [25].

The current study aimed to determine some chemical parameters of CSD sold in Peshawar so that they could be evaluated for human consumption. Sugar, phosphoric acid, citric acid, and caffeine are the main CSD constituents evaluated in this study. At the same time, brix% and CO_2 contents were also evaluated.

2. METHODOLOGY

2.1. Instruments

The instrument and testing assemblies used for this experimental work were: A Spectrophotometer (model 721, Cangzhou, China), digital balance (model Ohaus AR 3130, Darmasdat, Germany), water bath (model HH4, Jiangsu, China), drying oven (model GRX-28A, Germany), refractometer (Atago Master-53PM, Berlin, Germany), and CO_2 testing assembly (BCC-200, Kowloon, Hong Kong).

2.2. Reagents

The ‘Analar’ reagents used during this experimental work were provided by: 0.25g of phenolphthalein powder dissolved in 25mL of ethanol and made up the volume to 50mL with distilled water. The standard caffeine solution was prepared by dissolving 100mg of anhydrous caffeine in 100mL

of methylene chloride (1000ppm stock solution). Solutions of different strengths, i.e., 100, 110, 120, 130, 140, and 150ppm, were prepared by the dilution of stock solution. After that, 1 g of NaOH was weighed and dissolved in little distilled water and then diluted to 250 mL with distilled water. The solution was standardized against potassium hydrogen Phthalate (KHP) using a phenolphthalein indicator till the appearance of a purple color.

2.3. Evaluation of Physical Parameters

Pepsi, Mountain Dew, 7-up, Mirinda, Coca cola, Sprite, Fanta, Amrat cola, and Amrat lemon were dark brown, greenish-yellow, colorless, orange, dark brown, colorless, orange, dark brown, and colorless, respectively. The taste of Pepsi cola, Mountain Dew, 7-up, Mirinda, Coca-cola, Sprite, Fanta, Amrat cola and Amrat lemon were caramel-taste, lemon-ginger, lemon, orange, caramel, lemon, orange, caramel-taste, and lemon, respectively**.**

2.4. Chemical Parameters

2.4.1. Brix percentage

A few drops of degassed (from which CO_2 is released through shaking) beverage were put on the refractometer to determine brix in a carbonated beverage. Closed the lid and pressed the start button. Brix percentage was displayed on the screen. The percentage of brix was recorded from the display of the refractometer.

Figure 1. Analog brix refractometer

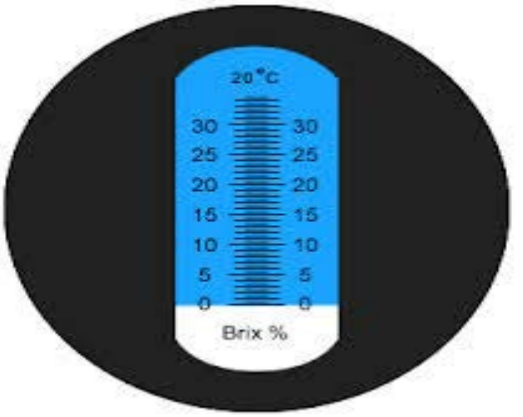

Figure 2. Scale showing the brix percentage.

2.4.2. Determination of CO_2 contents

A chilled bottle was fitted in the CO_2 testing assembly. The headstand was pressed down on the head of the filled bottle. Shacked the assembly vigorously and noted the pressure on the meter and the temperature. Compare the pressure against the temperature in the CO_2 *G. V* chart. The gas volume recorded was converted to grams/sample by multiplying gas volume with sample quantity in liters and density of CO_2.

Grams/sample of CO_2= *G. V* × Vol. of Beverage (in Liters) × Density of CO_2

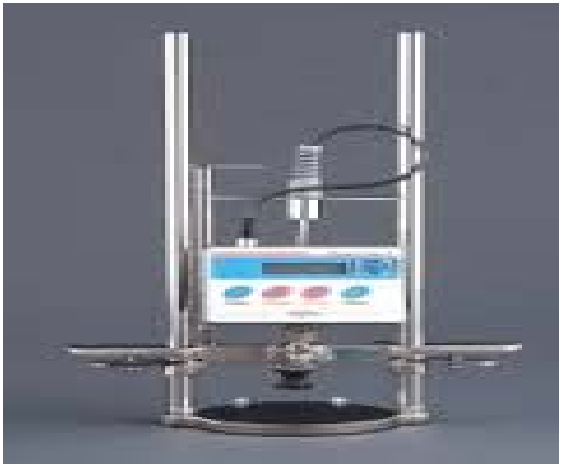

Figure 3. Digital CO_2 testing assembly

Figure 4. Analog CO_2 testing assembly

2.4.3. Determination of caffeine contents

The 50.00 mL of caffeine standard (100, 110, 120, 130, 140, and 150 ppm) was diluted quantitatively from the 1000 ppm stock solution. 10 mL of each caffeine standard was placed in a separating funnel along with the subsequent addition of 25 mL methylene chloride. The caffeine extraction was carried out by inverting the funnel at least 3 times and by venting the separating funnel after every inversion. Methylene chloride forms the lowest layer. It is than removed and saved in a clean Erlenmeyer flask that was covered and added another 25 mL of methylene chloride to the separating funnel. The extraction was done twice by repeating all steps and combining the methylene chloride layers. Add 10mL of soda in which gas was removed to a clean, rinsed separating funnel. Extracted the soda 3 times with 25 mL portions of methylene chloride. The methylene chloride layers were saved in another clean and stoppered Erlenmeyer flask. The standard solutions were run one by one, and the calibration curves were prepared from the standard solutions. Next, the sample was run, and the concentration of the unknown was calculated from the calibration curve [26].

2.4.4. Determination of citric acid

To 100mL of a degassed sample, add a few drops of phenolphthalein indicator and titrate against 0.1N NaOH. The following formula determined the concentration of citric acid [27].

mg/L of citric acid=Concentration of NaOH×64×mL of NaOH used×1000/sample vol.

2.4.5. Determination of phosphoric acid

Phosphoric acid was determined through titration with 0.1N NaOH. To 100mL of a degassed sample, add a few drops of phenolphthalein indicator and titrate against 0.1N NaOH [28]. The following formula determined the concentration of phosphoric acid.

mg/L of phosphoric acid = N of NaOH×49×mL of NaOH used×1000/sample vol.

3. RESULTS AND DISCUSSION

3.1. Physical Parameters

3.1.1. Colour and flavor

The color and taste of carbonated soft drinks are based on the actual flavor and color of the related fruits or the natural ingredients. The brand Mountain Dew has the flavor of lemon and ginger, and that is why this flavor is called the lemon ginger flavor. The brand 7-up, Sprite, and Amrat lemon have also lemon flavor. The brand Mirinda and Fanta have the flavor of orange. In contrast, the brand Pepsi, Coca cola, and Amrat cola has cola flavor in it [29].

3.2 Chemical Parameters

3.2.1 Brix percentage

The brix of different brands is adjusted according to their taste and flavor. The lemon flavor tastes good with 10.80%-11.00% brix. Lemon ginger flavor taste is good with brix ranging from 11.70-12.10, and the orange flavor taste is good at brix ranging from 12.80-13.10.

An interesting feature of the brix of cola flavor is that it contains relatively strong acidulent, i.e., phosphoric acid, which converts the sucrose in the cola flavor to glucose and fructose. The process of conversion of sucrose into fructose, and glucose is called inversion. Due to inversion in sucrose, the refraction changes, and with the change in the refraction, the brix meter. i.e., the refractometer shows a relatively high brix percentage. It was studied that when Pepsi is reversed from sucrose to glucose and

fructose, the brix increases from 10.80-11.20. It was the final brix after complete inversion.

3.2.2. Carbon dioxide contents

CO_2 gas provides the beverage with sparkle and tangy taste and avoids spoilage. The tangy sensation of the drinks is mainly due to the presence of dilute carbonic acid produced during 'carbonation'.The carbon dioxide contents of the beverages also change and vary from flavor to flavor.

By following these steps, CO_2 was calculated.

1. First, the temperature and the pressure on the slow force chart were observed.
2. Afterward, the CO_2 gas volume was observed.

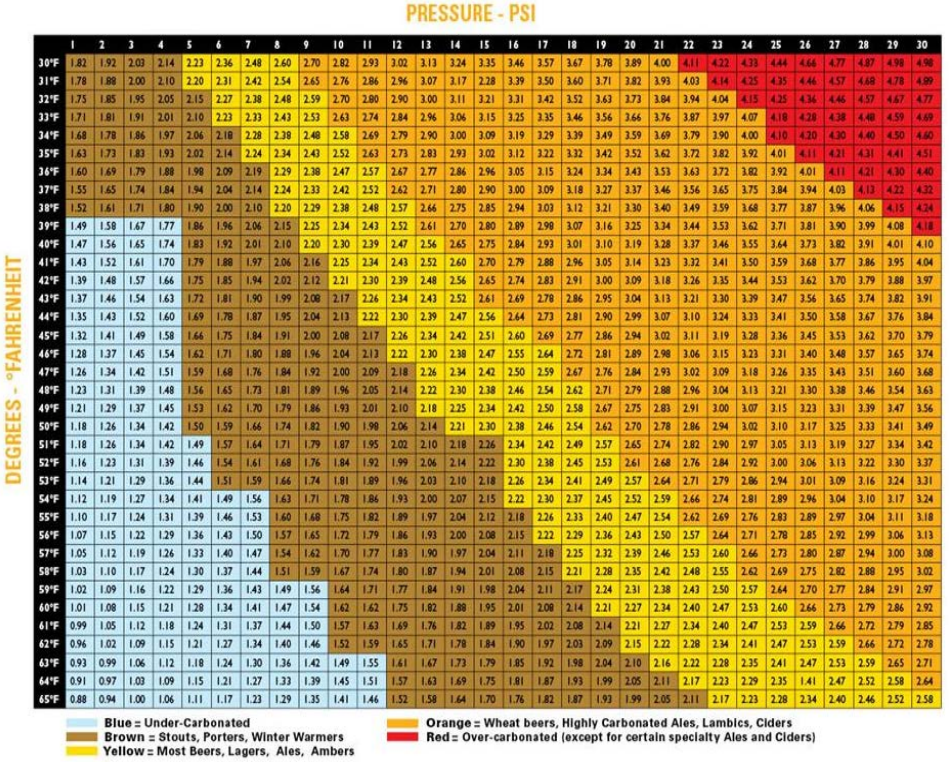

Figure 5. Slow force carbonation chart for determination of CO_2 contents (https://www.kegoutlet.com/media/uploads_ckeditor/Carbonatin-Chart.jpg)

3.2.3. Citric acid

Citric acid contents are based on flavor. Orange flavor has a high quantity of citric acid; on the other hand, cola flavor has no citric acid. The results are shown in **Table 1**.

3.2.4. Phosphoric acid

An enhanced flavor could be obtained by adding Phosphoric acid to soft drinks. It is observed that it retarded the growth of fungus and bacteria which would grow exponentially in the solution containing sugar. Phosphoric acid is found only in cola flavor.

3.2.5. Caffeine contents

Caffeine is a renowned brain stimulator which is added as a component to numerous carbonated soft drinks. Being a stimulant and having physiological effects, individuals are immensely interested in knowing the quantity of caffeine in these beverages. In the nine samples of CSD, caffeine was found only in Pepsi, Coca-Cola, Amrat cola, and Mountain dew by a calibration curve. It was plotted between absorbance and concentration as these were directly proportional. The absorbance was measured at 274 nm using chloroform as blank sample.

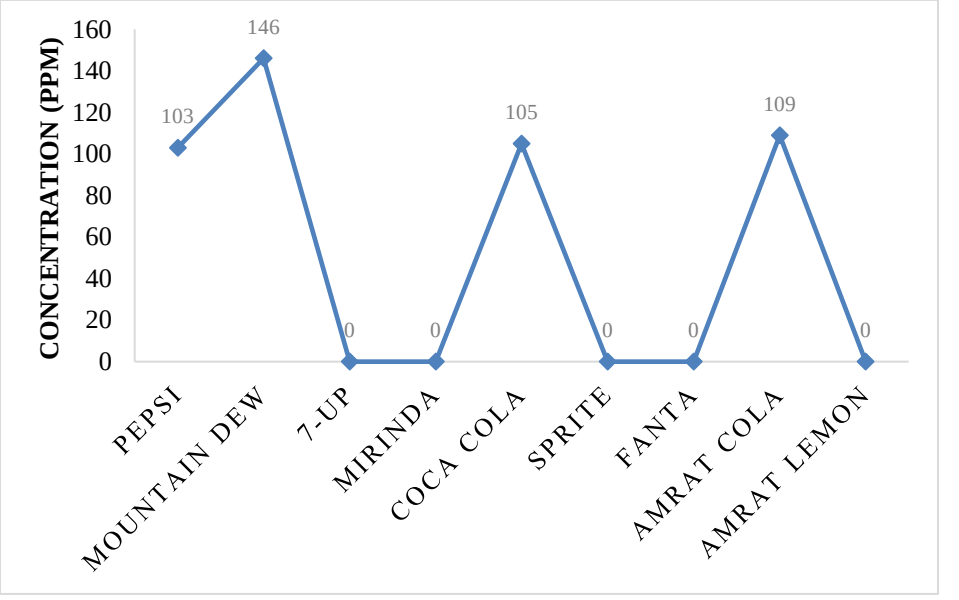

Figure 6. Concentration of caffeine in different carbonated soft drinks

Table 1: Physico-Chemical Parameters of Carbonated Soft Drinks

Product	Flavor	Brix**(%)		CO_2 contents**(G.V)		Colour	Citric acid contents * (mg/L)		Phosphoric acid contents *(mg/L)		Caffeine contents *(mg/L)	
		Obtain Results	Max Limits	Obtain Results	Max Limits		Obtain Results	Max Limits	Obtain Results	Max Limits	Obtain Results	Max Limits
Pepsi	Cola	11.40	11.20 to 11.60	3.60	3.4 to 3.8	Dark Brown	----	----	583.1	4000 mg /day	103	400 mg /day
Mountain Dew	Lemon ginger	11.90	11.70 to 12.10	3.20	3.0 to 3.4	Greenish Yellow	1337.6	100 mg/kg of body weight/day	----	----	146	400 mg /day
7-up	Lemon	10.70	10.50 to 10.90	3.70	3.5 to 3.9	Colourless	1459.2	100 mg/kg of body weight/day	----	----	Nil	----
Mirinda	Orange	12.90	12.70 to 13.10	1.80	1.6 to 2.0	Orange	1816.32	100 mg/kg of body weight/day	----	----	Nil	----
Coca cola	Cola	10.37	10.17 to 10.57	3.80	3.6 to 4.0	Dark Brown	----	----	490	4000 mg /day	105	400 mg /day
Sprite	Lemon	10.00	9.80 to 10.20	3.80	3.6 to 4.0	Colourless	1196.8	100mg/kg of body weight/day	----	----	Nil	----
Fanta	Orange	13.00	12.80 to 13.20	1.80	1.6 to 2.0	Orange	1664	100 mg/kg of body weight/day	----	----	Nil	----
Amrat cola	Cola	10.60	10.20 to 10.60	3.80	3.6 to 4.0	Dark Brown	----	----	588	4000 mg /day	109	400 mg /day
Amrat lemon	lemon	10.20	10.00 to 10.40	3.70	3.6 to 4.0	Colourless	1216	100 mg/kg of body weight/day	----	----	Nil	----

(*) Limits taken from Federal Drug Authority USFDA; (**) Limits taken from Pepsi Cola International (PCI)

4. CONCLUSION

Although, the concentrations of these ingredients are well within limits, except for citric acid, the harmful effects of these ingredients cannot be underestimated. The harmful effects of cold drinks include: sugar whose excess amount could cause diabetes and obesity. Phosphoric acid causes kidney stones in the form of phosphates. Citric acid causes osteoporosis. Caffeine is a brain stimulator used to boost brain activity and causes insomnia and caffeine addiction. It is observed that the frequent/regular use of carbonated soft drinks might cause serious health issues that is why only their casual consumption is recommended. In comparison, the consumers should cautiously select the drink of their choice from different brands available in the market which would minimize and sustain different health problems occurring because of cold drinks. Therefore, it is highlighted that frequent use of carbonated soft drinks could cause serious health damage but could only be used casually by avoiding its regular use.

Conflict of Interest

The authors declare no conflict of interest.

REFERENCES

1. Osborne DR, Voogt PI. *The analysis of nutrients in foods*. Academic Press Inc; 1978.
2. Pomeranz Y. *Food analysis: Theory and practice*. Springer; 2013.
3. Agbazue VE, Ibezim A, Ekere NR. Assessment of sugar levels in different soft drinks. *Int J Chem Sci*. 2014;12(2):327-34.
4. Ashurst PR. *Chemistry and technology of soft drinks and fruit juices*. Blackwell Publishing; 2005.
5. Stevenson and Howell. *The manufacture of aerated beverages, cordials, etc*. Stevenson & Howell; 1986.
6. Arafat AM. Consumer choice of soft drinks: A causal path analysis. *East West J Bus Soc Stud*. 2011;2:109-122.
7. Downes JW. *Production and packaging of non-carbonated fruit juices and fruit beverages*. Blackie & Son Ltd; 1990.

8. Yu J. *The behavior of invert sugar in sugar refining* [doctoral dissertation]. Louisiana State University and Agricultural & Mechanical College; 1998

9. Kregiel D. Health safety of soft drinks: contents, containers, and microorganisms. *BioMed Res Int.*, 2015;e128697. https://doi.org/10.1155/2015/128697

10. Somavarapu S, Mubeena B. A consumer survey on preferences of soft drinks in different stages of adolescence. *J Dairy Sci Technol*. 2017;6(3):54-73.

11. Bassiouny MA, Yang J. Influence of drinking patterns of carbonated beverages on dental erosion. *General Dentistry*. 2005;53(3):205-210.

12. Heuberger R, O'Boyle I. Beverage consumption, and its associations with BMI and lifestyle factors in rural community participants. *Calif J Health Promotion*. 2009;7(SI):62-74.

13. Greenberg CC, Jurczak MJ, Danos AM, Brady MJ. Glycogen branches out: new perspectives on the role of glycogen metabolism in the integration of metabolic pathways. *Am J Physiol-Endocr Metabol*. 2006;291(1):E1-E8. https://doi.org/10.1152/ajpendo.00652.2005

14. Klurfeld DM, Foreyt J, Angelopoulos TJ, Rippe JM. Lack of evidence for high fructose corn syrup as the cause of the obesity epidemic. *Int J Obesity*. 2013;37(6):771-773. https://doi.org/10.1038/ijo.2012.157

15. Tasevska N, Jiao L, Cross AJ, et al. Sugars in diet and risk of cancer in the NIH-AARP Diet and Health Study. *Int J Cancer*. 2012;130(1):159-169. https://doi.org/10.1002/ijc.25990

16. Javed M, Aslam MU, Nadeem S, Aftab H, Hussain S, Arif M, Raza H, Haroon SM, Khan MA. Microbial Contamination in Drinking Water of Saggiyan-Lahore, Pakistan. *Int J Econo Environ Geology*. 2021;12(1):76-80.

17. Vieira SM, Theodoro KH, Glória MB. Profile and levels of bioactive amines in orange juice and orange soft drink. *Food Chem*. 2007;100(3):895-903. https://doi.org/10.1016/j.foodchem.2005.10.050

18. Jenner MR, Smithson A. Physicochemical properties of the sweetener sucralose. *J Food Science*. 1989;54(6):1646-1649. https://doi.org/10.1111/j.1365-2621.1989.tb05179.x

19. Massey LK. Dietary influences on urinary oxalate and risk of kidney stones. *Front Biosc-Landmark.* 2003;8(6):584-94.
20. Ponduri S, Macdonald E, Addy M. A study in vitro of the combined effects of soft drinks and tooth brushing with fluoride toothpaste on the wear of dentine. *Int J Dent Hyg*. 2005;3(1):7-12. https://doi.org/10.1111/j.1601-5037.2004.00110.x
21. Iqbal S, Iqbal MM, Javed M, et al. Modified QuEChERS extraction method followed by simultaneous quantitation of nine multi-class pesticides in human blood and urine by using GC-MS. *J Chromatogr B*. 2020;1152:e122227. https://doi.org/10.1016/j.jchromb.2020.122227
22. Yasien S, Iqbal MM, Javed M, et al. Quantification of multi-class pesticides in stomach contents and milk by gas chromatography–mass spectrometry with liquid extraction method. *Arab J Chem*. 2022;15(7):e103937. https://doi.org/10.1016/j.arabjc.2022.103937
23. Gilbert-López B, Jaén-Martos L, García-Reyes JF, et al. Study on the occurrence of pesticide residues in fruit-based soft drinks from the EU market and morocco using liquid chromatography–mass spectrometry. *Food Control*. 2012;26(2):341-346. https://doi.org/10.1016/j.foodcont.2012.01.025
24. Javed M, Hussain S, Khan MA, et al. Potential of Scorpion Venom for the treatment of various diseases. *Int J Chem Res*. 2022;6(2):1-9.
25. Ferraro PM, Taylor EN, Gambaro G, Curhan GC. Soda and other beverages and the risk of kidney stones. *Clin J Am Soc Nephrol*. 2013;8(8):1389-1395. https://doi.org/10.2215/CJN.11661112
26. Newton JM. Spectrophotometric determination of caffeine in coffee products: Collaborative study. *J Assoc Official Analy Chem*. 1979;62(4):705-708. https://doi.org/10.1093/jaoac/62.4.705
27. Plantá M, Lázaro F, Puchades R, Maquieira A. Determination of citric acid and oxalacetic acid in foods by enzymic flow injection. *Analyst*. 1993;118(9):1193-1197. https://doi.org/10.1039/AN9931801193
28. Murphy J. Determination of phosphoric acid in cola beverages: a colorimetric and pH titration experiment for general chemistry. *J Chem Edu*. 1983;60(5):e420. https://doi.org/10.1021/ed060p420
29. Abu-Reidah IM. Carbonated beverages. In: *Trends in non-alcoholic beverages*. Academic Press; 2020.