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Determination Of Sodium Benzoate and Ascorbic Acid in Soft Drinks

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تحديد بنزوات الصوديوم وحمض الاسكوربيك في المشروبات الغازية

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Abstract:
Objective: To measure the concentration of sodium benzoate and ascorbic acid in soft drink samples, to ensure compliance with permissible limits, and to assess the risk of benzene formation resulting from their reaction. Methodology: Samples were collected from 7 beverages (local and imported). Spectroscopic methods (UV-Vis) and iodine titration were used to measure the two substances. Results were compared with international standards. Results: PH ranged from 2.05 (most acidic: Al Ain) to 3.08 (least acidic: Shani). Ascorbic acid: 6.66–26.66 ppm (higher in Fanta, lower in Mirinda). Sodium benzoate: 16.76–49.98 ppm (higher in Fanta, lower in Al Ain). All concentrations fall within the limits permitted for food additives according to international standards, without representing nutritional fortification with Vitamin C. Most prone to benzene formation: Fanta and Shani. Conclusion: Levels are safe, but improper storage (heat, light) increases the risk of benzene formation. Recommendations: Improved transportation and storage, regular monitoring, and broader studies on benzene formation and its health effects.

Keywords: Ascorbic acid; Sodium benzoate; Benzene formation; Soft drinks; Chemical reaction.

الملخص:
الهدف: قياس تركيز بنزوات الصوديوم وحمض الأسكوربيك في عينات من المشروبات الغازية، لضمان الالتزام بالحدود المسموح بها، وتقييم خطر تكوّن البنزين الناتج عن تفاعلهما. المنهجية: جُمعت عينات من 7 مشروبات (محلية ومستوردة). استُخدمت الطرق الطيفية (الأشعة فوق البنفسجية والمرئية) ومعايرة اليود لقياس المادتين. قُورنت النتائج بالمعايير الدولية. النتائج: تراوح الرقم الهيدروجيني من 2.05 (الأكثر حمضية: العين) إلى 3.08 (الأقل حمضية: شاني). حمض الأسكوربيك: 6.66-26.66 جزء في المليون (أعلى في فانتا، وأقل في ميراندا). بنزوات الصوديوم: 16.76-49.98 جزء في المليون (أعلى في فانتا، وأقل في العين). تقع جميع التركيزات ضمن الحدود المسموح بها للمضافات الغذائية وفقًا للمعايير الدولية، دون أن تمثل تدعيمًا غذائيًا بفيتامين ج. الأكثر عرضة لتكوّن البنزين: فانتا وشاني. الخلاصة: المستويات آمنة، لكن التخزين غير السليم (الحرارة، الضوء) يزيد من خطر تكوّن البنزين. التوصيات: تحسين النقل والتخزين، والمراقبة الدورية، وإجراء دراسات أوسع نطاقًا حول تكوّن البنزين وآثاره الصحية.

الكلمات المفتاحية: حمض الأسكوربيك؛ بنزوات الصوديوم؛ تكوين البنزين؛ المشروبات الغازية؛ تفاعل كيميائي

1. Introduction

Soft drinks are one of the largest categories of beverages consumed throughout the world. This is because they are pleasurable to drink and come in a range of flavours. They are also widely available. With the immense rise in the consumption of these drinks, there is also a corresponding rise in concern about the quality and safety of these beverages. Soft drinks contain a large number of chemical ingredients added to the product to enhance the taste and to preserve the quality. Soft drinks are considered by many to be one of the major contributors to obesity and related disorders and have hence been targeted as a way to help reduce the rising prevalence of obesity, particularly among children.

Children, teenagers, and young adults are the biggest consumers of soft drinks. Boys consume signifyingly more soft drinks then the girls, and adult males aged 19- 24 are the next highest consumers. Determination of sodium benzoate and ascorbic acid in soft drinks is an important issue in food analysis because both compounds influence the safety and quality of the product, and their possible health effects are discussed upon interacting with each other. (2)

One or more soft drinks a day may put people at risk for a wide array of health problems such as obesity, diabetes mellitus, tooth decay, osteoporosis, nutritional deficiencies, heart disease, and also a host of neurological disorders. Who has reported rising incidence of obesity and chronic diseases in individuals who consume more od soft drinks. Sodium benzoate is very often used in foods and beverages. In particular, it is used as a bacterial growth inhibitor, including fungi, which prolongs the product's shelf life in acidic beverages like soft drinks and juices. It is generally used, under international food regulations, in concentrations not exceeding 0.1%. Internationally, there is no legal standard reference value beyond which benzene poses lifetime cancer risk to consumers however, an expert report by who sets reference limit of 10 ug/l.. (3)

Ascorbic acid, commonly referred to as vitamin C, is used to prevent oxidation and improve the quality of food and beverages; this natural additive has a multitude of health benefits. Boosting the immune system is just one of many health benefits. Ascorbic Acid and Sodium Benzoate Reaction Determining whether commercial items meet the given criteria and evaluating the danger associated with potential chemical interactions are, therefore, important aspects of this effort. Different accurate chemical analysis methods will be used in determining the concentrations of these two compounds in soft drinks, including: (4)

1. High-performance liquid chromatography (HPLC) is one of the most accurate and popular methods used to determine sodium benzoate and ascorbic acid separately or together. It is characterized by high sensitivity and accuracy in separation and identification.
2. UV-Vis spectroscopy was applied, which measures the absorbance at specific wavelengths for each of the two compounds. It is cheaper and faster, though less accurate, than HPLC..
3. Electrochemical methods: Such as voltammetry or alternating current analysis, can be used to specifically determine ascorbic acid.

Objectives of this research as follow:

1. Checking the safe levels of sodium benzoate and ascorbic acid to avoid any form of poisoning or formation of benzene.
2. Ascorbic acid (vitamin C) can react with sodium benzoate to form benzene, a carcinogen, when a source of heat, light, or metals is present. Knowing the concentration of both compounds will prevent this reaction from happening.
3. To ensure producers comply with the international food specifications for preservatives and antioxidants.
4. Ascorbic acid-content control: In this context, the aim is to maintain its effectiveness as a natural antioxidant and prevent loss of color and taste in beverage samples.
5. Development of analytical methods like HPLC, UV-Vis, and Mass Spectrometry for precise identification of these compounds in beverage samples.
6. Provide correct information to food regulatory authorities in order to help them come to decisions like product recall or formulation changes.

2. Literature Review

2.1. Chemical Composition and Function of Preservatives and Antioxidants in Soft Drinks

2.1.1. Sodium Benzoate (E211)

Sodium benzoate is an synthetic preservative obtained from benzoic acid. Sodium benzoate is effective at low pH levels, typically less than 4.5, by preventing the action of fungi, bacteria, and yeast. Poisonous amounts can be ingested if not well monitored. Sodium benzoate, according to Al-Shoeb's work, causes liver impairments and DNA damage when administered to rats in high concentrations, as evidenced in the increased serum AST activity and lymphocyte DNA fragmentation. Again, this adds that regulatory agencies like the USEPA and WHO have approved a permissible limit of 150mg/L for the intake of sodium benzoate in beverages to ensure no harm to human health. However, quite a large per cent of the soft drink samples analyzed in Ghana exceeded this limit and could mean non-compliance and possible exposure risks. (5)

2.1.2. Ascorbic Acid (Vitamin C)

Ascorbic Acid acts as a nutrient additive and as a natural preservative. It enhances product shelf life through preventing oxidation and delaying color degradation and loss of freshness-all highly important consumer acceptability factors. When both ingredients are used together, the ascorbic acid can be converted to sodium benzoate by initiating an acid catalyzed decarboxylation reaction that yields benzene, a very harmful and carcinogenic chemical, especially when at high temperature and when exposed to sunlight. Ascorbic acid content in beverages needs to be controlled so that a balance between the protective effect and a potential contribution to harmful chemical formation may be reached. (6)

2.2. Formation of Benzene in Soft Drinks

Theoretically, the reaction could lead to the formation of benzene under unsuitable storage conditions. This is catalyzed by light and heat, among other transition metals such as copper and iron, which accelerate the decarboxylation of benzoic acid and release the strong carcinogen benzene . The likelihood of the occurrence of such a reaction is high in tropical regions and under conditions of poor storage, where light and temperature conditions favor chemical instability. (7)

International investigations and regulatory reviews done around the world found benzene traces in soft drinks, and most of such findings led to the recall of batches and close monitoring of manufacturing processes. Long-term exposure causes health damage even if the concentration is generally low. Hence, the mechanism of benzene formation and its control from contributing factors continue to hold significance to ascertain product safety, especially in regions like the Jafara Plain where storing conditions remain rather unfavorable. (8)

2.3. Analytical Methods for Determination of Sodium Benzoate and Ascorbic Acid

2.3.1 High-Performance Liquid Chromatography (HPLC)

Some of the most reliable and sensitive methods used for quantification of sodium benzoate and ascorbic acid in beverages are HPLC. HPLC to determine the levels of sodium benzoate in 38 varieties of soft drinks from Ghanaian markets. Concentrations ranged between 51.0 mg/L and 277.0 mg/L. Detection was accurately done with this approach, and estimation based on consumer intake data was able to be made, proving that a number of these products exceeded the limits recommended by USEPA. (9)

HPLC is ideal for regulatory and quality assurance laboratories due to its precision and reproducibility. It is highly selective and sensitive, enabling the simultaneous detection of various analytes, which also includes preservatives and antioxidants. Its integration into food monitoring systems ensures more effective compliance assessments and reduces the likelihood of hazardous exposure through commercially available beverages. (10)

2.3.2 UV–Visible Spectrophotometry

A spectrophoto-metric method for the simultaneous estimation of sodium benzoate and caffeine in soft drinks, using absorbance at specific wavelengths, 224 nm and 274 nm. This technique is less complicated and expensive than HPLC; besides, it is characterized by good accuracy and precision: the recovery rates vary from 99.5% to 100.6% for sodium benzoate. Though this method was applied for caffeine instead of ascorbic acid, its principle may be adapted for antioxidant analysis in beverage matrices. (11)
UV–Vis spectrophotometry may be considered very useful in preliminary screening or routine monitoring when more sophisticated equipment is not available. The disadvantages are lower sensitivity and the possible interference of other beverage components. When validated in accordance with ICH guidelines, however, it provides reliable results for quality control applications. (12)

2.4. Review of Previous Studies on Soft Drinks and Health Impacts

2.4.1 Consumption Trends & Health Risks

About 85.79% of the population consumes soft drinks regularly; the predominant consumption age group was teenagers, between 15–25 years. Both studies identified a serious lack of awareness about the health effects; in their findings, they mentioned that frequent consumers have a high tendency to get diseases like diabetes, obesity, osteoporosis, and heart-related diseases. (13)
Moreover, gender-based trends were identified: females more commonly suffered from metabolic and bone disorders, while males displayed higher prevalence of cardiovascular and dental issues. These findings demonstrate that behavioral and social factors significantly influence soft drink consumption and that greater public education is needed to promote healthier alternatives such as fresh juices. (14)

2.4.2 Sodium Benzoate and Benzene Risk

Serious public health risks from sodium benzoate concentrations exceeding regulatory limits. Approximately 16% of the analyzed soft drinks contained sodium benzoate above 150 mg/L, resulting in hazard quotients (HQ > 1) and lifetime cancer risks (LTCR > 10^{-6}), both considered unacceptable by international safety standards. This underscores the need for stronger enforcement of preservative usage limits in beverage industries. (15)
Likewise, animal study gave biological evidence for the toxicity of sodium benzoate, showing that high dosages (120 mg/kg body weight) resulted in serious DNA damage and also increased AST levels, indicating impairment of the liver(16). These findings strengthen the point that even preservatives legally permitted can be hazardous to health when misused or poorly monitored. (17)

2.4.3 Soft Drinks and Oral and Health Impacts

Accordingly, research that linked soft drink consumption with oral health problems, such as periodontal disease, enamel demineralization, and tooth erosion. Research on how soft drinks affected dentistry and medical students' bone markers. Significant reductions were found in bone density, calcium, and vitamin D levels, together with increased alkaline phosphatase activity. The bone changes were more severe among those who consumed diet soft drinks containing phosphoric acid and aspartame; both sugar-sweetened and sugar-free beverages may have an adverse effect on bone metabolism. (18)
In addition to concerns regarding oral health, research has shown that the consumption of soft drinks can negatively impact both bone health and biochemical parameters. There is a significant association between the daily consumption of approximately 200 mL of soft drinks by medical and dental students and those who consume very little soft drinks. Regular consumption of diet soft drinks is associated with decreased density of mineralized bone, decreased levels of serum calcium and vitamin D, and increased activity of alkaline phosphatase, suggesting higher levels of bonemineral turnover and potentially greater risk of

developing weak bones. There is proposed that this concerns the potential mechanism behind decreased bone mineralization; this includes both phosphoric acid and aspartame creating an acidic systemic condition that promotes bone demineralization. (19)

2.4.4 Glycemic and Metabolic Effects
Changes in GI after the intake of soft drinks among university students and demonstrated a significant rise in the level of glucose in the blood following consumption. In this respect, the Pepsi drink appeared to have the highest glycemic index; $p = 0.001$. This means that repetitive drinking leads to glucose swings and can result in diabetes. Even though students knew the composition of soft drinks, most still consumed them for pleasure, demonstrating how lifestyle can take priority over knowledge. (20)
Complementing this, excessive soft drink consumption has an adverse effect on various body systems, such as the cardiovascular, gastrointestinal, and neurological systems. It established a correlation between sugar-sweetened beverages and metabolic disorders, independent of body fat levels, reinforcing that habitual soft drink consumption poses systemic health threats beyond mere weight gain. (20)

2.5. Hypothesis
Sodium benzoate is used generally as a preservative to inhibit the growth of microbes, while ascorbic acid is added mainly as an antioxidant and promoter of nutrition. These substances react through the decarboxylation reaction upon. These substances react via a decarboxylation reaction when combined under specific environmental conditions of high temperature and prolonged storage time, resulting in the carcinogenic compound benzene (C_6H_6). Indeed, studies have been conducted by the FDA and WHO confirming that the generation of benzene in beverages increases with increased heat and light due to the acceleration of the breakdown process of the benzoate ions and the promotion of oxidative decarboxylation. The combination of these two constituents, therefore, presents potential health hazards in soft drinks under poor storage conditions. (21)
At the level of the Jafara Plain, high ambient temperatures, direct sunlight exposure, and poor storage may increase the chemical reaction between sodium benzoate and ascorbic acid. The region’s prolonged heat and dry air provide a suitable environment for thermal degradation and oxidative reactions in soft drink packages. Previous research has proved that benzene formation in soft drinks is affected by temperature and period of storage; higher concentrations were found after a longer storage period in high temperatures. Based on all factors mentioned above, this study assumes that soft drinks in the Jafara Plain may be prepared with both sodium benzoate and ascorbic acid, and under the local conditions of storage and temperature, a measurable quantity of benzene may form due to their interaction. This assumption is important for the determination of consumer safety and the preparation of local measures for control with the aim of minimizing potential toxicological risk related to soft drink consumption in the region. (22)
H: It is hypothesized that sodium benzoate and ascorbic acid are present in all soft drink samples collected from the Jafara Plain, and that under certain environmental conditions such as high temperature and improper storage, these compounds interact to form benzene through a decarboxylation reaction.

3. Methodology
3.1 Research Location and Materials
This research was carried out between May and July 2025 at Delta Technical Services and the University of Jafara, Faculty of Biotechnology in Sahel Jafara, Libya. The region was selected based on its hot and dry climatic conditions; these can, thus, influence chemical stability and re-activity in soft drink samples, especially on the formation of benzene from sodium benzoate and ascorbic acid under elevated temperatures. Materials used in this study included glass wool, shaker, analytical balance, magnetic stirrer, pH meter, oven, glassware,

volumetric flasks, separating funnels, beakers, and a UV–visible spectrophotometer. Reagents of analytical grade were used to ensure experimental accuracy. Soft drink samples of different brands were purchased from local markets across the Jafara Plain for laboratory analysis (Figure 1).

Figure 1. Sample Preparation for the Determination of Sodium Benzoate

3.2 Experimental Procedures

The experimental procedures were conducted to analyze the concentrations of sodium benzoate and ascorbic acid in soft drink samples and to assess their potential interaction under local environmental conditions. Experimental work in this study was carried out using both iodine titration and UV–visible spectro-photometric methods. In this respect, the stabilizing mixed solution was prepared by mixing ortho-phosphoric acid, acetic acid, and distilled water to prevent oxidation or evaporation of ascorbic acid during titration. A diluted iodine solution was applied as a titrant, where starch was used as an indicator for the end-point because its color changed visibly from colorless to deep blue–black. In carrying out the titration, 10 mL of the mixed stabilizing solution, 10 mL of the vitamin C sample, and 1 mL of starch indicator were added into a conical flask. Afterwards, iodine was added dropwise into the flask up to the endpoint (Figure 2).

Figure 2. Sample Preparation for the Determination of Sodium Benzoate

In parallel, sodium benzoate concentrations were determined using UV–visible spectrophotometry. Standard stock and working solutions of sodium benzoate were prepared (200 ppm, 1000 µg/mL, 100 µg/mL and 10 µg/mL) to construct calibration curves. The soft drink samples were degassed to remove carbon dioxide. The samples were then extracted sequentially with hydrochloric acid and diethyl ether, followed by treatment with 5 wt% Na_2HPO_4. The ether was evaporated by heating the solution at 60°C, and the remaining extract was diluted for measurement. The absorbance of each sample and standard was recorded at 225 nm against deionized water as a blank (Figure 3).

Figure 3. Different Soft Drink Sample

The Q-absorbance ratio method was applied to calculate component concentrations using the equation:

$Cx = (Qm - Qy) / (Qx - Qy) * A/a1$

$Cy = (Qm - Qx) / (Qy - Qx) * A/a2$

The concentrations of sodium benzoate and caffeine, respectively. All procedures were carried out exactly according to the laboratory protocols to ensure the accuracy and reproducibility.

3.3 Data Analysis Methods

Experimental data from the titration and spectrophotometric analyses were analyzed using SPSS version 21. Descriptive statistics in the form of mean, median, and standard deviation were calculated in order to assess the distribution and variability of sodium benzoate and ascorbic acid concentrations across different soft drink brands. Descriptive analysis was used to present and compare results between different brands. Non-parametric tests were also used where the data failed to meet normality assumptions. The UV–visible absorbance data were used to generate calibration curves, from which sample concentrations were interpolated. Results of the statistical analysis were used to determine the relationship between reagent concentrations, storage conditions, and possible benzene formation risk. The results provided a quantitative basis for assessing the chemical stability of soft drinks sold in the Jafara Plain and drawing conclusions relevant to consumer safety and environmental health.

4. Result and Discussion

4.1. Result

4.1.1. Effect of PHs on soft drinks

The pH of soft drink ranges from 2.5-3.4 which generates a highly acidic environment in the stomach. Throughout the digestive system, that starts from the mouth and ends up at the anus (liver, gallbladder and pancreas play the role of accessory organs) only the stomach can resist an acidic environment up to pH 2.0. All soda is 100% Acid forming regardless of the type or brand. It has a pH balance of two. this is a very low PH number Our bodies' normal pH balance is 7.3, which is rather alkaline. Low pH values indicate the highly acidic nature of soft drinks, which is associated with tooth enamel erosion and potential digestive effects with frequent consumption. The result of this study in pH scale low below (Figure 5):

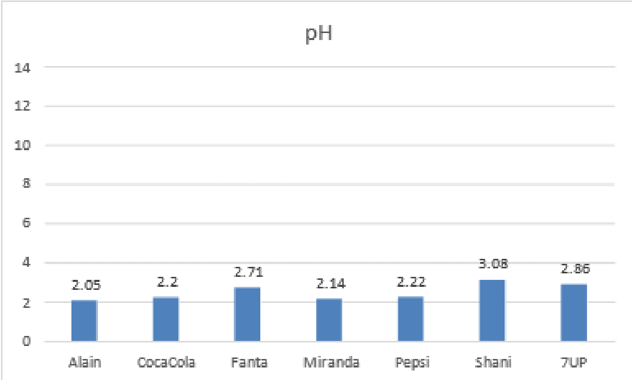

Figure 5 pH value of different samples of soft drink

The pH of the various soft drink samples was measured to assess their acidity, an important factor in taste and potential health consequences like dental erosion. From Figure 1, there are striking differences between the different beverages that were tested. Alain had the lowest pH with 2.05 and hence the most acidity. Coca-Cola had a pH of 2.20, slightly less acid than Alain. Miranda and Pepsi had 2.14 and 2.22 pH, respectively, proving them to be highly acidic types of soft drinks. Shani had the highest pH of 3.08, proving to be the least acid drink within this group. Most commercial soft drinks have a pH less than 3.5, which has generally been classified as strongly acidic and erosive to dental enamel and gastrointestinal health when consumed frequently. (23)

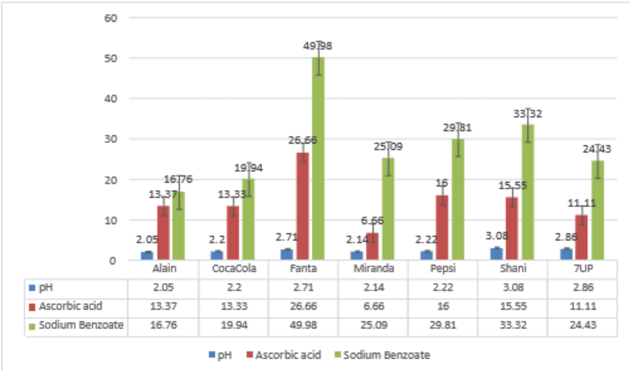

Figure 6 Effect of Ascorbic Acid and Sodium Benzoate on soft drinks

The concentrations of ascorbic acid and sodium benzoate in various soft drink samples analyzed in Figure 6 had significant differences which may affect the potential for benzene ring formation in certain conditions. Of the analyzed drinks, Shani had the highest pH value of 3.08 and thus could be termed the least acidic. The quantity of sodium benzoate added as a preservative to these samples was also different. Amongst all the samples, Fanta had the highest amount, that is 49.98 ppm, while Al Ain had the lowest amount with 16.76 ppm. These results further indicate that Fanta and Shani are the most prone to a chemical reaction between ascorbic acid and sodium benzoate, thus leading to the formation of a benzene ring under high-temperature and poor storage conditions. On the other hand, Al Ain and Coca-Cola were found to have a lower susceptibility, thus being relatively safer for the risk of forming benzene.

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Table 1 Statistical Analysis of Carbonated Beverages Samples

Beverage	Sodium Benzoate (ppm)	Ascorbic Acid (ppm)	pH
Alain	16.76	13.37	2.05
CocaCola	19.94	13.33	2.20
Fanta	49.98	26.66	2.71
Miranda	25.09	6.66	2.14
Pepsi	29.81	16.00	2.22
Shani	33.32	15.55	3.08
7UP	24.43	11.11	2.86

Statistical analysis of carbonated beverage samples was carried out to establish the concentration of sodium benzoate and ascorbic acid, as well as the pH range in different beverages (Table 1). On the matter of acidity, the drinks had an average pH value of 2.44, with a standard deviation of 0.36, and all samples were thus highly acidic. The minimum pH was recorded for Al Ain at 2.05, while the maximum pH was recorded for Shani at 3.08; thus, it was the least acidic among all the soft drinks analyzed. In general, statistical results indicated that most of the soft drink samples were within acceptable limits concerning additive and preservative concentrations by the food industry. (24)

4.1.2. Descriptive Analysis Of Soft Drink Sample Results

This report details several Carbonated Beverage Samples analyzed for their content of Sodium Benzoate and Ascorbic Acid through a statistical analysis, determining an arithmetic mean, standard deviation, and highest and lowest values for each substance.

Table 2 Descriptive Analysis Of Soft Drink Sample Results

Beverage	Sodium Benzoate (ppm)	Ascorbic Acid (ppm)
Alain	16.76	13.37
Coca-Cola	19.94	13.33
Fanta	49.98	26.66
Miranda	25.09	6.66
Pepsi	29.81	16.00
Shani	33.32	15.55
7UP	24.43	11.11

Concentrations of ascorbic acid and sodium benzoate were highly variable among the carbonated beverage samples. Sodium benzoate was also shown to vary somewhat amongst different beverage brands, with a standard deviation of 10.28 ppm along with an arithmetic mean concentration of 28.19 ppm. Sodium benzoate concentrations ranged between 16.76 and 49.98 parts per million, all of which are significantly below internationally permitted maximum limits (Table 2).

The ascorbic acid content also varied significantly among samples with an arithmetic mean of 14.67 ppm and a standard variation of 5.60 ppm. Ascorbic acid concentrations ranged between 6.66 and 26.66 parts per million, which are low concentrations. Relatively speaking, it is used as an antioxidant (300E) to protect flavor and prevent oxidation, not for the purpose of nutritional fortification with vitamin C. These results confirm the presence of both substances in all soft drink samples analyzed within ranges that could impact the chemical stability of the beverages and the potential for benzene formation under specific conditions. (25)

4.1.2.1. Effect of Ascorbic Acid and Sodium Benzoate on Alain

Ascorbic acid or vitamin C and sodium benzoate, under specific conditions, can react to form the harmful chemical benzene, and this might be an important factor in the interpretation of the results obtained from the Alain soft drink sample. Consequently, it became relevant to determine the pH of the beverage, along with the quantity present of these two additives, for judgments about product safety and chemical stability. The pH, ascorbic acid concentration, and sodium benzoate content of Alain measured are presented in the graph below.

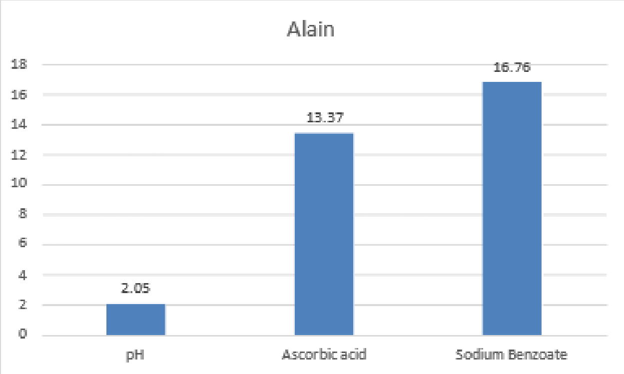

Figure 7 Effect of Ascorbic Acid and Sodium Benzoate on Alain

Figure 7 demonstrates that for Alain, the pH is 2.05, hence it is an intensely acidic drink. The concentration of ascorbic acid is pretty low, at 13.37 ppm. This is less than half of the maximum permissible limit as laid down by international food standards. From the two aspects, this LRB may be considered chemically stable and additive-safe despite its acidity. The low concentrations of both ingredients minimize the risk of forming benzene, making Alain one of the least susceptible beverages to the reaction under normal conditions of storage. (26)

4.1.2.2. Effect of Ascorbic Acid and Sodium Benzoate on Coca Cola

Analyzing the concentration of these compounds together with the pH value of the drink enables the assessment of both the safety and stability of the product. The following bar chart reflects the relative levels of pH, ascorbic acid, and sodium benzoate in Coca-Cola.

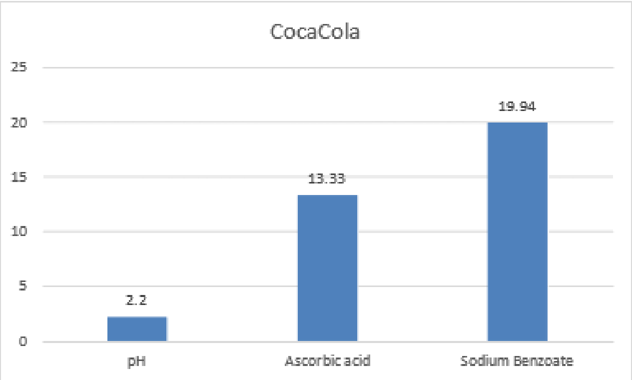

Figure 8 Effect of Ascorbic Acid and Sodium Benzoate on Coca Cola

Coca-Cola had a pH of 2.20, which is quite acidic but also within the normal range for carbonated drinks, as represented in Figure 8. The content of ascorbic acid was 13.33 parts per million and low enough to be safe for ingestion. The amount of sodium benzoate, on the other hand, was 19.94 parts per million and thus far below the allowable range by international food safety regulators. Overall, our results indicated that Coca-Cola has a suitable compositional balance with both chemicals at low risk levels. However, caution

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should be observed in storage and handling, as sustained exposure to unfavorable conditions could increase the possibility of benzene formation despite its current safe formulation. (27)

4.1.2.3. Effect of Ascorbic Acid and Sodium Benzoate on Fanta

From Figure 8, Coca-Cola had a pH of 2.20, highly acidic and within the normal range for carbonated beverages. Its acidity might be critical and needs to be regulated with care to avoid possible chemical reactions when preservatives and additives are present together. However, handling and storage should be done with caution because continuous exposure to unfavorable conditions will increase the chances of formation of benzene even though it is in a safe composition. Results show that the chemical makeup of Fanta is within the limits of safety and is industrially acceptable. The acidity and concentration of preservatives are acceptable to be used by consumers and do not pose serious concerns in safety. Since Fanta has high levels of both ascorbic acid and sodium benzoate, careful storage away from heat and sunlight is recommended to minimize the possibility of forming benzene through a chemical reaction during consumption. (28)

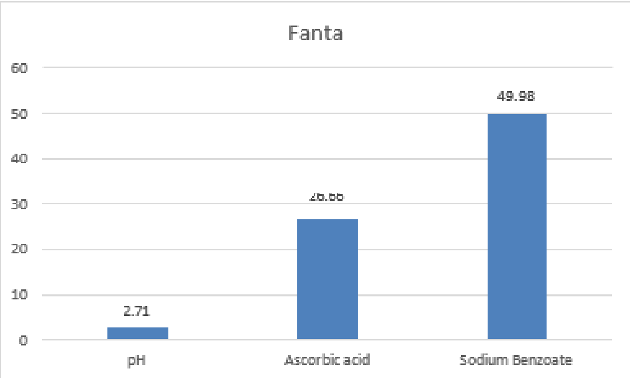

Figure 9 Effect of Ascorbic Acid and Sodium Benzoate on Fanta

4.1.2.4. Effect of Ascorbic Acid and Sodium Benzoate on Miranda

The pH value of Miranda was 2.14 (Fig. 10), highly acidic and within the normal range for soft drinks. The ascorbic acid content in Miranda was 6.66 ppm and the lowest among the tested samples, hence safe and within acceptable limits regarding food safety. The concentration of sodium benzoate was 25.09 ppm, also substantially below the maximum acceptable limit of 200 ppm specified by several international organizations like the FDA and WHO.

Results obtained from this experiment confirm that Miranda is safe and compliant to drink. Although quite acidic, the low levels of ascorbic acid and sodium benzoate present would not pose any significant risk of forming benzene under normal conditions of storage. However, due to its strong acidity, consumption over a period or in excess may have an effect on dental enamel, so intake must be in moderation. (29)

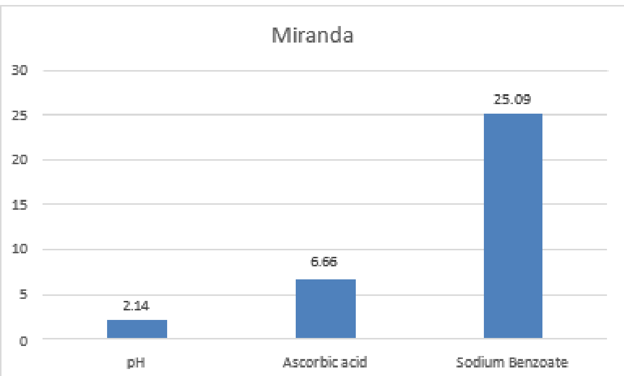

Figure 10 Effect of Ascorbic Acide Sodium Benzoate on Miranda

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4.1.2.5. Effect of Ascorbic Acid and Sodium Benzoate on Pepsi

Figure 11: The pH of Pepsi is 2.22, which lies within the acceptable range of acidity for soft drinks. It is acid enough to give Pepsi its sharp taste and low enough not to support microbial growth. The concentration of ascorbic acid was 16 ppm, which is quite low and completely safe; thus, it serves as an antioxidant against oxidation of flavor compounds. The concentration of sodium benzoate was 29.81 ppm-a modest amount, well below the internationally permitted limit of 200 ppm-and thus confirms the safety of this beverage.

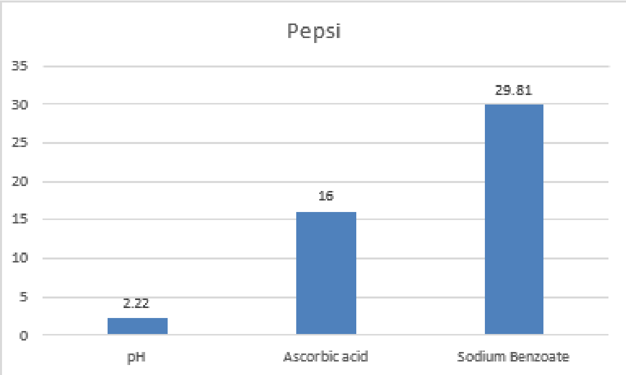

Figure 11 Effect of Ascorbic Acid and Sodium Benzoate on Pepsi

From this, it can be observed that the chemical composition in Pepsi is in balance, especially with respect to acidity and preservative concentration. The level of ascorbic acid and sodium benzoate is within the limit in the context of safe consumption and no substantial risk due to the formation of carcinogenic benzene exists, provided it the beverage is stored accordingly. Similar to all carbonated soft drinks, though, consumption should be done on a regular but controlled basis to offset the probable chronic health effects associated with chronic consumption of an acidic drink. (30)

4.1.2.6. Effect of Ascorbic Acid and Sodium Benzoate on Shani

The pH of Shani was 3.08, as shown in Figure 12, making it the highest among all soft drinks analyzed in the present study. This can be interpreted to mean a slightly higher pH, which has less potential for acid-related corrosion or tooth enamel erosion compared to more acidic drinks. The concentration of ascorbic acid was relatively low, indicating that vitamin C, though present, is in small quantity enough to be completely safe and chemically stable under normal storage and consumption conditions. In addition, the sodium benzoate concentration in Shani was far below the international permissible limit, 200 ppm, reflecting very good compliance with WHO and FDA standards for food safety.

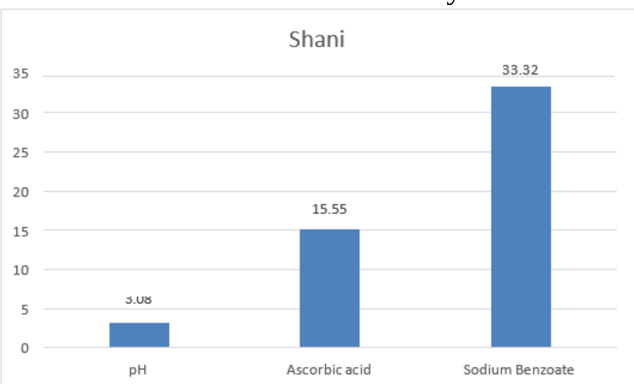

Figure 12 Effect of Ascorbic Acid and Sodium Benzoate on Shani

The chemical composition reveals that Shani exhibits a fairly good safety profile. Accordingly, Shani shows a well-balanced acidity and low additive content, limiting the chances of having consumed chemicals along with this drink. The potentiality of a benzene ring may also be considered low because the interaction between ascorbic acid at low concentration and sodium benzoate at an average pH may not support a potential reaction under thermal or light exposure. Hence, Shani could be considered one of the least reactive and safest soft drinks when compared to other soft drinks like Fanta or Miranda. Moreover, its formulation indicates that Shani would pose a minimal health risk under appropriate storage conditions, enjoying consistent product safety across typical environmental variations in the Jafara plain region. (31)

4.1.2.7. Effect of Ascorbic Acid and Sodium Benzoate on 7UP

Figure 13 presents the analysis that indicates the 7UP has a balanced chemical composition, with all tested parameters - pH, ascorbic acid, and sodium benzoate concentrations - within internationally accepted safety standards. Such acidity is acceptable because it preserves flavor and inhibits the growth of microorganisms and still keeps the product within the allowed limits of food safety. The content of ascorbic acid in 7UP is very small, confirming that the product fully corresponds to the standards and does not create health problems. Since ascorbic acid also serves as an antioxidant, its insignificant amount benefits the stability of the product, not creating any suspicion of undesirable chemical interactions.

These results all together suggest that 7UP indeed has a very stable and safe formulation; its moderate acidity, minimal ascorbic acid, and low sodium benzoate levels ensure that no significant risk of benzene formation is a concern when these two compounds coexist under extreme storage conditions. Compared to other tested beverages, 7UP shows excellent compliance with food safety standards and can be considered chemically stable, thus safe for regular consumption and also resilient to environmental conditions, particularly those occurring under the normal temperature fluctuations of the Jafara plain region. (32)

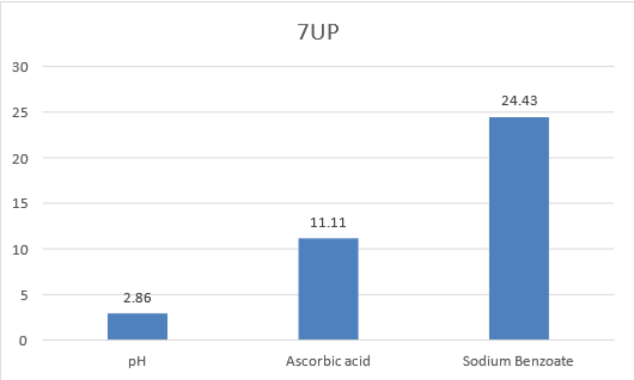

Figure 13 Effect of Ascorbic Acid and Sodium Benzoate on 7UP

4.1.3. Effect Of Soft Drinks On The Health Of The Consumer

For health risk estimates to trigger any important food safety deliberation, the estimated values have to be compared with established thresholds. According to the European food safety authority (EFSA) and the United States environmental protection agency (USEPA), a HQ>1 presents considerable risk and calls for public health concern.

The HQ may be used as one risk index to quantify the risk of exposure to benzene, defined to be the ratio of the CDI to the reference dose of benzene. The product of the CDI of human exposures to a hazard and the potency factor for the hazard yields the lifetime estimate for the risk of developing cancer, another risk index. The potency factor is the risk produced by ingesting an average dose of 1mg/kg(bow)-d of the hazard over a lifetime. (33)

Internationally, there is no legal standard reference value beyond which benzene poses lifetime cancer risk to consumers. However, an expert report by WHO sets a reference limit of

10µg/L. USEPA also set a 5µg/L benchmark while the European commission has set a limit of 1µg/L for benzene in non-alcoholic carbonated drinking water. Statistic available from the WHO indicates that in 2015 more than 8.8million deaths globally were due to cancer and 70% of that number was from low to middle income countries.

According to experts, precursors of benzene, which are regulated for use as food additives, such as benzoic acid and its sodium benzoate salt, are commonly abused. There's a chemical reaction between sodium benzoate, a preservative, and ascorbic acid-or vitamin C-found in soft drinks, and it certainly is something that scientists and regulators have studied closely. These substances can combine under certain conditions to form the carcinogenic compound benzene. It involves decarboxylation of benzoic acid, originating from sodium benzoate, catalyzed by metal ions such as iron or copper. Most soft drinks today are formulated to minimize this risk. For instance, regulatory bodies like the FDA and WHO have set very strict limits on levels of benzene in beverages. In most cases, the quantity of benzene formed will be very low and thus not considered harmful upon casual consumption. (34)

Factors that influence benzene formation as follow: (35)

a. Temperature: The higher the heat, the faster the reaction occurs.
b. Light exposure: UV light can initiate this process.
c. Presence of metal ions: These act as catalysts.
d. Storage conditions: Poor storage conditions can lead to an increase in the levels of benzene.

Figure 14 shows some soft drink samples that have been subjected to improper storage conditions, such as high temperature and direct light exposure. These are highly contributory environmental factors to chemical instability, especially in the interaction between the preservative sodium benzoate and vitamin C (ascorbic acid). Under these conditions, benzene formation can arise from the degradation of benzoic acid with metals acting as catalysts along with elevated temperature. Such a figure shows how correct storage practices are important for product safety and for preventing the build-up of harmful by-products. It could also show that improper storage conditions can make up an unsafe beverage which is otherwise a harmless one for consumption. (36)

Figure 14 A group of soft drinks exposed to poor storage

Figure 15 shows the analytical instruments and laboratory setup for measuring the ascorbic acid concentration in soft drink samples. In most cases, this is done through either UV-visible spectrophotometry or titration methods to measure the content of vitamin C accurately. The ascorbic acid content is considered essential because this chemical can act as a reactant in the formation of benzene when mixed with sodium benzoate. The figure indicates that the laboratory techniques are accurate and reliable when it comes to the determination of chemical safety for soft drinks, making sure that all values lie within the set limits by such authorities as World Health Organization and the U.S. Food and Drug Administration. (37)

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Figure 15 instruments used to determine ascorbic Acid

Figure 16 shows the proposed chemical pathway for sodium benzoate reacting with ascorbic acid to produce benzene. First, the ascorbic acid reduces benzoate ions to form benzoic acid, which then decarboxylates, losing CO_2 and producing benzene, C_6H_6. This reaction is catalyzed by metals, typically Fe^{2+} or Cu^{2+}, and occurs at an increased rate when the temperature and light exposure are increased. Hence, this figure gives a clear reaction pathway to understand the chemical mechanism in the reaction yielding benzene in beverages containing preservatives and antioxidants. It further justifies that a controlled formulation of nutritional beverages would be necessary, together with appropriate pH, in order not to generate hazardous reactions. (38)

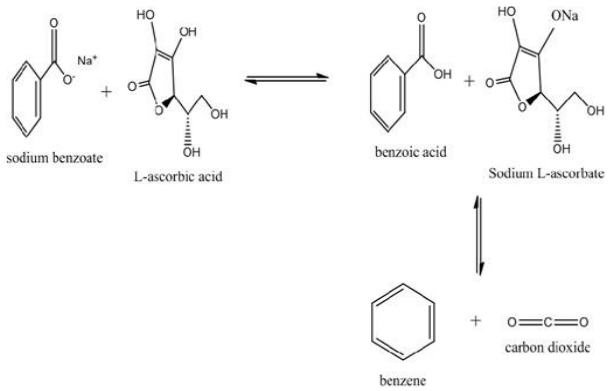

Figure 1. Propose reaction pathway for the reaction of sodium benzoate with ascorbic acid.

Figure 16. Propose Reaction Pathway for The Reaction of Sodium Benzoate with Ascorbic Acid

4.2. Discussion

The results indicate a clear variation in the concentrations of sodium benzoate and ascorbic acid between different brands, which is attributed to differences in industrial formulation, storage conditions, and shelf life. Al-Salihiya. Although all values fall within the safe limits for food additives, the simultaneous presence. The presence of these two substances in an acidic medium may form a theoretical basis for the formation of benzene upon exposure to high temperatures, light, or the presence of catalytic metal ions. The pH values ranged between 2.05 and 3.08. This range is common in commercial soft drinks, as acidity contributes to improved flavor and inhibits microbial growth; however, it is also associated with potential negative effects on dental health with frequent consumption. (39)

Beverages containing relatively higher concentrations of both ascorbic acid and sodium benzoate are theoretically more prone to this reaction than others; however, this does not necessarily mean that benzene will actually form under normal consumption conditions, but rather depends mainly on the conditions. This acidity level in carbonated drinks is common because it enables them to attain their characteristic taste and quality that is stable microbiologically. Variation in the ascorbic acid levels among samples may be due to the difference in formulation, period of storage, and exposure to light and temperature. Ascorbic acid acts as an antioxidant, but in the presence of sodium benzoate, when subjected to heat or light, or under metallic contamination, it may provoke the formation of the carcinogenic

benzene compound. These results underscore the importance of adhering to the cold chain and proper storage, especially in hot climates such as the Jafara Plain, where high temperatures can accelerate chemical reactions. (40)
From a public health perspective, the risk associated with benzene exposure as estimated in this work is low for most commercial beverages if regulatory guidelines are followed. The EFSA and USEPA give an HQ value greater than 1 as being a potential health risk; levels here would suggest HQ values well below that level. However, results indicate the need for ongoing monitoring, since a potency factor for benzene would show that low-level, chronic exposures could be adequate to potentially develop cancers in an individual over a lifetime (WHO, 2016). Most of the deaths from cancer which happen worldwide occur in low-income and middle-income countries; therefore, sticking to standards for food additives must be emphasized in these regions. Generally, the result proved that the examined drinks, which include Coca-Cola, Pepsi, Fanta, Miranda, 7UP, Shani, and Al Ain, are chemically safe and within standard conditions of storage and consumption. Quality controls, consumer awareness, and environmental management of stored products are always important in reducing health risks because of soft drink consumption. (41)

5. Conclusion

The results of this study showed that the levels of sodium benzoate and ascorbic acid were within limits considered to be safe in all soft drink samples analyzed. This research, however, highlighted a situation where, under improper conditions-like storage at temperatures above 25°C, direct sunlight, and poor handling-a chemical reaction might occur between these two compounds to produce benzene. This is a potent carcinogenic substance, a chemical known to increase serious health hazards through causing various types of cancers. Thus, though the drinks are safe to consume if manufactured and stored properly, the conditions on the supply side are seriously jeopardizing consumer safety.
Scientific analyses related to the detailed mechanism of benzene formation and carcinogenic impacts should be further advanced. Monitoring and regular testing of soft drinks and their storage facilities would be likely to provide some assurance on the applicability of the products within safety standards. On the part of the manufacturers and retailers, improvement in storage practices is needed to prevent harmful chemical reactions by creating ideal conditions for storage that keep temperature and sunlight away from the products so as not to harm public health.
This study was limited to estimating the concentration of sodium benzoate and ascorbic acid without direct measurement of benzene, and therefore the assessment was based on theoretical risk analysis. In the future, it is recommended to use GC techniques to determine benzene actually.

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