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Ecological and microbiological quality of some soft drinks and juices in the Iraqi markets

AL-Yasari Wameedh

Department of Biology, College of Science, University of Babylon, Iraq. E-mail address: wameedadil_83@yahoo.com

Al-Jewahery Hala

*Corresponding author: Department of Biology, College of Science, University of Babylon, Iraq. E-mail address: sci.hala.ali@uobabylon.edu.iq

Abstract

Objective

Soft drinks and fruit juices are among the most widely consumed beverages globally, containing in Iraq, where they are dietary staples in many households. Despite their popularity, concerns remain regarding their nutritional composition and potential microbial contamination, which may pose public health risks if not properly regulated. This investigation aims to evaluate the ecological, physicochemical, and microbiological quality of selected soft drinks and fruit juices available in markets across Babylon Province, Iraq.

Materials and Methods

Samples of packaged fruit juices and soft drinks were gathered from various markets across all districts of Babylon Province. The samples were analyzed for selected physical and chemical parameters, containing sugar content, pH, carbon dioxide (CO_2), and citric acid concentration. Microbiological assessments were also conducted to detect the presence of bacteria, molds, and yeast.

Results

Sugar content in soft drinks varied from 14.22 to 19.99 g/100 mL (e.g., SD15 and SD2, respectively), while in fruit juices it reached up to 23.3 g/100 mL (FJ7) and was 22 g/100 mL in samples FJ5, FJ6, and FJ11. CO_2 was detected in soft drinks, with a maximum value of 4.3 g/100 mL in SD4; it was absent in all fruit juice samples. The pH values of soft drinks varied from 2.0 (SD2) to 4.1 (SD14), while fruit juices varied from 2.0 (FJ1, FJ5, FJ15) to 5.0 (FJ3). Citric acid

concentrations in soft drinks varied from 1.04 g/L (SD2) to 3.25 g/L (SD11), while in fruit juices, values varied from 0.99 g/L (FJ1) to 5.11 g/L (FJ7). Phosphoric acid was existed only in Coca-Cola, Pepsi, grape juice, and pomegranate juice samples, with no diagnosis of alcohol in any beverage tested. No bacterial growth was observed in most soft drink samples, except for SD2, SD4, SD5, SD6, SD9, SD12, and SD18. In fruit juices, bacterial counts varied from no detectable growth in FJ3, FJ4, FJ8, FJ9, and FJ14 to 3 CFU/100 mL in FJ5. Yeast growth was found only in SD4, SD10, FJ8, and FJ14, while molds were detected in SD1, SD7, SD12, FJ3, FJ12, and FJ15.

Conclusions

The majority of tested soft drinks and fruit juices complied with general safety and quality standards, showing limited microbial contamination and acceptable physicochemical properties. Nonetheless, periodic monitoring and strict quality control remain essential to ensure the continued safety of these commonly consumed beverages.

Keywords: beverage quality, fruit juice, Iraq, microbial contamination, soft drinks

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Introduction

A carbonated beverage is distinguished as a non-alcoholic drink and typically contains water (approximately 90%), a sweetening substance, acidulants, carbon dioxide (CO_2, approximately 3.5%), fruit juice, minerals, vitamins, preservatives, colorants (either natural or artificial), and flavoring agents (Godwill et al., 2015). These components work synergistically to generate the taste, appearance, and shelf stability of the final product. A small quantity of caffeine, an alkaloid compound, may also be exist in many soft drinks. Caffeine has been announced to contribute a bitter taste depending on its concentration, and it is also known to interact with certain flavor

compounds, affecting their solubility and ultimately improving the sensory perception of flavor (King & Solms, 1982; Keast & Roper, 2007; Heidarpour et al., 2011). Soft drinks are generated and marketed under various brand names and formulations by different companies throughout the country, each offering variations in flavor, components, and nutritional content to appeal to consumer preferences (Ambler & Styles, 1997; Francis et al., 2011). Similarly, fruit juices are complex beverages composed primarily of water, sugars, organic acids, natural and synthetic flavors, preservatives, and various minor components that contribute to their nutritional and sensory properties. These constituents significantly influence the quality and acceptance of the final product (Ashurst et al., 2017). Due to their attractive taste, refreshing properties, and capability to relieve thirst, both soft drinks and fruit juices are consumed in large quantities globally, containing in Iraq (Phillip et al., 2013). The sensory characteristics of these beverages are primarily determined by their components—sugar prepares sweetness; carbon dioxide adds effervescence, which enhances thirst-quenching properties; and flavoring agents contribute to the characteristic taste and aroma (Kirk & Sawyer, 1991; Eghtedari et al., 2024). In addition to these sensory attributes, many beverages also contain added micronutrients like vitamins and phosphates that may offer some functional health benefits (Pofahl et al., 2005). Achieving the desired quality in fruit juices and carbonated beverages needs careful regulation of various physicochemical parameters like taste, mouthfeel, pH, Brix value, fruit content, and the permissible amounts of additives (Ashurst et al., 2017). However, the growing request for these beverages may place pressure on manufacturers, sometimes resulting in lapses in quality control, particularly through critical processes like pasteurization, disinfection, and packaging. Under such situations, microbial contamination becomes more likely. Microorganisms exist in raw materials or introduced through processing may grow in the final product, potentially leading to the formation of small quantities of alcohol as a result of microbial fermentation (Juvonen et al., 2011). Although soft drinks may contribute minimally to the daily intake of vitamin C when fortified, they are generally poor sources of other nutrients. They are entirely devoid of dietary fat and fiber, and they contain only trace levels of protein (Wedzicha, 2003; Shahsavari et al., 2023). In many formulations, artificial or non-nutritive sweeteners are applied as alternatives to sugar. These sweeteners enhance sweetness without contributing to the caloric content of the drink (Shahsavari et al., 2022). The principal sweetening component in most carbonated beverages is carbohydrates, a class of organic compounds derived from plant or microbial sources (O'Brien-Nabors, 2012). Carbon dioxide, one of the essential components in soft drinks, not only adds carbonation and mouthfeel but also serves as a mild preservative. A liter of water can dissolve up to 8 grams of CO_2 under pressure. Upon opening the container and exposing it to atmospheric pressure, the gas escapes rapidly, creating the familiar fizz. CO_2 inhibits the growth

of many spoilage microorganisms and helps preserve the product through storage and distribution. Additionally, it plays a structural role by exerting internal pressure on cans and bottles, preventing deformation (Eweis et al., 2017; Vahabzadeh et al., 2020). Despite advances in manufacturing technology, various microorganisms can still be found in beverages. These microorganisms may originate from the raw materials, processing environment, or handling stages. While only a limited number of these microbes can survive in the low pH and low oxygen environment typical of soft drinks and juices, some containing yeasts, are particularly resilient and can create spoilage. Yeasts are the most commonly encountered spoilage organisms, although bacteria like *Acetobacter*, *Bacillus*, *Clostridium*, and *Lactobacillus* are also associated with deterioration in the soft drink and juice industry (Jayalakshmi et al., 2011; Ashurst et al., 2017). In light of these considerations, this investigation aims to investigate selected physical, chemical, and microbiological properties of commercially available soft drinks and fruit juices in the Iraqi market, with a centralize on products sold in Babylon Province and evaluate their conformity with safety standards and evaluate their suitability for human consumption.

Martials and methods

Samples collection: A total of thirty packaged beverage samples—comprising fifteen soft drink samples and fifteen fruit juice samples, were gathered from various commercial markets across all major districts of Babylon Province, Iraq. The areas included in the sampling process were Al-Hilla, Al-Musayyib, Jebala, Al-Mahaweel, and Al-Hashimiyah. Sampling was conducted over a period of two months, from March 2021 to April 2021, with approximately five samples gathered from each beverage category per district to ensure a representative distribution across brands, types, and packaging formats. All samples were purchased in their original, unopened retail packaging to reflect the products available to consumers. The beverages were immediately labeled, stored in clean, insulated containers, and transported under ambient situations to the microbiology and chemistry laboratories at the relevant research facility for further analysis. Upon arrival at the laboratory, the samples underwent preliminary inspection to confirm their integrity. This included visual examination of each package to detect any signs of tampering, leakage, discoloration, swelling, or other forms of physical or chemical degradation. Only samples that showed no evidence of internal or external damage were selected for subsequent analysis. Additionally, the nutritional information printed on each product label, particularly the declared sugar content, was recorded to be compared with experimentally measured values. All handling and storage of the samples were carried out in accordance with standard hygienic and procedural

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guidelines to prevent contamination and ensure the reliability of the results. The samples were then prepared for further physicochemical and microbiological testing.

Physical and chemical examinations – Determination of sweeteners (sugar): The determination of sugar content in the gathered beverage samples was carried out applying standard sucrose solutions as references. Analytical-grade sucrose was achieved from Sigma-Aldrich (USA) for this purpose. Prior to analysis, soft drink samples were degassed to remove dissolved carbon dioxide, which could otherwise interfere with accurate refractometric measurements. Fruit juice samples were treated with activated charcoal to remove natural pigments and other colorants that might affect optical readings. Subsequently, all samples underwent centrifugation at 4000 rpm for 10 minutes to eliminate suspended solids and ensure sample clarity. Standard sucrose solutions were prepared by dissolving appropriate quantities of sucrose in deionized water to achieve concentrations ranging from 10 to 20 g/100 mL. The exact concentration ranges were selected based on the expected sugar content of the beverage type being analyzed. Both the standard solutions and the prepared beverage samples were analyzed applying an Abbe refractometer. This device measures the refractive index of a solution, which correlates directly with its sugar concentration. The refractometer was calibrated with deionized water before each apply to ensure accuracy. Readings from the standard sucrose solutions were applied to construct a calibration curve by plotting refractive index values against known concentrations. Sugar content in the beverage samples was then determined by interpolating their refractive index readings on the standard calibration curve (Figure 1), following the method described by Ramasami et al. (2004). All measurements were carried out in triplicate to ensure reproducibility, and the mean values were recorded and announced.

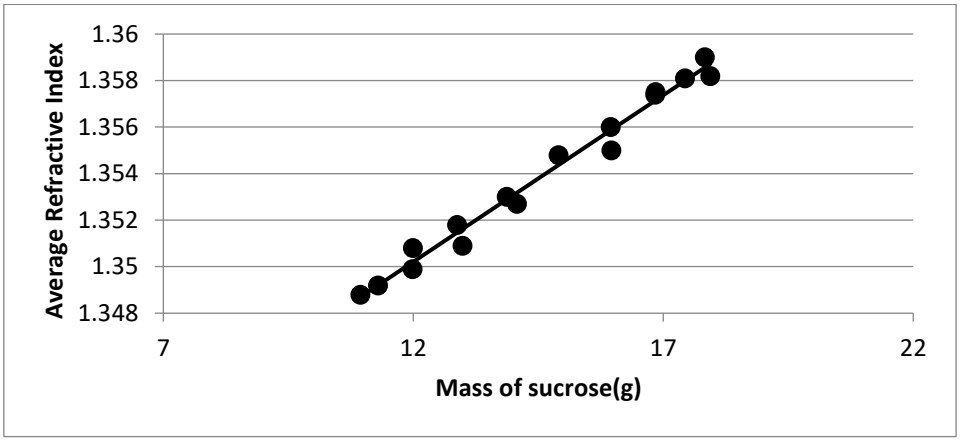

Figure 1. Calibration curve of standard sucrose solutions (10–20 g/100 mL) prepared in deionized water. The refractive index was measured applying an Abbe refractometer. The resulting linear relationship was applied to determine sugar concentration in the beverage samples

Determination of pH: The pH of each beverage sample was determined applying a digital multimeter (pH meter), which was calibrated prior to apply with standard buffer solutions at pH 4.0, 7.0, and 10.0. Calibration was carried out based on the manufacturer's guidelines to ensure accuracy. After calibration, the electrode was rinsed with distilled water and immersed directly into each sample. Measurements were taken in triplicate, and the mean values were recorded as the final pH values for each sample.

Determination of carbon dioxide (CO_2): The quantification of free carbon dioxide was carried out based on the method recommended by the FAO/WHO Codex Alimentarius (2005). Approximately 250–300 mL of each beverage sample was first gathered in a Nessler tube. From this, a 100-mL portion was transferred to a clean conical flask. A few drops of phenolphthalein solution (dissolved in ethanol) were added to the sample. If the solution turned pink, it indicated the absence of free CO_2. If no color exchange was observed, the sample was titrated with 0.05 N sodium hydroxide (NaOH) until a faint pink color persisted, signifying neutralization of the dissolved carbonic acid. The volume of NaOH applied was recorded, and the procedure was repeated three times per sample to ensure consistency and reliability of the results.

Determination of citric acid: Citric acid concentration was estimated following the method described by Brima and Abbas (2014). Beverage cans and bottles were opened and left uncovered in a clean, dark area for different hours to permit for complete degassing. A 10-mL aliquot of each degassed sample was then titrated with 0.1 N NaOH solution applying phenolphthalein as an indicator. The endpoint was identified by a persistent pale pink coloration, and the volume of titrant applied was recorded. Each measurement was carried out in triplicate, and average values were calculated.

Determination of phosphate content: The presence of phosphate ions in the beverage samples was tested applying the colorimetric method described by Godwill et al. (2015). In a clean test tube, 3 mL of the beverage sample was mixed with 2 mL of ammonium molybdate reagent, followed by the addition of 1 mL concentrated nitric acid (HNO_3). The test tubes were then placed in a hot water bath at 80°C for 10 minutes. The appearance of a yellow precipitate indicated the presence of phosphate compounds in the sample. All reactions were observed immediately after removal from the water bath.

Determination of alcohol: The presence of ethanol (alcohol) in beverage samples was analyzed applying the chemical test method adopted by Godwill et al. (2015). For each sample, 3 mL of the beverage was transferred into a clean test tube, followed by the addition of 1 mL each of iodine solution, potassium iodide solution, and sodium hydroxide solution. After thorough mixing, the test tubes were placed in a water bath at 60°C for 30 minutes. The formation of a

yellow precipitate was interpreted as a positive indication of alcohol presence in the sample. Negative samples showed no exchange in appearance.

Microbiological examination-bacteriological counts: The total viable bacterial count in the beverage samples was determined applying the spread plate technique as described by Berhanu et al. (2020). Briefly, 1 mL of each beverage sample was aseptically transferred and evenly spread onto sterile nutrient agar plates applying a glass spreader. All procedures were carried out under sterile situations to avoid contamination. The plates were incubated at 37 °C for 48 hours. After the incubation period, visible colonies were counted and recorded. Each sample was analyzed in triplicate, and the mean number of colonies was calculated and expressed as colony-forming units per milliliter (CFU/mL).

Mold and yeast counts: Mold and yeast populations in the beverage samples were evaluated applying the spread plate method, following the procedure outlined by Beuchat (1992). A 1 mL aliquot of each sample was aseptically spread on Sabouraud Dextrose Agar (SDA) for mold enumeration, and on Potato Dextrose Agar (PDA) for yeast enumeration. Plates were incubated at 25 °C to 30 °C for a period of 5 to 7 days. After incubation, colonies were examined, differentiated by morphology, and counted. The results were expressed as colony-forming units per milliliter (CFU/mL). All analyses were conducted in triplicate to ensure reproducibility and statistical accuracy (Berhanu et al., 2020).

Results and discussion

Sugars serve as the primary energy source for all living organisms. However, humans have taken sugar consumption a step further, adding it to foods and beverages that would typically contain little to no sugar. This has led to an increased intake of refined sugars, far beyond what the human body can effectively metabolize. Consequently, understanding the sugar content in commonly consumed food and beverage products is crucial for public health. Numerous investigations have demonstrated a correlation between excessive sugar consumption and various cardiometabolic health issues, containing obesity, diabetes, and heart disease (Ramasami et al., 2004; Idris et al., 2016; Khabiri et al., 2023; Gonzalez, 2024). In the current investigation, sugar content in soft drinks varied, with the highest value recorded at 19.99 g/100 mL in the SD2 sample, and the lowest at 14.22 g/100 mL in the SD15 sample (Table 1, Figure 2). In fruit juices, sugar content varied from 22 g/100 mL (FJ5, FJ6, FJ11) to 23.3 g/100 mL in FJ7 (Table 2, Figure 3). All soft drinks and fruit juices contained sugar, but the amounts varied across samples. Notably, the sugar content was higher in fruit juices compared to soft drinks. This could be attributed to the fact that soft drinks, like 7Up, need less sugar to achieve a satisfactory flavor compared to other beverages like cola. In contrast, fruit juices are naturally sweeter, and their

flavor is heavily dependent on their sugar content (Godwill et al., 2015). Based on the World Health Organization (2015), the daily intake of sugar should be limited to less than 10% of total energy consumption. Different recent investigations have linked excessive consumption of sugar-added beverages with the global rise in obesity and chronic diseases. Some research has also centralized on whether modifications in beverage formulations could alter consumer sugar intake (Jensen, 2024; Khabiri et al., 2025). The WHO further advises that over 90% of dietary carbohydrates should come from polysaccharides, with less than 10% derived from refined sugars, containing monosaccharides and disaccharides (Paik, 2008). The acidity of beverages plays a significant role in the leaching of elements from their containers. Leaching increases significantly at lower pH levels, often by a factor of 10 or more. In the current investigation, the pH of soft drinks varied from a high of 4.1 in SD14 to a low of 2 in SD2 (Table 1, Figure 4). In fruit juices, the pH varied from 5 in FJ3 to 2 in FJ1, FJ5, and FJ15 (Table 2, Figure 5). The highest carbon dioxide value was 4.3 g/100 mL in the SD4 sample, and the lowest was 3 g/100 mL in SD12, SD14, and SD15 samples (Table 1, Figure 6). Notably, no carbon dioxide was detected in the fruit juice samples (Table 2). Beverages generally have elevated acidity levels. For example, soft drinks often have a pH ranging from 2.32 to 5.24, with an average of about 3.12. Through the carbonation process, carbon dioxide dissolves in water, producing carbonic acid, which contributes to the elevated acidity of these beverages. Fruit juices also exhibit noticeable acidity, with pH values ranging from 2.25 to 4.69 and an average of approximately 3.48. This acidity is largely attributed to organic acids, like citric and malic acids, exist in fruits (Reddy et al., 2016). The acidity in commercially available drinks can pose a potential risk to dental health, as drinks with a pH below 4 may contribute to tooth enamel erosion (Chowdhury et al., 2019). The addition of acids to beverages not only enhances their distinctive flavor but also counteracts the sweetness of sugar, creating a more balanced taste profile. The combination of acid and sugar is essential for the flavor of many popular drinks. Dark beverages, like cola, often contain phosphoric acid, which imparts a sharp, tangy taste. Additionally, phosphoric acid acts as a preservative, preventing microbial growth and extending the shelf life of these beverages (Reddy et al., 2016).

Citric acid (E330), a naturally occurring organic acid found in citrus fruits, is commonly added to beverages to enhance their tartness and prolong shelf life. It imparts a sharp, refreshing flavor and serves as an effective preservative. Regulatory agencies like the FDA and EFSA classify citric acid as generally distinguished as safe (GRAS) for apply in foods and beverages (Singh et al., 2022). It is also considered the additive of choice for regulating acidity (pH) in food products due to its buffering capacity and natural origin (Steen & Ashurst, 2006). In this investigation, the citric acid content in soft drink samples varied from 1.04 g/L in SD2 (the lowest)

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to 3.25 g/L in SD11 (the highest), as shown in Table 1 and Figure 7. For fruit juice samples, citric acid levels were slightly broader in range, with a minimum of 0.99 g/L in FJ1 and a maximum of 5.11 g/L in FJ7 (Table 2, Figure 8). These findings align well with the permissible limits set by the Prevention of Food Adulteration (II Amendment), 2005, which prepare regulatory guidelines for acceptable acid content in consumable beverages. Therefore, all analyzed samples were within safe limits for human consumption.

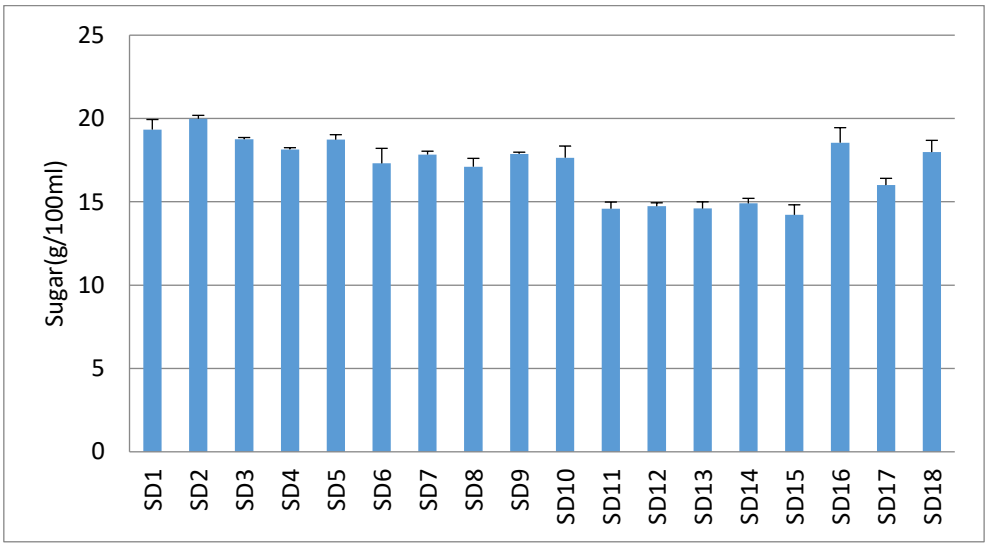

Figure 2. Sugar content values in the studied soft drinks, measured in g/100 mL. The range of sugar content varies across different brands and types of soft drinks, with SD2 containing the highest amount of sugar (19.99 g/100 mL) and SD15 the lowest (14.22 g/100 mL)

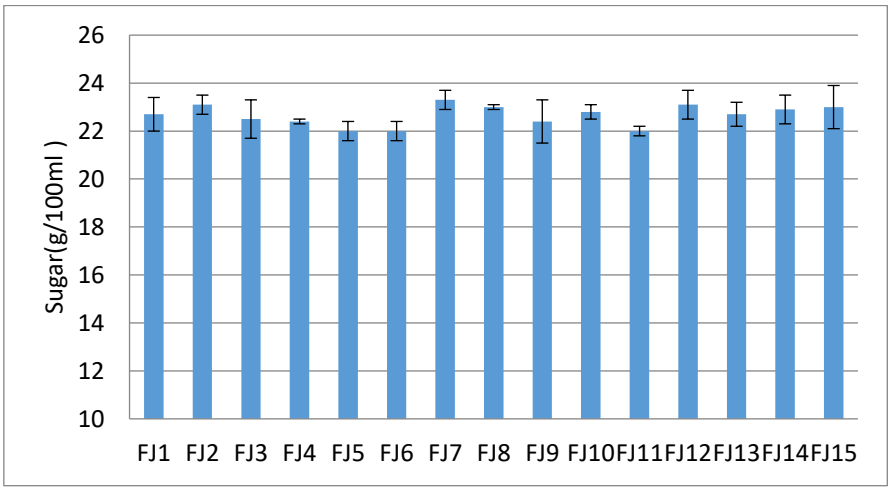

Figure 3. Sugar content values in the studied fruit juices, measured in g/100 mL. The sugar content in fruit juices ranges from 22 g/100 mL (FJ5, FJ6, FJ11) to 23.3 g/100 mL (FJ7), reflecting the natural sugar content of the fruit juice samples

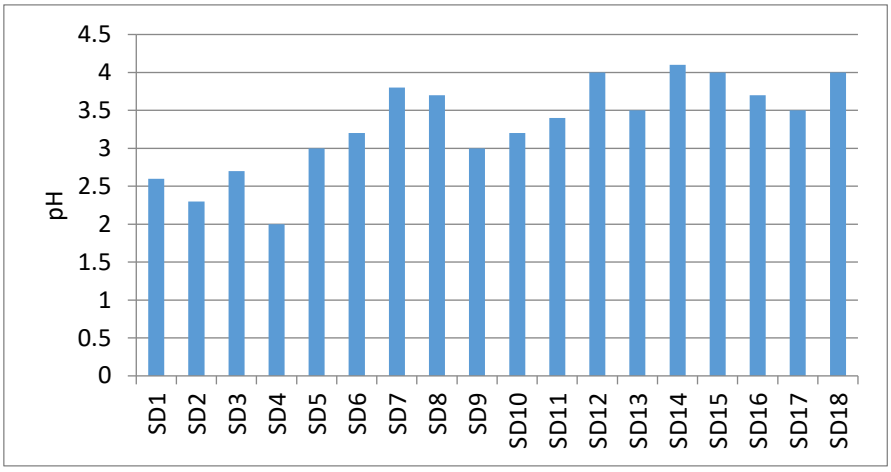

Figure 4. pH values in the studied soft drinks. The pH of soft drinks varies between 2 (SD2) and 4.1 (SD14), indicating the range of acidity levels found across different brands of carbonated beverages

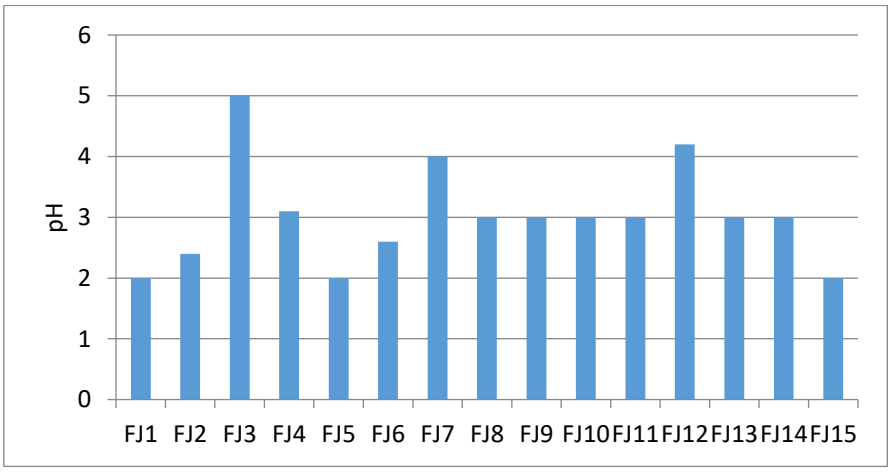

Figure 5. pH values in the studied fruit juices. The pH values in fruit juices range from 2 (FJ1, FJ5, FJ15) to 5 (FJ3), highlighting the variability in acidity among fruit-based beverages

In the current investigation, the citric acid content in soft drink samples varied from 1.04 g/L in SD2 (the lowest) to 3.25 g/L in SD11 (the highest), as shown in Table 1 and Figure 7. For fruit juice samples, citric acid levels were slightly broader in range, with a minimum of 0.99 g/L in FJ1 and a maximum of 5.11 g/L in FJ7 (Table 2, Figure 8). These findings align well with the permissible limits set by the Prevention of Food Adulteration (II Amendment), 2005, which prepare regulatory guidelines for acceptable acid content in consumable beverages. Therefore, all analyzed samples were within safe limits for human consumption. These results are consistent

with previous investigations evaluating citric acid concentrations in commercial beverages available in markets across the USA and Saudi Arabia, which announced similar acid levels (Brima & Abbas, 2014; Penniston et al., 2008). Citric acid not only contributes to flavor and preservation but also plays a role in chelating metal ions, thereby preventing oxidative spoilage and extending the product's shelf life.

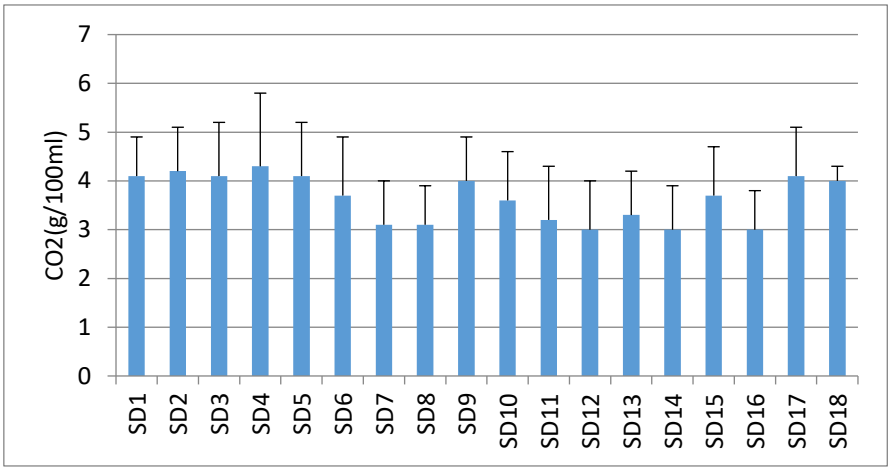

Figure 6. CO2 content in the studied soft drinks, measured in g/100 mL. The CO2 content varies across the soft drink samples, with SD4 containing the highest level (4.3 g/100 mL) and others, like SD12, SD14, and SD15, containing lower levels (3 g/100 mL)

Despite its widespread apply, the consumption of acidic beverages like soft drinks has sparked concerns regarding gastrointestinal and dental health. However, current literature prepares no conclusive evidence directly linking soft drink consumption to gastroesophageal reflux disease (GERD). Likewise, investigations on salivary pH and its correlation with soft drink intake suggest that the relationship between frequent consumption of carbonated beverages and the incidence of dental caries remains inconclusive, especially among children (Johnson et al., 2010; Gamal & Hamdy, 2024). Further research is needed to fully elucidate these associations. Phosphorus is an essential element for numerous biological functions. It plays a pivotal role in the structural makeup of nucleic acids (DNA and RNA), cellular membranes (as phospholipids), and energy transfer (as part of ATP). Additionally, it is crucial for healthy teeth and bone formation (EFSA, 2008). In the food and beverage industry, phosphorus—particularly in the form of phosphoric acid—is commonly added to enhance the acidity and flavor profile of cola-type soft drinks. Consistent with findings from previous investigations, the current investigation identified phosphoric acid solely in Coca-Cola and Pepsi samples, as well as in select grape and pomegranate juices. While this additive contributes to the characteristic tangy taste of colas, its apply remains controversial. High levels of dietary phosphorus have been associated with adverse

health outcomes. Excess phosphorus in the bloodstream can impair kidney function, reduce calcium levels, and increase the risk of osteopenia and osteoporosis. Furthermore, hyperphosphatemia may promote vascular calcification and elevate the risk of cardiovascular disease (Martin & González, 2011; Calvo & Tucker, 2013; Calvo & Uribarri, 2013).

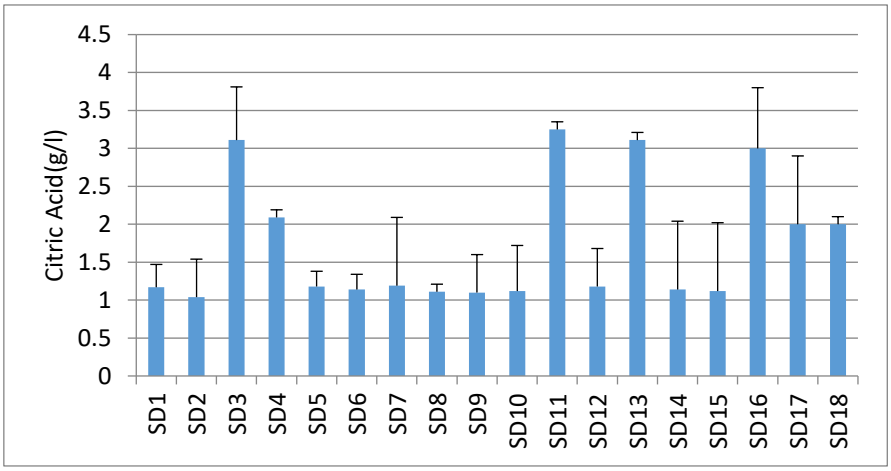

Figure 7. Citric acid concentrations (g/L) in the analyzed soft drink samples

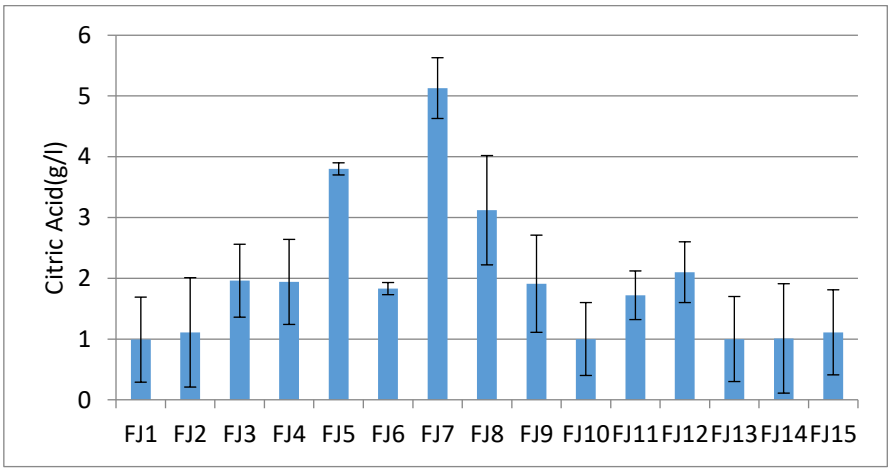

Figure 8. Citric acid concentrations (g/L) in the analyzed fruit juice samples

The European Food Safety Authority (EFSA) has determined that a daily intake of up to 3000 mg of phosphorus is safe for healthy individuals. However, some people may experience mild gastrointestinal symptoms at supplemental intakes exceeding 750 mg/day (EFSA, 2013). National food safety legislation, containing that of the FAO, recommends that the phosphate content in beverages should not exceed 700 mg/L. Since 2009, phosphorus and its derivatives have been permitted in food production within the European Union and are currently under reassessment in the context of food additive safety (EFSA, 2013). Another potential safety

concern in beverage production is the formation of alcohol. Inadequate sterilization or poor hygiene through manufacturing can permit microbial contamination, which may lead to fermentation of sugars and the production of ethanol (Juvonen et al., 2011). However, in the current investigation, no alcohol was detected in any of the soft drink or fruit juice samples. This aligns with other reports indicating that while trace amounts of ethanol may occasionally be exist, the levels are generally negligible and not sufficient to create intoxication (Juvonen et al., 2011).

Table 1. Selected physical and chemical parameters in the analyzed soft drink samples (mean ± S.D.)

Sample	Sugar (g/100 mL)	pH	CO_2 (g/100 mL)	Citric Acid (g/L)	Phosphate	Alcohol
SD1	19.34 ± 0.01	2.6	4.1 ± 0.8	1.17 ± 0.3	+	–
SD2	19.99 ± 0.20	2.3	4.2 ± 0.9	1.04 ± 0.5	+	–
SD3	18.76 ± 0.10	2.7	4.1 ± 1.1	3.11 ± 0.7	+	–
SD4	18.15 ± 0.10	2.0	4.3 ± 1.5	2.09 ± 0.1	–	–
SD5	18.73 ± 0.30	3.0	4.1 ± 1.1	1.18 ± 0.2	+	–
SD6	17.31 ± 0.90	3.2	3.7 ± 1.2	1.14 ± 0.2	–	–
SD7	17.84 ± 0.20	3.8	3.1 ± 0.9	1.19 ± 0.9	–	–
SD8	17.11 ± 0.50	3.7	3.1 ± 0.8	1.11 ± 0.1	–	–
SD9	17.88 ± 0.10	3.0	4.0 ± 0.9	1.10 ± 0.5	+	–
SD10	17.65 ± 0.70	3.2	3.6 ± 1.0	1.12 ± 0.6	+	–
SD11	14.59 ± 0.40	3.4	3.2 ± 1.1	3.25 ± 0.1	+	–
SD12	14.74 ± 0.20	4.0	3.0 ± 1.0	2.18 ± 0.5	+	–
SD13	14.60 ± 0.40	3.5	3.3 ± 0.9	3.11 ± 0.1	+	–
SD14	14.91 ± 0.30	4.1	3.0 ± 0.9	1.14 ± 0.9	+	–
SD15	14.22 ± 0.60	4.0	3.7 ± 1.0	1.12 ± 0.9	+	–
SD16	18.55 ± 0.90	3.7	3.0 ± 0.8	3.00 ± 0.8	–	–
SD17	16.01 ± 0.40	3.5	4.1 ± 1.0	2.00 ± 0.9	–	–
SD18	17.99 ± 0.70	4.0	4.0 ± 0.3	2.00 ± 0.1	+	–

Note: "+" indicates presence; "–" indicates absence.

Table 2. Selected physical and chemical parameters in the analyzed fruit juice samples (mean ± S.D.)

Sample	Sugar (g/100 mL)	pH	CO_2 (g/100 mL)	Citric Acid (g/L)	Phosphate	Alcohol
FJ1	22.70 ± 0.70	2.0	0	0.99 ± 0.3	–	–
FJ2	23.10 ± 0.40	2.4	0	1.11 ± 0.9	+	–
FJ3	22.50 ± 0.80	5.0	0	1.96 ± 0.6	–	–
FJ4	22.40 ± 0.10	3.1	0	1.94 ± 0.7	–	–
FJ5	22.00 ± 0.40	2.0	0	3.80 ± 0.1	+	–
FJ6	22.00 ± 0.40	2.6	0	1.83 ± 0.1	+	–
FJ7	23.30 ± 0.40	4.0	0	5.11 ± 0.9	+	–
FJ8	23.00 ± 0.10	3.0	0	3.10 ± 0.9	+	–
FJ9	22.40 ± 0.90	3.0	0	1.91 ± 0.8	+	–
FJ10	22.80 ± 0.30	3.0	0	1.00 ± 0.6	–	–
FJ11	22.00 ± 0.20	3.0	0	1.72 ± 0.4	+	–
FJ12	23.10 ± 0.60	4.2	0	2.10 ± 0.5	+	–
FJ13	22.70 ± 0.50	3.0	0	1.00 ± 0.7	–	–
FJ14	22.90 ± 0.60	3.0	0	1.01 ± 0.9	+	–
FJ15	23.00 ± 0.90	2.0	0	1.11 ± 0.9	–	–

Note: "+" indicates presence; "–" indicates absence.

Microbial spoilage remains one of the key challenges in beverage quality control. Contamination can occur at any stage of production—from the raw materials (e.g., water, sugar, fruits) to packaging and storage. If not properly managed, this can lead to bacterial, yeast, or mold growth that compromises safety and shelf-life (Koc et al., 2007; Rahman et al., 2011). In the current investigation, bacterial growth was absent in the majority of soft drink samples, with exceptions observed in SD2, SD4, SD5, SD6, SD9, SD12, and SD18 (Table 3, Figure 9). In fruit juices, total bacterial counts varied from no growth in FJ3, FJ4, FJ8, FJ9, and FJ14 to a maximum of 3 CFU/100 mL in FJ5 (Table 3, Figure 10). Yeast growth was detected only in SD4 and SD10 among soft drinks, and mold growth was limited to SD1, SD7, and SD12 (Table 3, Figure 11). Among the fruit juice samples, yeast was detected in FJ8 and FJ14, while mold was found in FJ3, FJ12, and FJ15 (Table 3, Figure 12). The sugar-rich environment of soft drinks and juices prepares a favorable medium for fungal proliferation, particularly yeasts and molds, if sanitary standards

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are not strictly maintained (Palou et al., 1998; Helal et al., 2024). Furthermore, the organic content and acidity of fruit-based beverages offer nutrients that can support microbial growth unless adequate pasteurization and preservation techniques are applied. Overall, the investigation highlights the importance of stringent quality control throughout beverage production to ensure microbiological safety and compliance with public health standards.

Table 3. Microbial indicators in studied soft drink and fruit juice samples (expressed as CFU/mL)

Soft Drinks	Total Bacteria (CFU/mL)	Yeast (CFU/mL)	Molds (CFU/mL)	Fruit Juices	Total Bacteria (CFU/mL)	Yeast (CFU/mL)	Molds (CFU/mL)
SD1	0	0	1	FJ1	1	0	0
SD2	2	0	0	FJ2	1	0	0
SD3	0	0	0	FJ3	0	0	1
SD4	3	1	0	FJ4	0	0	0
SD5	1	0	0	FJ5	3	0	0
SD6	2	0	0	FJ6	2	0	0
SD7	0	0	1	FJ7	1	0	0
SD8	0	0	0	FJ8	0	1	0
SD9	2	0	0	FJ9	0	0	0
SD10	0	1	0	FJ10	2	0	0
SD11	0	0	0	FJ11	2	0	0
SD12	1	0	1	FJ12	2	0	1
SD13	0	0	0	FJ13	1	0	0
SD14	0	0	0	FJ14	0	1	0
SD15	0	0	0	FJ15	1	0	1
SD16	0	0	0	–	–	–	–
SD17	0	0	0	–	–	–	–
SD18	1	0	0	–	–	–	–

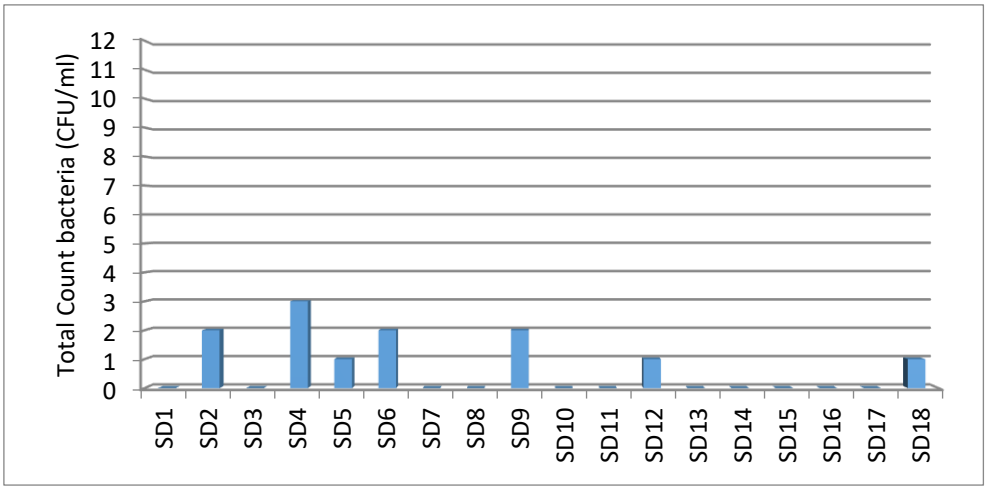

Figure 9. Total bacterial count (CFU/mL) in studied soft drink samples.

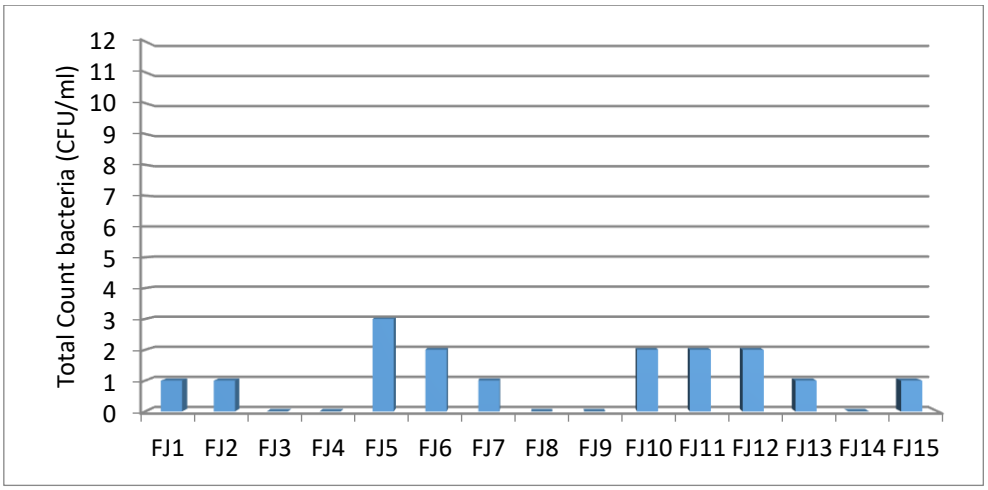

Figure 10. Total bacterial count (CFU/mL) in studied fruit juice samples

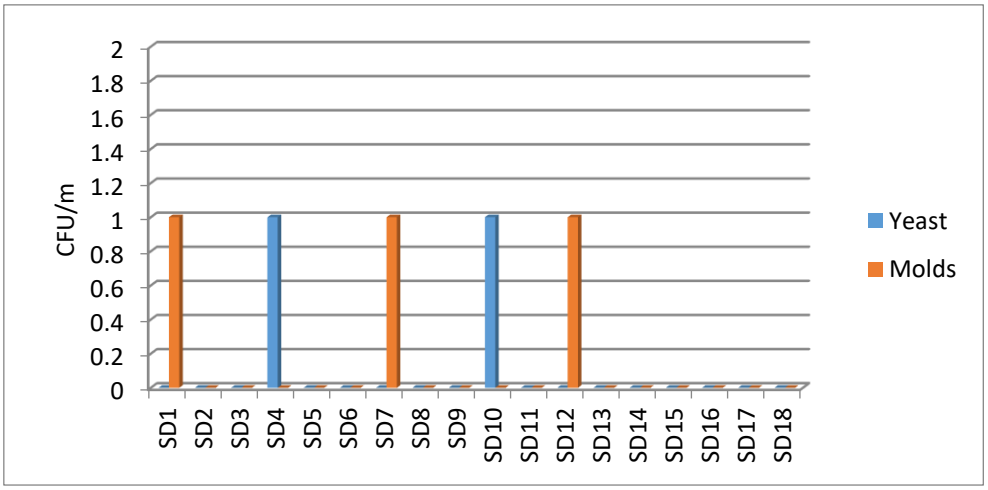

Figure 11. Yeast and mold counts (CFU/mL) in soft drink samples

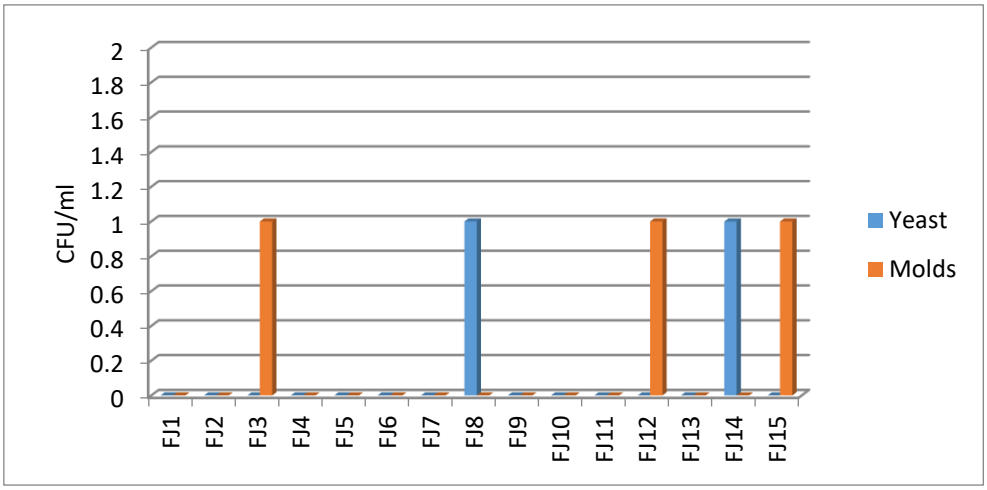

Figure 12. Yeast and mold counts (CFU/mL) in fruit juice samples

Conclusions: The findings of this investigation demonstrate that the majority of soft drink and fruit juice samples available in the Babylon Province markets comply with established safety and quality standards. Most products exhibited acceptable concentrations of sugar, pH, citric acid, and carbon dioxide, aligning with national and international guidelines. Microbial evaluating revealed minimal contamination, with only a few isolated cases of bacterial, yeast, or mold presence—none of which posed a substantial public health risk. These results indicate that the beverages analyzed are generally safe for consumer consumption. Nevertheless, ongoing surveillance, stringent quality control, and good manufacturing practices are essential to uphold beverage safety and prevent potential risks associated with contamination or non-compliance with regulatory thresholds.

Author contributions

Hala Al-Jewahery conceptualized the investigation, oversaw the project, and was primarily responsible for data organization and manuscript preparation. Wameedh Al-Yasari conducted the majority of the experimental work and data analysis, and contributed to drafting and revising the manuscript. Both authors reviewed and approved the final version of the manuscript and prepared valuable input throughout the research process.

Data availability statement

The datasets generated and/or analyzed through the current investigation are available from the corresponding author upon reasonable request.

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Ethical considerations

All sample handling and storage procedures were conducted in accordance with standard hygienic practices and institutional guidelines to ensure the integrity and reliability of the results. No human or animal subjects were involved in this investigation.

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Conflict of interest statement

The authors declare that there are no conflicts of interest related to the publication of this manuscript.

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کیفیت بوم‌شناختی و میکروبیولوژیکی برخی نوشابه‌ها و آب‌میوه‌ها در بازارهای عراق

وَمیض الیاسری

گروه زیست‌شناسی، دانشکده علوم، دانشگاه بابل، عراق. ایمیل: wameedadil_83@yahoo.com

هاله الجواهری

*نویسنده مسئول: گروه زیست‌شناسی، دانشکده علوم، دانشگاه بابل، عراق. ایمیل: sci.hala.ali@uobabylon.edu.iq

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چکیده

هدف: نوشابه‌ها و آب‌میوه‌ها از پرمصرف‌ترین نوشیدنی‌ها در سطح جهان محسوب می‌شوند و در عراق نیز جزو اجزای اصلی رژیم غذایی بسیاری از خانوارها هستند. با وجود محبوبیت بالای آن‌ها، نگرانی‌هایی درباره ترکیب تغذیه‌ای و احتمال آلودگی میکروبی این نوشیدنی‌ها وجود دارد، که در صورت نبود نظارت مناسب، ممکن است سلامت عمومی را به خطر بیندازند. هدف این مطالعه، ارزیابی کیفیت بوم‌شناختی، فیزیکوشیمیایی و میکروبیولوژیکی تعدادی از نوشابه‌ها و آب‌میوه‌های موجود در بازارهای استان بابل عراق است.

مواد و روش‌ها: نمونه‌هایی از نوشابه‌ها و آب‌میوه‌های بسته‌بندی‌شده از بازارهای مختلف در تمام نواحی استان بابل جمع‌آوری شدند. این نمونه‌ها از نظر پارامترهای فیزیکی و شیمیایی از جمله میزان قند، pH، دی‌اکسید کربن (CO_2) و غلظت اسید سیتریک مورد بررسی قرار گرفتند. همچنین، آزمایش‌های میکروبیولوژیکی برای شناسایی حضور باکتری‌ها، کپک‌ها و مخمرها انجام شد.

نتایج: میزان قند در نوشابه‌ها بین ۱۴/۲۲ تا ۱۹/۹۹ گرم در ۱۰۰ میلی‌لیتر (به ترتیب در نمونه‌های SD15 وSD2) و در آب‌میوه‌ها تا ۲۳/۳ گرم در ۱۰۰ میلی‌لیتر (FJ7) و ۲۲ گرم در ۱۰۰ میلی‌لیتر در نمونه‌هایFJ5 ، FJ6 و FJ11 گزارش شد. دی‌اکسید کربن تنها در نوشابه‌ها یافت شد و حداکثر میزان آن ۴/۳ گرم در ۱۰۰ میلی‌لیتر در نمونه SD4 بود، در حالی که در هیچ‌یک از نمونه‌های آب‌میوه مشاهده نشد. مقدار pH در نوشابه‌ها بین ۲ (SD2) تا ۴/۱ (SD14) و در آب‌میوه‌ها بین ۲ (FJ1، FJ5 و FJ15) (FJ3) متغیر بود. غلظت اسید سیتریک در نوشابه‌ها از ۱/۰۴ گرم در لیتر (SD2) تا ۳/۲۵ گرم در لیتر (SD11) و در آب‌میوه‌ها از ۰/۹۹ گرم در لیتر (FJ1) تا ۵/۱۱ گرم در لیتر (FJ7) بود. اسید فسفریک تنها در نمونه‌های کوکاکولا، پپسی، آب انگور و آب انار یافت شد و هیچ‌گونه الکلی در هیچ‌یک از نوشیدنی‌ها شناسایی نشد. رشد باکتریایی در اکثر نمونه‌های نوشابه مشاهده نشد، به‌جز در نمونه‌های SD2، SD4، SD5، SD6، SD9، SD12 وSD18. در آب‌میوه‌ها، شمارش باکتری‌ها از عدم رشد در نمونه‌هایFJ3 ،

FJ4، FJ8، FJ9 و FJ14 تا ۳ کلنی در ۱۰۰ میلی‌لیتر در FJ5 متغیر بود. رشد مخمر تنها در SD4، SD10، FJ8 و FJ14 مشاهده شد و کپک‌ها درSD1، SD7، SD12، FJ3، FJ12 و FJ15 یافت شدند.

نتیجه‌گیری: اکثر نوشابه‌ها و آب‌میوه‌های مورد بررسی با استانداردهای ایمنی و کیفیت عمومی مطابقت داشتند و آلودگی میکروبی محدودی نشان دادند و ویژگی‌های فیزیکوشیمیایی قابل قبولی داشتند. با این حال، نظارت‌های دوره‌ای و کنترل کیفیت سخت‌گیرانه همچنان برای حفظ ایمنی این نوشیدنی‌های پرمصرف ضروری است.

کلمات کلیدی: آب‌میوه، آلودگی میکروبی، عراق، کیفیت نوشیدنی، نوشابه‌ها

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