QUALITY CHARACTERISTICS AND CONSUMER EXPOSURE TO SULPHUR DIOXIDE FROM FRUIT-BASED NONALCOHOLIC BEVERAGES COMMERCIALLY TRADED IN NAIROBI

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DEPARTMENT OF FOOD SCIENCE NUTRITION AND TECHNOLOGY
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I NAOMI MARIACH declare that this Dissertation is my original work and has not been submitted for a degree award in any other University.

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DEDICATION

This Dissertation is dedicated to my Loving husband, Nick Rutto and my children Daniel Twalan, Victoria Relin, David Kalya and Vianna for their Prayers, encouragement and support throughout my study.

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ABBREVIATIONS AND ACRONYMS

ADI	Acceptable Daily Intake
AOAC	Association of Official Analytical Chemists
CODEX	Codex Alimentarius Commission
CXS	Codex Standard
bw	Body weight
FAO	Food and Agriculture Organization
FSANZ	Food Standards Australia New Zealand
FDA	Food and Drug Administration
INS No.	International Numbering System for Food Additives
JECFA	Joint FAO/WHO Expert Committee on Food Additives
KNBS	Kenya National Bureau of statistics
KS	Kenya Standard
LOD	Limit of Detection
g/l	grams per litre
Mg/kg	milligrams per kilogram
MPL	Maximum permitted level
SO_2	Sulphur dioxide
TSS	Total soluble solids
WHO	World Health Organization

GENERAL ABSTRACT

A diversity of fruit based non- alcoholic beverages, locally produced, and imported are sold and consumed in Kenya. The choice preservative for these beverages is Sulphur dioxide, making it one of the potential causes of exposure to Sulphur dioxide (SO_2). Therefore, the aim of this study was to establish the presence of Sulphur dioxide residues in the fruit-based non-alcoholic beverages that are widely consumed in Nairobi, Kenya with a view to determining the level of exposure of the chemical to the Kenyan consumer. A Total of 384 fruit based beverage samples were sampled and collected from the major supermarket chains in Nairobi, Kenya using a self-structured guide, followed by analysis for Sulphur dioxide residues, pH and total soluble solids (°Brix) content using Tanner titration, potentiometric and refractrometric method, respectively. The dietary exposure of Sulphur dioxide to the Kenyan consumer was determined using a deterministic method. Sulphur dioxide exposure was then compared to the respective acceptable daily intake (ADI).

Results showed that most of the beverages had SO_2 residual levels, pH and total soluble solids content that were within the specifications set in the Kenya Standards.

The SO_2 residue levels in ready- to- drink fruit drinks, fruit juices, fruit nectars; and the dilutable fruit drinks were 1.25±2.58, 0.56±1.71, 0.49±1.47 and 21.52±13.85 mg/kg respectively, compared to the tolerated level of 10 mg/kg maximum. Only 13.1% fruit juices, 12% of fruit nectars and 22.5% of fruit drinks contained Sulphur dioxide residues, which were all within the acceptable level. However, of the 86.3% of dilutable fruit drinks contained Sulphur dioxide residues, of which 71.3% had Sulphur dioxide residues above the acceptable limit. Therefore, the main source of SO_2 exposure comes from the dilutable fruit drinks.

Daily intakes of SO_2 from consumption of fruit-based beverages were 0.032, 0.21, and 0.20 mg/kg body bw/day in preschool children aged 3-6, 7-18 years group and adults respectively, which were all below the 0.7 mg/kg b/t/day ADI set by JECFA; while risk of Sulphite exposure was 5 %, 3 % and 3 % of the ADI for preschool children, children aged 7 to 18 and adults aged 19 years and above, respectively. In conclusion, exposures from consumption of fruit- based beverages were within the relevant Acceptable Daily Intake (ADI) for all population groups including the high-end consumers. However, frequent overindulgence on dilutable drinks, even in low at low levels can pose a health risk to SO2-sensitive individuals, hence should be aware of the risks associated with high levels of residual SO2.

CHAPTER ONE: INTRODUCTION

1.1 Background Information

Sulphur dioxide (SO_2) is widely used as a preservative and antioxidant in the food and beverage industry worldwide (Cressey & Jones, 2009). It functions to control microorganisms especially in acidic ready to drink fruit beverages, in sun-drying of fruits, and also to prevent enzymic and non-enzymic discoloration of food during processing (Vandevijvere *et al.*, 2010). Sulphur dioxide is used as gas, obtained by burning Sulphur (Roberts & McWeeny, 2007). When Sulphur dioxide dissolves in water, it produces a weak acid, sulphurous acid which is favoured by the presence of an acid medium, and is the agent for preservation against microorganisms.

The acid under the circumstances dissociates into a bisulphite ion which is the agent that prevents discoloration of food (Ough & Were, 2005). Sulphur dioxide is also added to foods in form of soluble salts of sodium or potassium which produce Sulphur dioxide in solution. The salts include bisulphites, metabisulphites and sulphates. These salts are most active with aldehydes, ketones, reducing sugars and vitamins (Leclercq *et al.*, 2009). Sulphur dioxide may be regarded as free or bound to food based on pH action. However, Sulphites are also naturally occurring in small amounts in foods, especially fermented beverage and foods that are available in human body, and are generated by other microorganisms (Ough & Were, 2005).

Although there are advantages of using Sulphur dioxide in beverage and food products, its exposure has been associated with allergic reactions that induces attack in individuals with asthma. Foods containing Sulphur dioxide are also not recommendable to persons with kidney problems (FSANZ, 2005), especially in beverages, where there is addition of high levels. For these reasons, Sulphur dioxide is used as a controlled food additive, limiting the highest level of use in ready to eat foods and mandatory requirement for declaration on the label.

A variety of fruit-based beverages, locally produced or imported are sold and consumed in Kenya. They can be categorized in various ways, for instance, based on their sugar and fruit juice content, key dry ingredients, flavorings, carbonation level, and function (Kriegel, 2015). These beverages include fruit juices, nectars, and dilutable (cordials, squashes/crushes and ready-to-drink beverages) with fruit juice. The choice preservative for these beverages is Sulphur dioxide, which may be in combination with benzoic acid. However, the use of this preservative is rarely declared on the label and when done, the levels are never indicated. The national tolerance for use of Sulphur dioxide as preservative in these beverages is 10 mg/kg (CAP 254, 2012). With the fraudulent use of food additives especially by Kenyan manufacturers, it is possible that more than the allowed levels are used, mainly to disguise the inferior process.

It is for the foregoing reasons that this project was designed to establish the presence and levels of Sulphur dioxide residues in the fruit-based non-alcoholic beverages consumed in Kenya with a view to determining the level of exposure of the chemical to the Kenyan consumer.

1.2. Statement of the problem

Sulphur dioxide is a choice preservative for fruit based beverages all over the World. However, because of the risk involved in its ingestion, it is used under control with regard to the residual levels in the fruit based non-alcoholic beverages.

In Kenya and particularly judging from the reports of its misuse in other products (Gitonga, 2019), it is possible that some beverage manufacturers use more than the allowed levels and some of them may not even declare it at all as required. Therefore, it is difficult to estimate consumer exposure to the chemical, more so to those persons who could elicit allergic responses. Little is known about the dangers associated with excessive use of SO_2 as a preservative in mostly consumed fruit based beverages, since the information on exposure to SO_2 by Kenyan consumers is limited or lacking.

Kenya has no data on Sulphur dioxide in foods and beverages, making it difficult to measure exposure levels, even when vulnerable populations such as children consume significant levels..

1.3. Justification of the study

This study assessed Sulphur dioxide use concern specific in Kenya. As a result of obtaining high levels of SO_2, solutions may be suggested to address these issues. The generated data will be used to measure exposure to SO_2 intake and linked risks. This data could also assist policy makers in the formulation and enforcement of policies on the prudent use of Sulphur dioxide as preservative in these beverages. From this study consumer will be enlightened and be able to make informed decisions and if need, avoid some food additives, when deciding on consumption of fruit based non-alcoholic beverages.

1.4. Aim of the study

This work aims to contribute to the quality and safety of fruit based non-alcoholic beverages for consumers in Kenya.

1.5. Purpose of the study

This study provides data on the SO_2 content and consumer exposure in commercially traded fruit based non-alcoholic beverages in Nairobi, Kenya.

1.6. Objectives

1.6.1. General Objective

To assess quality characteristics and consumer exposure to Sulphur dioxide from commercially traded fruit-based nonalcoholic beverages in Nairobi.

1.6.2. Specific Objectives

i. To determine diversity and quality characteristics of the non-alcoholic fruit-based beverages sold in the major supermarkets in Nairobi, Kenya

ii. To determine the Sulphur dioxide dietary exposure to consumers of different population groups of fruit-based non-alcoholic beverages sold in Nairobi, Kenya.

1.7. Research Questions

i. What is the diversity and characteristics of the non-alcoholic fruit-based beverages sold in the major supermarkets in Nairobi, Kenya?

ii. What is the dietary exposure to Sulphur dioxide by the consumers of different population groups of fruit-based non-alcoholic beverages sold in Nairobi, Kenya?

CHAPTER TWO: LITERATURE REVIEW

2.1 Background information

2.1.1 Sulphur dioxide (SO_2)

Sulphur dioxide consists of one Sulphur atom linked to two oxygen atoms and is represented by the formula SO_2. It is a Colourless, heavy, nonflammable gas, with a strong suffocating odour. It is usually distributed in pressurized containers available in liquid and gaseous form (JECFA, 2006).

2.1.2 Information on occurrence of Sulphur dioxide in Food and beverages

The first case of anaphylaxis from ingestion of sodium metabisulphite in a restaurant salad was reported in 1976, and SO_2 in orange drinks caused asthma the following year. Severe reactions after sulfite ingestion by affected individuals were also reported in the 1980s (Vally & Misso, 2012).

In 1996 to 1999, FDA evaluated 59 food recalls of various food products on undisclosed sulphites and reported cases of suspected reactions because of consuming foods having undisclosed sulfites, which led to 13 deaths, particularly in people with asthma (Vally *et al.*, 2009). Thus, from 1986, United States, European Union and several other countries around the world require the labeling of beverage and food or their ingredients products having any Sulphur dioxide levels above 10 ppm (Vally & Misso, 2012).

Arushi Jain and Pulkit Mathur (2016) estimated the sulphite content of foods available in Delhi, India. In this study foodssuch as fruit bars, fruit digestives, jams, raw sugar, refined sugar, dessert toppings, and ready- to- drink fruit juices and beverages, and syrup sugars were added at levels higher than those permitted in the national or international laws.

In a study carried out in 2008 and 2012, in Australia, foods and beverages were analyzed for sulphites, and its exposure to the Australian people determined (FSANZ, 2005). Dietary exposure tests suggested that certain groups of people exceeded the appropriate SO_2 reference health level (Leclercq *et al.*, 2009). The determined dietary exposures was significantly higher in young ones because of higher consumption of food for a kilogram of body weight, hence higher exposure. Comparable findings were outlined by another study (Machado & Toledo, 2008); and while determining the levels of sulphite in fruit juice found in the Brazilian market.

2.2. Sulphur dioxide in food production

Sulphur dioxide is widely used in the production of various food and beverage products (Silva and Lidon, 2016; Stražanac *et al.*, 2019). Sulphur dioxide has a number of functions such as inhibiting the enzymatic oxidation of polyphenols, preventing Maillard reactions and leakage of mineral ions from organic acids. It inhibits browning at certain stages of processing such as evaporation and crystallization. When producing fruit juices, the obtained fruit juice preserved with Sulphur dioxide and citric acid until it crystalizes (Lou et al., 2017; Machado et al., 2009).

Fruit purees and fruit juice concentrates can be stored in sealed containers by adding Sulphur dioxide (SO_2), as per the GMP. The concentrates may be kept for some months (FAO, 1995). Although the SO_2 taken in in the course of storage can be removed through drying, it is suggested that the puree should be boiled first, then dried in order to bring down the levels of remaining residues of SO_2 (Roberts & McWeeny, 2007).

Sulphites are also naturallypresent in small amounts in other foods and beverages as a result of fermentation (Taylor et al., 1986). It also act as bleaching agent, antioxidant, or reducing agent. It perform a variety of other technical functions (Sapers, 1993). Sulphur dioxide (SO2) or its salt is also used as antioxidant, preservative and performs other roles in cereal products, processed meats, fruit based beverages, dried vegetables and fruits, snacks and wine (Sapers, 1993 and Taylor et al., 1986); with aim of inhibiting microbial growth and preventing polyphenol oxidase catalysing browning of food products (Wedzicha et al., 1991).

Sulphiting agents can go through various actions in food and beverage products, releasing a variety of compounds such as bisulfite, metabisulphite and other sulphite compounds that are binding or may be converted to food or beverage components based on the beverage or food pH (Wedzicha, 1992) However, free and total sulphites are of interest to the food and beverage industry.

There are two main ways to add Sulfur dioxide to food; sulphuring and sulphiting methods, which are common for fruits and vegetables respectively. Sulphuring which uses Sulphur in form of a rock, is easily available than sodium or potassium metabisulphite. One drawback of sulphiting is that it moistens the fruit, when it is immersed in a metabisulphite solution, thereby increasing the time needed for drying (Madhavi *et al*., 1995). The levels of Sulphur used and its time of exposure is based on product type, humidity, and sizes of pieces and permissible levels of finished product. Sulphuring produces unpleasant fumes and can be harmful if inhaled, thus should always be conducted in properly ventilated areas (Madhavi *et al*., 1995).

2.3. Critical conditions in determining the fate of sulphites in food

The procedure used for applying sulphites, composition of food, time, processing, storage temperature and other conditions can affect the final amount of Sulphur dioxide in food (Madhavi et al., 1995). This information is important about the safety assessments of actual consumer exposure.

The sulphite amounts originally used to treat food do not show the levels of residues after processing. Loss mechanisms include SO_2 variability in acidic conditions, leaching, auto-oxidation, and irreversible reaction of nutrients (EFSA, 2016).

2.4. Sulphite reactions in food

Generally, the sulphites, if used in foods, undergoes various reactions with numerous constituents (Taylor et al., 1986) due to sulphite ion nucleophicility ($SO_3$2-) (Wedzicha & Kaputo, 1992).

2.4.1. Sulphite reactions with reducing sugars

Sulphites uniquely with aldehydes or ketones in various foods and beverage products to produce hydroxysulfonates (Jarvis and Lea 2022; Adachi et al., 1979).

The reaction level of sulphites and carbonyl group is quicker with hydroxysulfonates, being in control at pH of between 1 and 8, whereas at raised levels of PH of 10, hydroxysulfonates decomposes to bisulphite ion and compounds of carbonyl ((Hamzaoğlu et al., 2022; Adachi et al., 1979). In most foods and beverages sulfonated carbonyl compounds formed by the reaction of unsaturated carbonyls with sulphites are intermediates in Maillard reaction. Sulfonates are stable and its formation is irreversible (Wedzicha et. al., 1992).

2.4.2. Sulphite reactions to vitamins

Sulphur dioxide and sulphitres reacts widely with vitamins such as including vitamins B1, folic acid, vitamin B12 and vitamin K. (Taylor et al., 1986). The literature indicates that thiamine is fragile in the diet and sulfating agents are ineffective (Davidson 1992; Studdert &Labuc, 1991). SO2 and sulphites decreases vitamin B1 absorption (Davidson 1992; Studdert & Labuc 1991). Low uptake of vitamins can lead to various health problems. Sulphites may also destroy carotene, hence low uptake of vitamin A (Taylor et al., 1986). Sodium bisulfite added at to rice at some ratios during washing prior to cooking has shown major reduction in levels of thiamine. (Vanier et al., 2015).

2.4.3. Sulphites reaction with pigments

Sulphites and Sulphur dioxide may react with antioxidants such as anthocyanins and phenols found in wine, which are readily converted in acidic state to colourless bisulphite anthocyanin (Burroughs, 1975). Sulphites reduce the quinone produced by the catalysis of polyphenol oxidase to make it less efficient, and colorless, thus preventing the appearance of pigment (Tao et al., 2007).

2.4.4. Sulphites reaction with other specific foods

The levels of Sulphur dioxide and its salts varies across various foods and beverage products. Different contents of total and free Sulphur dioxide has been show in white wines, orange juice concentrates, corn starch and molasses at 2.3, 22.3, 34.4 and 14.8 percentages respectively (Mitsuhashi et al., 1979).

2.5. Absorption, Distribution, Metabolism of Sulfur Dioxide (SO_2)

Immediately it is absorbed, sulphhites can react in presence of water to release sulphites and its salts (Lester, 1995). Bisulphites and SO_2 are the ones that are found in the stomach (Takahama & Hirota, 2012). Normally this depends on the acidic condition inside the abdomen, but usually at neutral PH, the SO_2 that present are hydrogen sulphide and sulphites (EFSA, 2016). SO_2 dissolves easily in water sources, but may be taken up to lungs (Ough & Were, 2005). Part of the absorbed sulphites can go through a series of gastrointestinal microflora metabolism to develop hydrogen Sulphite (H2S) (Rey et al., 2013). Up to 97 % may be ingested in the intestines (JECFA, 1987). After absorption, sulphite is transformed to sulfate, mainly in the liver by sulphite oxidase (Gunnison, 1981). Sulfates are then discharged in urine (van den Born et al., 2022). The life span of sulphites in human body is about 15 mins, although elderly and victims with seizures can have lesser action of sulphites (JECFA, 1987). Furthermore, under heavy load, the development of sulfonates and proteins of sulfonates is possible (JECFA, 1987). Depending on chemical determinants of sulfites food additives, dominant ones are bisulfite ions and sulfites, which are usually in liquid state (EFSA, 2016).

2.6. Non - alcoholic Fruit based beverages

2.6.1. Fruit based- non-alcoholic beverages consumption

Fruit based beverages are among the most popular beverages consumed in the world. They are non-alcoholic fruit-based beverages that are either sweetened or acidulated; and may contain only approved additives (Codex, 1995). Fruit-based drinks are one of the most popular drinks in the world. They are non-alcoholic fruit juices that are sweet and acidic; and may contain only authorized additives (Codex, 1995).

Kenyan market is dominated by carbonated and synthetic drinks, but the rising number of health-conscious middle- and high-class consumers' population in Kenya is giving a boost to fruit based beverages (Euromonitor, 2019). It has been observed that consumers are switching from carbonated soft drinks to fruit-based drinks and juices which are considered a healthier alternative. This demand has led to both multinationals and local firms to shift their focus from water-based beverages to fruit juices, targeting on-trade channels as well as home-based consumption (Mwangi, 2014).

Fruits of varied types are used as raw materials in industries which process, package and supply the fruit juice for sale to the local market and for export (Mwangi, 2014). The common fruits which are being used for raw materials in the processing of juice include Mangoes, pineapples, bananas, oranges, Strawberry, Papaya, Lemons and many more fruits (Mwangi, 2014).

The fruit-based beverage category is one of the fastest growing categories in the Kenyan beverage market. According to Kenya Statistics Center KNBS (2016) data, this category has grown by more than 30 percent over the past decade and is expected to grow by 30% over the next three years. Fruit-based beverages available in Kenya, may be segregated into four subcategories of fruit beverages, juices and nectar beverages and dilutable drink. Fruit-beverages, with a fruit content of 10% or more are the most popular, with a market share of 50%. . Conversely, fruit juices with 100% juice currently have a 15% market share, while nectar drinks with 25-90% juice only have a 17% market share (Euromonitor, 2019).

The small packet size is preferred because it is simple, and_ easy to carry and use. They are especially needed as out-door consumption increase, especially among young children and in school (Euromonitor, 2019). As a result, there is a growing consumer base, as well as greater competition. Tetrapak is very popular among manufacturers and consumers. Some companies also supply their products with PET cans and bottles, but are costly compared to tetrapak. This increases manufacturing value, therefore, influencing market price (Euromonitor, 2019).

2.6.2 Process of making Fruit based beverages

All ingredients used in fruit based beverages must be clean, sound and wholesome in order to obtain a quality drink. Fruit juices or pulp used to prepare these products are subject to minor processing such as juice extraction, filtration, clarification, concentration, pasteurization, filling, sealing and sterilization, then cooling aseptically at around 30 ° C, labeled and packaged in containers such as cartons, cans, glass and plastic bottles of various shapes and sizes (Ashurst et al., 2009)

Fruit juice is added to ingredients such as sugar, acid, solvents, vitamins, minerals, carbon dioxide (optional) and preservatives to enhance the beverages. A maximum of 10 ppm of sulfur dioxide and benzoic acid are the allowed levels of these preservatives. (Sharma, 2017).

These products are then heated at 100 ° C for 30 minutes. The addition of organic acids is necessary to prevent the invasion of the microorganism and to prevent color variation. Heat treatment aims to inactive, pectinase by acting on pectin to reduce its viscosity and causing browning through phenolase action (Grumezescu & Holban, 2019). Therefore, it is necessary to separate the pulp of the resulting fruit from unacceptable materials to achieve a final product that can be fortified with active compounds and ingredients (Ottaway, 2009).

2.6.2.1 Fruit drink (ready- to- drink)

According to Kenyan standards, ready-to-drink fruit beverages must have at least 10% fruit juice/fruit puree, at least 10 soluble solids (^{O} Brix) and a pH of at least 2.5 in the final product (KEBS, 2019).Fruit drinks contain fruit juice, fruit pulp or other edible fruit components. It can be developed from one, mixed, or more fruits with or without the addition of carbon dioxide or other allowed food additives, or contain sugars or non-nutritive sweeteners (KEBS, 2019). Fruit drinks may contain a number of approved preservatives to achieve extra shelf life up on opening. Preservatives such as Sulphur dioxide, benzoic and sorbic have been mostly used in the fruit beverage industry (Ashurst et.al, 2009).

2.6.2.2 Fruit juice

Juice is a fermented but unfermented liquid found in the edible component, of a fresh, well-ripened fruit that is kept in appropriate ways including post-harvest treatment (Codex, 2005). The juice is developed from appropriate processes that preserves important physicochemical, organoleptic and nutritional properties of the fruit juice. Juices are developed through appropriate processes that retain the key physico-chemical, organoleptic, and nutritional properties of fruit juices. One type of fruit yields one juice. Mixed juices are obtained by combining two or more juices or juices with purees of different types of fruit. Fruit juices can be obtained directly by mechanical extraction methods or concentrated with drinking water meeting appropriate requirements. The fruit juice derived from concentrate is obtained by restoring water to the concentrated fruit juice obtained upon concentration. The final product obtained should then be at least equivalent to its fresh counterpart in basic sensory and analytical properties (Ashurst et al, 2009). Fruit juices should have a °Brix content of 6-18.5% in reconstituted fruit juices and purees based on the fruit type, a minimum juice or puree content of 100% and a high pH of 4.5% (KEBS, 2019).

Fruit juice, especially in the form of concentrates, has been an important component of soft drinks for many years, leading to the development of various categories including the dilute-to-taste products (Ashurst, 2012). Its use provides many benefits, including reduced costs compared to non-concentrated juices, nutritional and health benefits associated with fruit juices, and juice content label claims etc., and the addition of natural color (especially in red fruit juices), flavor and haze (Ashurst, 2012).

2.6.2.3 Fruit nectar

Fruit nectar is a fruit juice, fruit juice concentrate, dehydrated fruit juice, fruit puree, fruit puree concentrate or fruit or fruit mixture of these products achieved by adding water, with or without the addition of either Sugar nutritious or/ and non-nutritive sweetener and also meet the specific requirements for fruit nectar (Codex, 2005). Mixed fruit nectar is found in two or more types of fruit (Grumezescu & Holban, 2019).

According to the specified requirements; fruit nectars should contain a minimum ^{O} Brix level for reconstituted fruit juices and reconstituted puree of between 6 and 18.5, a minimum content of juice and/ or puree between 25 and 50 %, based on the type of fruit; and a maximum pH of 4.5 % (KEBS, 2019). Fruit nectars can be fortified with calcium and vitamin C (Ottaway, 2009).

2.6.2.4 Dilutable fruit drinks

As per fruit drinks specification; dilutable drinks are fruit based drinks that need dilution to taste before use. Conventionally, the dilution ratio has been 4 parts water per concentrate, but now the market segment includes soluble soft drinks that can be diluted with 9 parts water per concentrate to obtain a soluble soft drink labeled as ready-to-drink (BSDA, 2009). Dilutable drinks consist of fruit pulp, colored, sweetened solutions in which the pulp is suspended to provide a "natural appearance." These Products are acidic and have a shelf life of 12 months (Grumezescu & Holban, 2019). The dilutables includes squashes, crush, cordials, crush, and fruit syrup/sherbet, fruit flavoured powders and other concentrations that need to be diluted to taste before use (BSDA, 2016).

Fruit cordial is a syrup concentrated drink which should be diluted to between one and three time's ratios, in order to give a satisfactory beverage upon dilution. The beverage is developed by combining clarified fruit juice with Sugars and/or non-nutritive sweeteners, water, acidulants, flavorings, antioxidants, preservatives, colouringss, and other additives fit for the beverage. Cordials must have a minimum juice or puree content of 24%, a minimum 30% soluble solids (^{O} Brix) and a minimum pH of 2.5% in the final product.

Fruit squash is a soft drink, which contains after diluting at least one to three fruit juices with normal strength. The beverage is obtained from fruit juices, sugars and/or non-nutritive sweeteners, preservatives, water, colourings, flavourings and other approved additives. The most commonly used preservatives in squash are Sulphites or benzoates. Potassium metabisulfite is not included in dark fruits as it can turn anthocyanin pigments. Sodium benzoate is used in such drinks. Mangoes, oranges, lemons, pineapples, strawberries, grape and litchis are often used to make squash for sale (Sharma, 2017). Fruit Squashes (in the undiluted form) have a minimum of 24 % fruit juice or/ and puree content in final product, a minimum total soluble solid (^{O} Brix) content of 40 %, and minimum pH of 2.5 % (KEBS, 2019).

Fruit Crush refers to a beverage that is obtained by squeezing/crushing fruits without filtration. Fruit crush drink contains at least 24% fruit juice or puree in the final product with a minimum content (O Brix) of 55% and a minimum pH value of 2.5% (KEBS, 2019).

Fruit syrups are a type of fruit beverage containing at least 25% fruit juice or pulp and more than 65% soluble solids content as ^{O} Brix, with 1.25-1.5 percent acid (Sharma, 2017).

2.7. Review of analysis of food and beverages

A number of methods are available for the analysis of sulphites in foods and beverages. This technique depends on getting rid of as many free and irreversible bound sulphites as much as possible. However, sulphites that are bound are immeasurable.

Determination of free sulphites is necessary and of concern in the food and beverage industry, for use in predicting the stability of the final product and the maximum authorized levels for free sulphites in relevant legislations applicable to exposure of sulphites and labeling requirements.

Various methods of determining the content of sulfite are used, and other new methods are constantly being proposed. Methods include the Monier-Williams Method with its various versions, colorimetry, and injection flow analysis, polarimetric, chromatographic, titrimetric, photometric, iodometric, electrochemistry, fluorometric, chemiluminescence, spectrometric and electroanalytical methods (OIV) are in use. Because sulphites can transform to SO_2, sulphites are estimated and expressed as SO_2. The most widely used method in determining total Sulphur dioxide in a variety of foods and beverage products is the Tanner method (Pearsons, 1981). The Tanner method is the widely recognized method of measuring sulphites food by general EC, Codex, OIV and IFJU

2.7.1 Tanner type procedure:

This method is based on estimating SO2 by titration after distillation of sulfur dioxide from aqueous suspensions of food acidified at pH 1 to 2 (AOAC, 2000).

CHAPTER THREE: DIVERSITY AND CHARACTERISTICS OF THE FRUIT- BASED NON-ALCOHOLIC BEVERAGES COMMERCIALLY TRADED IN NAIROBI, KENYA

3.1 Abstract

Fruit based non- alcoholic beverages are becoming increasingly popular across the globe. They are an excellent source of vitamins, minerals, flavonoids, antioxidants, fibre and bioactive compounds. A diversity of fruit based non- alcoholic beverages, locally manufactured, and imported are sold and consumed in Kenya, but there is little or no information to help people differentiate them, and make informed decision. This study was therefore conducted to determine the diversity and characteristics of various fruit based non-alcoholic beverages sold and consumed in Nairobi, Kenya. Data on fruit based non-alcoholic beverages diversity were collected using self-structured guide. The samples were then analyzed for total soluble solids (°Brix) and pH contents using refractrometric and potentiometric methods, respectively. Data analysis was evaluated with SPSS statistical software. Results were compared to those specified in the respective Kenya standards.

The study identified 4 diverse groups of fruit based non- alcoholic beverages in the market, which were available in a wide variety of flavours, pack sizes and containers. They include the) fruit drinks, fruit juices, fruit nectars and dilutable fruit drinks. The study identified 48 brands of 80 different fruit flavors in the market; 80% were locally manufactured while 20% were imports. The most popular flavors across all the brands were tropical/mixed fruit, mango, orange, apple, pineapple, passion, lemon and guava. The fruit juice content and ingredients added varied among the brands and beverage types in the Market. The fruit juice content ranged from 5 % to 100 % for the dilutables and fruit juices respectively. Eight (8) brands declared use of preservatives as either Sodium benzoate, sodium chloride, potassium sorbate, sodium metabisulphite, or Sulphur dioxide or in combinations.

The pH in the various fruit based beverages varied between 2.28 and 4.59 in the dilutable drinks and fruit juices respectively, while, the total soluble solids ranged between 12.31and 35.85 (º Brix) in fruit drinks and the dilutable drinks respectively. Most brands met Kenyan standards, with the exception of a few brands that did not declare the juice content and the names of preservatives used. This study can therefore be used to educate the population about the differences between various commercially traded fruit based beverages available in the market, so they can make informed decisions.

3.2 Introduction

Consumption of fruit based non- alcoholic beverages has increased worldwide, with increasing demand from health-conscious consumers. They are considered to be a better source of vitamins, minerals, flavonoids, antioxidants, fibre and bioactive compounds, compared to the synthetic beverages (Wardlaw 2004; Potter & Hotchkiss 2006; Franke et al., 2005; Thorpe 1995). In addition, some fruit juices and drinks are fortified with vitamins and minerals (Codex, 2005).

Non-alcoholic fruit based beverages comprise a wide range of products. They can be categorized in various ways based on fruit juice content, sugar content, key dry ingredients, flavouings, carbonation level and function (Kriegel, 2015). They include ready to drink beverages and the dilutables (concentrated beverages). Fruit drinks, 100% fruit juices, and nectars belong to the ready-to- drink beverages category, while the fruit cordial, squash, crush, syrup belong to dilutable beverages category (Sharma, 2017). Dilutables require dilution before consumption. The Fruit based non-alcoholic beverages are offered in a variety of containers with different shapes and pack sizes, such as tetra packs, glass bottles, cans and PET bottles (Grumezescu & Holban, 2019).

The main purpose of fruit juice processing is to preserve perishable fruits into shelf-stable products such as juices, nectars, fruit drinks, fruit squashes, crushes and fruit cordials in order to prevent post-harvest loss, so that they can be stored and supplied to the markets throughout the year (Sharma, 2017. Other than reducing wastage through utilization of the surplus fruits during the harvesting season, it can also add nutrition and palatability to the fruit based beverages.

In Kenya, Fruit based beverages are covered by Kenya standards, which prescribes their quality, composition, microbiological limits and labelling requirements. The physicochemical parameters set in the standards for fruit based beverages include pH and total soluble solids (°Brix) (KEBS, 2019). Furthermore, fruit drinks and juices should possess the nutritional value, characteristic, color, aroma and taste of juices made from the same type of fruit from which they are derived (Codex, 2005).). The standards further require compliance to use and labelling of food additives. Water is the main ingredient in all fruit drinks, hence its quality is critical. The Water used should to the requirements for potable water standards.

Fruit based beverages typically contain the fruit juice or pulp, water, sugar, acidity regulators, stabilizers, micronutrients, preservative, flavourings and colourings (Ali, 2008). They are optionally sweetened, carbonated and acidulated and may contain only the food additives permitted for these products (Codex, 1995). A wide range of fruits are used as raw materials to developed fruit based beverages. The most common ones include pineapple, mangoes, oranges, apples, bananas, guava, Pawpaw, and passion fruit (Euronomitor, 2019).

Fruit drinks usually contain either Sucrose, glucose, or fructose (Ashurst et al., 2009). Sugar is the second most important ingredient after water, making up to 12% of fruit drinks (Mitchel, 1995). Used in a dry or syrup form, sugar maintains and enhances the flavor of drinks and provides a feeling of satisfaction (kriegel 2015; Pietka & Korab 2021; kriegel 2015). Sugar also balances flavors and acids (Mitchel, 1990). For health reasons, including dental health, other approved non-nutritive sweeteners are often added to fruit beverages. The most often used sweeteners are Saccharin, aspartame, sucralose acesulfame-K, sorbitol, mannitol and xylitol, stevia and saccharin (EFSA, 2019).

Acidity Regulators and Carbon Dioxide are also permitted in fruit based beverages. Carbonation enhances taste and flavor, and helps keep drinks longer and gives the drink its sparkle (Bertos et al., 2004), while the regulators are used to enhance the flavor by balancing sweetness. The most often used acidity regulators are citric acid, malic acid, and pantothenic acid (codex, 1995).

Natural or artificial flavorings and Colorings can also be used for a variety of functions, including making the product more attractive; to help correct color variations or changes during processing or keeping and preserving the characteristics of which the beverage is well known of (Ashurst, Hargitt & Palmer, 2009). Ingredients such as pectin, xanthan, guar and gum are also used as stabilizers and thickeners, to give uniform texture and satisfying feel; and prevent phase separation. Nutrients such as ascorbic acid are usually used to inhibit flavors and color loss, particularly when beverages are packagedin oxygen-filled bottles or tetra packs (kriegel, 2015).

Fruit based beverages are obtained by subjecting fruit juice or pulps to minimal processing steps such as filtration, clarification and pasteurization (Grumezescu & Holban, 2019). The composition of fruit juices is not modified during production, but in that of fruit based beverages like nectars, fruit drinks, squashes, cordial, crush and concentrated fruit drinks; the fruit juice or pulp and allowed additives and ingredients, are formulated in suitable portions to an acceptable flavour (Sharma, 2017).

The shelf life of fruit based beverages is attained through thermal processing. Normally, fruit drinks will not require use of preservatives if they are appropriately heat-treated and aseptically packaged. Nevertheless, other fruit based beverage may have some amounts of authorized preservatives to gain extended shelf life after opening (Grumezescu & Holban, 2019). As per the Kenya general standards for food additives KEBS (2019); the maximum permitted levels of preservatives in fruit based beverages are10 ppm for Sulphur dioxide and benzoic acid. The regulations further require that fruit drinks containing Sulphur dioxide (SO_2) must be declared on the packaging for the presence of sulphites, when residue levels exceed some specified concentration.

Sorbates, benzoates, and sulfites are the most commonly used preservatives in the fruit beverage industry, more so in acidic beverages (BSDA, 2016) The efficacy of these additives is based on physicochemical characteristics of the preservatives and beverages. Product pH, vitamins availability, packing, and state of storing will dictate preservative type to be used to prevent bacterial growth (Sharma, 2017).

A wide range of fruit based non-alcoholic beverages are commercially traded in Kenya, yet there is limited or no Information on the Diversity and characteristics of these beverages, that would enable consumers in Nairobi, Kenya make informed choices. This research was therefore carried out to determine the diversity and quality properties determine the diversity and physicochemical properties of non-alcoholic fruit based beverages sold and consumed in Nairobi, Kenya.

3.3 MATERIALS AND METHODS

3.3.1 Study Design

This study incorporated a cross-sectional survey with the analysis component. The survey targeted the major supermarkets in Nairobi County.

3.3.2 Study Area

The survey was conducted in different parts of Nairobi County between July 2020 and April 2021 and covered five major supermarket chains in Nairobi Metropolis. The choice of the major supermarkets is because they normally stock a wide variety of the fruit based non-alcoholic beverages compared to other outlets, hence the major source of the beverages to the Nairobi population.

Nairobi county was also selected for this study because of the large population, which is estimated to be about 4,397,073 with a total area of 704 km^2 (KNBS, 2019). It has a total of seventeen sub-counties, namely; Makadara, Starehe, Embakasi North, Embakasi South, Langata, Embakasi East, Embakasi west, Embakasi Central, Kibra, Kasarani, Mathare, Roysambu, Ruaraka, Westlands, Kamukunj and Dagorreti North, Dagorreti South. The study targeted 76 major supermarket chains, which are spread in the seventeen sub-counties in Nairobi County. These included Tuskys, Carrefour, Naivas, Chandarana (food plus) and Quick matt.

The map of Nairobi is as given in Figure 1.

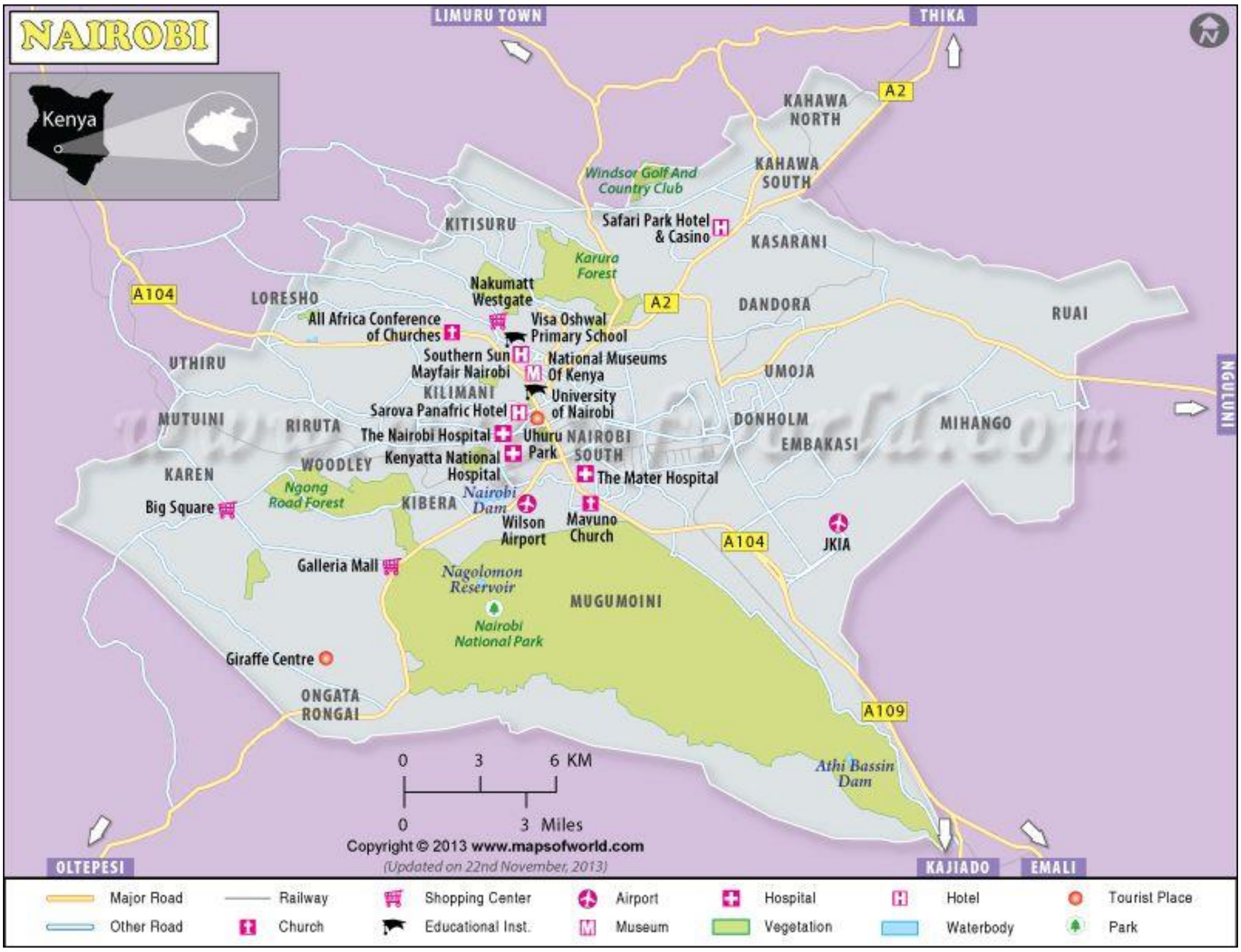

Figure 1: Map of Nairobi County, Source (Maps of the World, 2016)

3.3.3 Sample size determination (Products)

Sample size was determined using Fisher's formula (Scott Smith, 1999). This formula is suitable for large populations or unknown population sizes. The formula for calculating the sample size is as follows:

$$n = \frac{Z^2 p(1-p)}{d^2}$$

Whereby n is the sample size expected for the population; Z corresponds to the selected confidence level of 95% (1.96) and margin of error 5%, using the recommended standard deviation suggestion of 0.05; p is the population with the desired characteristics, for this case, p being proportion of fruit based non-alcoholic beverages consumed in Nairobi county containing SO_2 set at 50% (p = 0.5).

Hence;

Sample size $n = \frac{(1.96)^2\ (0.5)\ (0.5)}{(0.05)^2} = 384$ samples

3.3.4 Sampling procedure

Multi-stage sampling was performed to select the seventy-Six supermarkets enrolled in the study. A list of 76 branches from the five Major supermarket chains, spread in the seventeen sub-counties in Nairobi County was and prepared, then clustered (Appendix 2) and were all included in the sampling frame. All samples were in ready for consumption form before analysis as this gives a true estimate of beverage exposure. For instance, cordials, squashes / crushes and syrups / sherbets were reconstructed as per the manufacturer's directions. The beverages were carefully prepared before being analyzed and stored at ambient temperature. Samples were analyzed repeatedly and analysis were done as soon as possible to stop SO_2 losses.

3.3.5 Data collection procedures and tool

Data were collected using self-structured guide (appendix 1) where by all the available brands were identified, categorized as presented in Appendix 1. From each supermarket, data on various beverages was collected. The data included; fruit flavor, the type of beverage as either fruit juice, juice concentrate, nectar, drink or cordial, ready to drink or dilutable (squashes), package type and sizes (converted paper/tetra pack 200, 1000 ml etc.; glass or PET/plastic bottles), declared added ingredients used, and country of origin.

3.3.6 Sample collection

A total of three hundred and eighty-four samples were collected from the five major supermarket chains in Nairobi, Kenya. Based on the market share information, 100 fruit juices, 80 fruit nectars, 120 fruit drinks and 84 dilutable/concentrated drinks were sampled. They were then taken to the Kenya Bureau of Standards laboratory for total soluble solids and pH analysis. The same samples were used for the analysis of Sulphur dioxide content.

3.3.7 Laboratory Analysis

3.3.7.1 Determination of PH content:

The pH of each beverage was measured in duplicates based on the potentiometric method described in (ISO, 1991).

3.3.7.2. Determination of Total soluble solids (TSS) as °Brix representing sugar:

3.3.8 Statistical Analysis

The computer software package for social scientists (SPSS) was used to analyze data on the diversity of fruit based non-alcoholic beverages from the supermarkets, while data from the laboratory was processed using SPSS 16.0 software and Microsoft Excel 2016. Means were tested using ANOVA and LSD test, considered at ($P < 0.05$).

3.4 Results

3.4.1 Diversity of fruits based non-alcoholic beverages sold and consumed in Nairobi, Kenya

3.4.1.1 Types of fruit-based non-alcoholic beverages sold and consumed in Nairobi, Kenya

All the 5 major supermarket chains stocked similar fruit based non- alcoholic beverages, which were broadly categorized into four groups on the basis of the fruit juice content and added ingredients. These included fruit drinks, fruit juices, fruit nectars and the dilutables. The dilutables comprised of fruit squash, cordials and concentrated fruit flavoured drinks. The survey further showed that there were 48 brands available in the market, as shown in tables 1(a-d). Out of the 48 brands, 23 were fruit drinks, 9 fruit juices, 7 were fruit nectars and 8 were the dilutables. The fruit drinks accounted for 49 % market share, followed with fruit juices at 19 % market share, followed closely by the dilutable drinks accounting for about 17 % of the market %, and then lastly fruit nectars at 15 % market share (Fig.2)

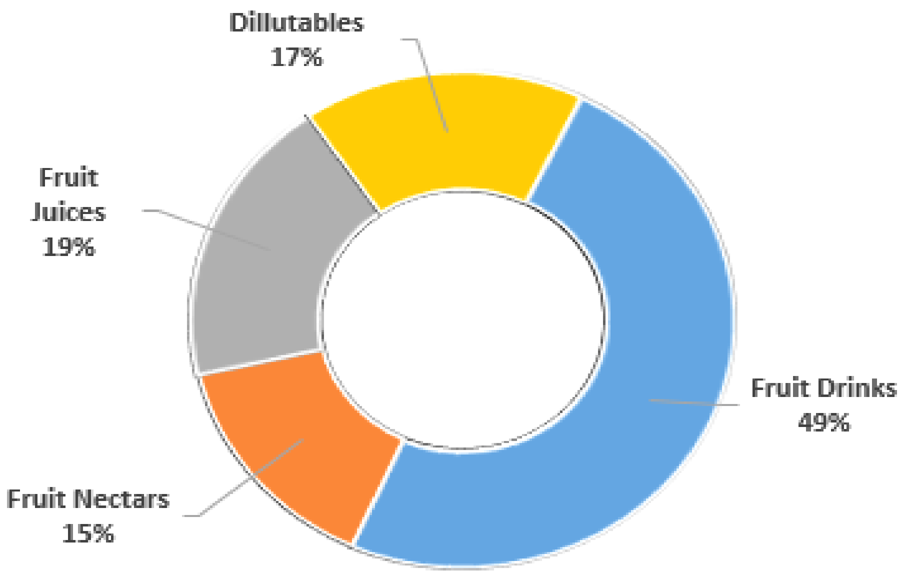

Figure 2: Market share distribution of fruit based non-alcoholic beverages sold in Nairobi, Kenya

The stocked brands within the fruit drinks category were; the Orchid valley, Ceres, Del monte, the berry company, Ocean Spray, Afia, Minute maid, Fruit ville, Fruit full, Treetop, gofruit, African fruit, Ribena, Jooz, Sun top, Brava, Tunda, Daima (Alive), PEP, Azam, Tamu juice, Aquamist frutz, YOU. C1000, Sun magic and Vimto.Within the fruit Juices nectar category were Del Monte, Orchid Valley, Ceres, Treetop, African fruit, Yatta, Sunich and KTC.

Within the fruit nectars category were Delmonte, Fruit full, Nature's Fresh, Ceres, Minute maid and Vitrac; and finally, within the fruit Dilutables/concentrated drinks were the PEP, Savanah, Clovers, Treetop, Highlands, Excel Quencher, Ribena and Sunquick. Of which 3 brands: PEP, savannah, treetop and excel quencher were the concentrated flavoured fruit drinks; clovers, pep and highlands were cordials, while Sun-quick was the only fruit squash available in the market.

The study further identified 80 fruit flavors Out of which, 32 were fruit drinks (Tropical/ Mixed fruit/fruit punch/cocktail Orange, Apple, Mango, Pineapple, Guava, Passion, Mango & apple, Orange &mango, Cranberry, Super berries purple (blackberry, blueberry, blackcurrant, grape), Pomegranate, Blueberries, Acai berry (grape, raspberry, aronia berries, and acai berry fruit), Cranberry & raspberry, Cranberry & pomegranate, Cranberry blackcurrant, Tropical carrot, Blackcurrant, Blackcurrant & strawberry, Strawberry & banana, Blackberry & grape, Cranberry & apple, Orange & carrot, Lemon mint (Mojito), Mango & passion, Strawberry & guava, Ginger lemon honey (Dawa drink), Ukwaju tamarind ,Peach, Banana, Lemon, and Tomato), 22 were fruit nectars (Pineapple, Orange, Mango, Peach, Guava, Tropical, Apple, Mango & pineapple, Orange & pineapple, Pineapple & passion, Mixed berries, Red grape, Litchi, Cranberry & apple, Orange & apple, Orange chocolate, Pinacolada, Orange carrot, Mango & Apple, Red Grape & Cherry, Apple & blackcurrant, Orange & mango), 14 were the fruit juices (Orange, Apple, Cranberry, Mango, Tropical, Litchi, Pineapple, Cranberry and kiwi, Red grape, White grape, Apple & palm, Passion, Lemon juice) and 12 were the dilutables (Orange, Apple, Cranberry, Mango, Tropical, Litchi, Pineapple, Cranberry and kiwi, Red grape, White grape, Apple & palm, Passion, Lemon juice). The most popular flavours across all the brands within the ready to drinks were tropical/mixed fruits, mango, orange, apple, pineapple, passion and guava, while the least common fruit flavors were the berries (blackberry, blueberry, Cranberry, acai berry & raspberry), which were mostly import brands, from the berry company and Ocean spray. Others were lemon juice, Lemon ginger and ukwaju (tamarind drink), and were available in KTC, PEP and Azam brands respectively.

The study also found that the characteristics assessed which included fruit juice content, Package size, added ingredients varied significantly ($P \leq 0.05$) across market brands and beverage type . The fruit juice content ranged from 10 to 27 % for the ready to drink fruit drinks; 25 to 55 % for the fruit nectars and 100% for the fruit juices, and from 5 % to 25 % for the dilutables. Within the dilutables, the fruit squash had 25 % fruit content, while the cordials and concentrated fruit flavoured drinks had between 5 % and 10 %.

3.4.1.2 Ingredients added in the fruit-based non-alcoholic beverages sold and consumed in Nairobi, Kenya

Various ingredients were added to the fruit based beverages sold and consumed in Nairobi, Kenya. Within the fruit drinks category; the ingredients which were listed on package label were the fruit juice, water, sugar/nutritive or and non-nutritive sweeteners, permitted organic acids, ascorbic acid, stabilizer, colouring and flavouring ingredients. All the ready to drink fruit juices declared 100% pure juice content with no added sugar, colour, flavor or preservatives, except for KTC, which indicated use of sulphites as a preservative. Fruit nectar listed ingredients were water, sugar/sweeteners, fruit juice, acidity regulator and Vitamin C as ascorbic acid, and declared no added preservatives, artificial colours, flavourings and sweeteners.

The listed ingredients within dilutables category were the fruit compounds/juice, water, sugar, permitted acid, food colour, flavor and presearvatives for the fruit flavoured drinks; and fruit juice concentrate, water, sugar/nutritive sweeteners, permitted acid, ascorbic acid (Vitamin c), stabilizer, preservative, colouring and flavouring ingredients for the fruit squash and cordials.

All the brands under the dilutables/ concentrated drinks category declared use of preservatives as part of the ingredients. All the five brands except Clovers declared the type of preservatives. KTC, PEP, Savanah, Treetop, Highlands, Excel Quencher, Ribena and Sunquick, declared use of either Sodium benzoate, sodium chloride, potassium sorbate, sodium metasulphite, sulphites, sulphur dioxide or in combinations.

Out of the 8 brands, 5 brands, namely; KTC, PEP, Quencher, Ribena and Sunquick declared use of SO2, sodium metasulphite and sulphites as preservatives in the ingredients list. Out of the 5 brands, 3 brands (KTC, sunquick and Ribena) declared sulphur dioxide and its salts as an allergen, while 2 brands declared use of carbon dioxide; Ribena and YOU. C1000. All the fruit- based beverages claimed addition of vitamin C (ascorbic acid) as an antioxidant among other nutritional claims, while 2 brands; Minute maid and Highlands declared fortification of their products with essential vitamins such as vitamin B6, Niacin, vitamin E, Folic acid, pantothenic acid; and minerals such as zinc.

3.4.1.3 Packaging of fruit-based non-alcoholic beverages

The Non-alcoholic fruit based beverage were available in a wide variety of pack sizes and containers including glass bottles, plastic bottles and cartons (Tetra packs). The pack sizes ranged from 100 ml to 5 litres. The fruit drink category was available in 100 ml, 200 ml, 300 ml, 325 ml, 400 ml, 500 ml, 1 litre and 1.5 litres, and were offered in Tetrapacks, PET bottles, glass bottles and cans. The fruit juices category was available in tetrapacks of 250 ml, 1 litre and 1.5 litres; except for one brand; KTC, which was available in plastic bottle of 500 ml.

All the fruit Nectars were available in Tetrapacks of 100 ml, 250 ml and I litre package sizes. 99% of the dilutable drinks were available in polyethylene terephthalate (PET) plastic bottles of 1 litre, 2 litres, 3 litres and 5 litres package sizes, with only two brands; sunquick and Ribena being available in glass bottles of 700 Ml; 300 and 600 ml respectively

In general, 50 % of fruit based beverages were offered in tetra pack and 54% in plastic bottles. Only three brands; YOU. C1000, sunquick and Ribena were offered in glass bottle and cans, respectively.

The most common pack size unit across all the brands and beverage type was 1 litre. 60 % of the beverages were offered in 1-liter pack sizes. All brands Complied with the labelling requirement of the Kenya Standards, Except for a few brands which did not declare the fruit juice content and the name of preservatives used.

3.4.2 Characteristics of fruits based non-alcoholic beverages sold and consumed in Nairobi, Kenya

The results obtained from the physicochemical analysis have been reported in two parts: a) based on the categories of the fruit based beverages and; b) based on the most common fruit flavors, as shown in tables 1 and 2 respectively.

There were no significant differences ($p>0.05$) in the PH and TSS content in the fruit drinks, fruit juices and nectars (Tables 1).

The pH content of the fruit based beverages ranged from 2.8 to 4.50 for the dilutables and fruit drinks respectively (Table 1). In all categories of fruit based nonalcoholic beverages, lime/lemon flavours showed higher acidity (2.28 to 2.86) when compared to all the other common fruit flavors (Table 2). The total soluble solids of the beverages ranged from 5.85-21.51 for the fruit drinks, 4.12-

20.50 for the fruit juices, and 9.64-24.13 for the fruit nectars and 21.32-67.15 for the fruit drinks, juices and dilutables.

Table 1: PH and total soluble solids (°Brix) content in non-alcoholic fruit based beverages consumed in Nairobi, Kenya

	PH					°Brix (%)	
Sample	**No**	**Mean±SD**	**Range**	**Minimum to Maximum Acceptable Limit**		**Mean±SD**	**Range**
				PH	**°Brix**		
Fruit Drinks	120	3.40±0.40a	2.03-4.43	Min 2.5	10 Min	12.48±2.52a	5.85-21.51
Fruit Juices	84	3.42±0.45a	2.56-5.30	Max 4.5	5.0 – 20.0	12.59±2.44a	4.12-20.50
Fruit Nectars	100	3.48±0.55b	0.01-4.50	Max 4.5	5.0 – 20.0	13.91±1.98b	9.64-24.13
Dilutables	80	2.87±0.33c	2.21-3.70	Min 2.5	30 Min	35.16±9.18ab	19.54-67.15

Within ready to drink fruit beverages; lemon juice, tomato juice, tangerine and papaya drink had the lowest ºBrix of 8.66, 9.83, 9.87 and 9.1 respectively, while pineapple drink, guava nectar, white grape juice and passion nectar had the highest ºBrix of 16.62, 16.43, 14.87 and 14.50 respectively**.**

Overall, the dilutables presented a higher content of °Brix compared to the ready to drink beverage category. The soluble solids (ºBrix) of dilutables ranged from 19.54 (Strawberry) to 58.97 (Blackcurrant) (Table 2).

Table 2: pH, and total soluble solids (°Brix) content in the common fruit-based beverage flavours consumed in Nairobi, Kenya.

Beverage type category	Fruit Juice Flavour/Base	PH content	TSS (o Brix)
Fruit Juices	Tropical/mixed	3.49±0.47c	12.79±2.16g
	Mango	3.68±0.41c	13.76±3.41f
	Apple	3.56±0.11b	12.8±2.16g
	Orange	3.59±0.4c	12.36±1.86g
	Pineapple	3.52±0.4b	13.43±3.32f
	Passion	3.21±0.4b	12.57±4.46g
	Lemon	2.34±0.08a	8.66±0.50i
	Grape	3.7±0.22c	12.82±3.59g
	Peach	3.85±0.17c	12.61±0.99g
	Guava	3.62±0.37c	11.98±1.43h
	Red grape	3.1±0.22b	14.15±1.58e
	White grape	3.0±0.12b	14.87±0e
Fruit Nectars	Tropical/mixed nectar	3.39±0.35b	14.33±1.25e
	Mango Fruit nectar	3.77±0.39c	13.8±1.35f
	Apple nectar	3.31±0.55b	11.3±0h
	Orange nectar	3.47±0.42b	12.08±0g
	Pineapple nectar	3.59±0.32c	13.87±3.16f
	Passion nectar	3.47±0.72c	14.5±4.7e
	Lemon nectar	2.39±0.51a	11.69±0h
	Grape nectar	3.81±0.56c	13.01±0f
	Peach nectar	3.94±0.54d	12.82±0g
	Guava nectar	4.48±0.86d	16.43±1.04d
Fruit Drinks	Tropical Or Mixed Drink	3.42±0.4b	12.23±1.56g
	Mango Drink	4.59±0.13d	11.74±3.99h
	Apple Drink	3.13±0.35b	11.56±2.51h
	Orange Drink	3.31±0.12b	11.17±2.04h
	Pineapple Drink	3.34±0.29b	16.62±9.39d
	Passion Drink	4.04±0.26d	11.49±1.86h
	Lemon Fruit drink	2.86±0.42a	10.38±1.75h
	Mixed berries drink	3.51±1.54c	11.92±0.87h
	Tamarind Drink	2.77±0.65a	11.29±2.09h
	Guava drink	3.53±0.43b	11.74±1.92h
Dilutables	Tropical/mixed/punch	3.35±0.42b	32.58±4.73c
	Mango	3.06±0.03b	35.38±10.14b
	Orange	3.29±0.32b	30.91±8.75c
	Pineapple	2.96±0a	31.68±10.58c
	Passion	2.58±0a	31.7±1.13c
	Lime	2.28±0.10a	32.07±0c
	Cocopine	3.06±0b	36.43±1.2b
	Blackcurrant	2.67±0a	58.97±0a
	Strawberry	2.55±0a	19.54±0d
	Tropical	2.55±0a	67.15±0a

The means with the same letter are not significantly different at 95% confidence interval (P> 0.05), while those with different letters are significantly different (P< 0.05).

3.5 Discussion

3.5.1 Diversity of fruits based non-alcoholic beverages sold and consumed in Nairobi, Kenya

Many studies have found out that non-alcoholic beverages fruit based beverages such as fruit drinks, juices, nectars; and dilutable are available in most of the countries in the world, as their production is relatively simple, and a great variety of local raw materials are available for use (Roethenbaugh, 2005). This demonstrates high level of product diversification, innovations, concepts and trends within the fruit based beverages industry and market throughout the world. The ready to drink fruit juices largely dominates global juice market (Euromonitor, 2016a, b). From this study, fruit drinks accounted for 49 % market share, followed with fruit juices at 19 % market share, followed closely by the dilutable drinks accounting for about 17 % of the market %, and then lastly fruit nectars at 15 % market share (Fig.1)

Across the globe fruit based drinks are available in a variety of flavors (Mintel, 2009). The current study identified 80 fruit flavors. The availability of a variety of flavors offers a wide range of juices to meet the taste preferences and needs to the ever-growing fruit beverage market.

The study also found that the most popular flavors across all the brands were tropical/mixed fruit, mango, orange, apple, guava and pineapple; while the least common fruit flavours were the berries, which were mostly import brands. This could be attributed to the availability of the fruits and cost effectiveness. The new and rare flavors are being introduced to the local market through imports so as to meet the consumer demand for different choices for flavors, including from exotic fruits. The beverages are intended to fulfill flavour needs of the consumer and also focus on health benefits (Reuters, 2008). In many countries, the most preferred flavors are orange, mixed fruit juices and apple (Euromonitor, 2016a, b).

The current study determined that diverse fruit based non-alcoholic beverages are sold and consumed in Kenya. In fact, there are many types of fruit based beverages that contain different contents of fruit juice. The beverages can include the ones that are in ready to drink form, or ones that are dilutables such as fruit cordials, squashes, powders and other concentrates that need to be diluted to taste by consumers, and usually filled with about four parts water to one drink (BSDA, 2016). The dilutable drinks contain between 6 % and 10% fruit juice content of other beverages, which are normally ready for consumption are the fruit juices and nectars. The fruit juice contains 100% fruit juice or puree content, usually with no added sugars, sweeteners, preservatives, flavorings, colorings or other ingredients (BSDA, 2016). On the other hand, fruit nectar is obtained by adding water and sugar to fruit juice, fruit juice concentrate, fruit puree, or concentrated fruit puree concentrate (or mixtures thereof)) (Jukes, 1997 but typically contain 25-99% juice content, based on the kind of fruit.

This study determined that the added ingredients varied across the beverage types and flavours. In most countries of the world, the usage of food additives worldwide is regulated by the laws and standards. 100 % fruit juice is the only extracted fruit juice and should not contain preservatives, or other added ingredients, if properly processed and packaged (Codex, 2005). However, the fruit drinks, fruit nectars and dilutables (cordials, squashes and other concentrated flavored drinks) should have some quantities of preservatives allowed to have longer shelf after opening.

With diversity in fruit based beverages segment, a variety of ingredients are needed in their composition. The addition of preservatives and other additives is necessary to prevent microbial spoilage, enhance Colors, odour, taste and consistency or texture (Monica et al., 2019), which are important for the acceptability of the beverages. Sugars or sweeteners are added basically as a taste enhancer of the beverages. There are various approved preservatives that can be used in fruit drinks, however, the three most common chemical preservatives used to prevent juice contamination are the Benzoates, Sorbates, and Sulphites (Ashurst et al, 2009). The study found out that most brands of fruit- based beverages claimed addition of vitamin C (ascorbic acid) as an antioxidant, while a few declared fortifications of their products with essential vitamins such as vitamin B6, Niacin, vitamin E, Folic acid, pantothenic acid; and minerals such as zinc. Fortification of fruit -based beverages has become increasingly popular due to its health benefits (Ottaway, 2009). This diversification has led to increase in nutrient intake, which can be an effective strategy to prevent micronutrient deficiencies (Chandra et al., 2014). Vitamins are added to beverages to correct losses during processing or boost the nutritive value and to maintain and prevent discoloration of ingredients from fruits. According to Codex (1995), when used as an antioxidant, ascorbic acid should be labelled as such and not as “added Vitamin C”. Mineral fortification also increases the intake of the minerals, which is normally reduced due to dilution (Ottaway, 2009). Minerals that are often used to fortify fruit based beverages are calcium, zinc, magnesium, potassium and iron.

Some brands declared use of carbon dioxide. Fruit- based beverages may also becategorized as per added carbon dioxide. Carbonation gives the beverages that sparkling and fizziness effect. (Chandra et al., 2004). According Codex (2005), carbon dioxide can be added to fruit juices, and if the drink includes more than one gas volume of carbon dioxide, the term carbonated /sparkling will appear in the label of the product.

The study determined that the fruit based beverages were available in a wide variety of pack sizes and containers including glass bottles, plastic bottles and cartons (Tetra packs). The pack sizes ranged from 100 ml to 5 litres. It further found that packaging fruit based beverages in tetrapack carton and plastic bottles was popular across the whole brands. 54 % were offered in tetra pack and 50% in plastic bottles, while only three brands were offered in glass bottle and cans respectively. This could be attributed to the fact that Tetra pack and plastic bottles are economical, available, easy to use, convenient and disposable. Tetra packs provides for space for images and for better shelf display and appeal. They also provide easy access to the contents, using unique easy-to-open features such as drink straw openers and removable tab holes that can be pulled out of the packet without compromising the integrity of the package (Kumar, 2002).

Most ready to drink beverages were packaged in aseptic packages in form of tetra packs. Aseptic packages safeguard the fresh, natural fruit flavors, taste and nutritional value of fruit based beverages (Kumar, 1985). They are preferred by manufactures because they are suitable in achieving commercial sterility. The 1 litre pack sizes were the most common pack size unit across all the beverage types. About 60 % of the beverages were offered in 1-liter pack sizes. This could be due to it’s to its convenience, easy to carry and consume, as well as ease of distribution and storage for refrigerated and shelf stable products (Kumar, 1985).

Sustainability and protection of the environment is a key issue for the soft drinks industry. Innovations in packaging of soft drinks reduces the environmental impact. Nearly 60% of all soft drink containers (Cans, bottles (glass and plastic) and cartons) are recyclable (Mitchel, 1995). This means they are returnable and reusable, hence environmentally friendly). However, beverage containers are sometimes kept in unknown conditions for longer periods prior to use, which may affect how they interact with contents inside. Glass bottles can, under certain circumstances, contaminate the bottle contents with lead (Pb) and zirconium (Zr) (Kriegel, 2015) Reimann et al. (2010) have shown that Polyethylene terephthalate (PET) plastic bottles can contaminate water with antimony (Sb), with increasing concentrations during storage. Plastic bottles containing chemicals such as (BPA) can contaminate beverages. Others, such as phthalates, which are used as plasticizers to make plastics, including polyvinyl chloride, more flexible can leach into the environment, as they are not chemically bonded to plastics (Kriegel, 2015). In Kenya, all the packaging materials must comply with the Kenyan materials in contact with food regulations (CAP 254, 2012) and environmental regulations (EMCA, 1999).

3.5.2. Characteristics of fruits based non-alcoholic beverages sold and consumed in Nairobi, Kenya

Results show that the pH of all fruit-based beverages ranged from 2.28 to 4.59. Therefore, it can be classified as an acidic food (pH < 4.6) (Breidt *et al.,* 2004). Fruit-based drinks have a lower pH because they are relatively high in organic acids. The overall pH range for common fruits is 2-5, with the most common value being 3-4 (Tasnim et al., 2010). These results correlate with the pH range of 3-4 for most fruit juices and drinks. Similar findings were reported in assessment of pH in non-alcoholic, nondairy beverages in the United States (Reddy *et al*., 2016). He found that most (93%) beverages had a pH of less than 4.0, hence potentially erosive to the dentition.

PH may be considered as the key factor in determining the heat tolerance of bacterial cells (Tola & Ramaswamy, 2014). The pH largely determines the stability of the beverages shelf-life. If the beverage is too acidic, it will be less susceptible to bacterial but more susceptible to yeast and fungi. Yeasts and fungi are the most important group of microorganisms involved in the putrefaction of fruit juices and beverages, due to their complete structure and resistance to acids and preservatives (Wareing & Davenport, 2007). Beverages can also be highly acidic due to the addition of various permitted organic acids acetic, tartaric, succinic, citric, and acetic acid. The acids act as acidity regulators during processing of the fruit based beverages (Morris *et al.,* 2001). The Mango drink flavor had very high concentration of acid.

The Brix content of fruit drinks, juices, and nectars differs slightly based on the fruit type of fruit. All fruit juices contain fructose, but the sugars content (sucrose, glucose, and sorbitol) varies. The content TSS (°Brix) is also directly related to both sugar and acids of fruit acids as they are the fundamental contributors (Codex, 2005). The content of TSS is greatly determined by the double effect of fruit ripening stages and ripening conditions. In this study, the content of TSS in tropical nectar, mango juice and nectar, pineapple juice and nectar, guava nectar, passion nectar, red grape and white grape juice and blackcurrant dilutables, were higher than the other fruit flavours (Table 2). Comparable findings were described by (Nonga *et al*., 2014). Total soluble solids (°Brix) are essential indicators of fruit juice content which is commonly used in characterizing the quality of fruit based beverages (Adubofuor & Appiah, 2010). From the analysis, most of the fruit based beverages conformed to the requirements of both the local and international standards.

3.6 Conclusion

The study has found that diverse types of fruit-based beverages are sold and consumed in Nairobi Kenya. They are available in different fruit flavors and packaging containers of different size, shape, and appearance. Generally, most of the brands complied with the labelling and packaging requirement of the Kenya Standards. The results on the characteristics of the fruit based beverages showed that most of these beverages conformed to the Kenya standards**.**

3.7 Recommendation

This study can be used to raise consumer awareness of the different fruit-based beverages and fruit juices available in the market. This allows consumers to make informed choices when choosing from a wide range of beverages. Among other things, the data could also help policy makers to enforce regulations on the labeling and use of food additives in these beverages.

CHAPTER FOUR: SULPHUR DIOXIDE EXPOSURE THROUGH CONSUMPTION OF FRUIT-BASED NON-ALCOHOLIC BEVERAGES IN NAIROBI, KENYA

4.1 Abstract

Fruit based non-alcoholic beverages is the possible cause of exposure to Sulphur dioxide (SO_2). Sulphur dioxide is the preservative of choice in these beverages all over the World. Fruit-based soft drinks can contribute to sulfur dioxide (SO2) exposure. Sulfur dioxide is the preservative of choice in these beverages around the world However, scarce information is available in the public about the risks associated with excessive use of SO_2 as a preservative in the mostly consumed fruit juices and drinks, since the information on exposure to SO_2 by Kenyan consumers is limited or lacking. The study was therefore designed to establish the levels of Sulphur dioxide residues in the fruit-based non-alcoholic beverages consumed in Nairobi, Kenya, with a view to determining the level of exposure of the chemical to the Kenyan consumer.

A Total of 384 fruit based beverage samples were collected from the Major supermarkets in Nairobi, Kenya. The sulfur dioxide content was determined using Tanner titration method. The Sulphur dioxide intake was then determined through the deterministic method and compared with the acceptable daily intake of 0.7 mg / kg-bw.

SO_2 residue levels in fruit drinks, fruit juices, fruit nectars, dilutable/concentrated drinks were 1.25±2.58, 0.56±1.71, 0.49±1.47, and 21.52±13.85 mg/kg, respectively. Only 13.1% fruit juices, 12 % fruit nectars and 22.5 % fruit drinks detected Sulphur dioxide residues, which were all within the acceptable level. However, of the 80 dilutable drinks samples 69(86.3 %) had Sulphur dioxide residues out of which 57 (71.3 %) them had Sulphur dioxide residues above the acceptable limit. The daily dietary exposure to SO_2 through the consumption of fruit based beverages for pre-school children, children aged 7-18 and adults were 0.041, 0.034 and 0.031 mg/kg body weight/day, respectively, which were all below the ADI. The risk of SO_2 intake associated with daily consumption of fruit based beverages was 5 % for preschool children, 3 % for children aged 7-118, and 3 % of ADI for adults. Dilutables/concentrated fruit drinks category was identified as the highest source of SO_2 representing more than 58 % of the estimated intake, hence, consumers sensitive to SO_2 should be informed to avoid its excessive consumption and check labels carefully.

4.2 Introduction

Sulphur dioxide and Sulphitesare widely used as antioxidants and preservatives in various food and beverage products to prevent oxidation and improve flavor and retain colour by inhibiting food browning and inhibiting microbial growth (Sapers 1993; Taylor *et al*. 1986; Lou *et al*., 2017; Machado *et al*., 2009). SO_2 can occur naturally in other foods and beverages through to fermentation ((Taylor *et al*., 1986).

Although there are technological benefits to use of SO_2 in in the food and beverage industry, exposure to high levels of sulphites has been linked to symptoms such as allergies and asthma reactions in sulphite sensitive individuals (FSANZ, 2005). This reactiveness can cause a variety of mild to threatening dermatological, pulmonary, gastrointestinal, and cardiovascular symptoms such as difficulty in breathing, sneezing, throat swelling, bronchospasm, angiodema, urticaria, anaphylaxis, nausea, abdominal cramping, diarrhea, and migraine headache (Lester 1995; Knodel 1997). In addition, it can cause DNA damage (Meng *et al*., 2005).

Although Sulphur dioxide use is authorized in Kenya, levels of sulfur dioxide or any other sulphiting agent above 10 ppm are subjected to labelling, as they may cause hypersensitivity (KEBS, 2019). According to the food additives committee JECFA (1999), the corresponding acceptable daily intake (ADI) for sulphites is 0.7 mg/kg body weight per day.

A diversity of fruit based beverages, locally manufactured or imported are sold and consumed in Kenya. The choice preservative for these beverages is Sulphur dioxide, which may be in combination with benzoic acid. However, the use of this preservative is rarely declared on the label and when done, the levels are never indicated. The national tolerance for use of Sulphur dioxide as preservative in these beverages is 10 mg/kg, as specified in the Kenyan standards KEBS (2019). With the fraudulent use of food additives especially by Kenyan manufacturers, it is possible that more than the allowed levels are used, mainly to disguise the inferior process.

In addition, in many previous studies conducted on the sulpite levels and dietary intake of various foods and beverages consumed in other countries, fruit-based beverages have been found to be one of the major sources of exposure to sulfites in various population groups, especially children (FAO/WHO, 2009Cressey and Jones 2009; FAO 2009; Lien *et al*., 2016; Machado et al., 2009; Vandevijvere *et al*., 2010).

It is for the foregoing reasons that this project was designed to establish the presence and levels of Sulphur dioxide residues in the fruit-based non-alcoholic beverages consumed in Kenya with a view to determining the level of exposure of the chemical to the Kenyan consumer.

4.3 Materials and Methods

4.3.1 Data Collection

4.3.1.1 Sample collection

This study was conducted from July 2021 to June 2021, where a total of 384 samples, comprising of 120 fruit drinks, 80 fruit nectars, 100 fruit juices and 84 dilutable fruit drinks samples were purchased from the Major supermarkets in Nairobi, Kenya. The samples were then analyzed for total Sulphur dioxide content (Appendix 1). Information on the distribution of different fruit-based beverages in the market was used to estimate the fruit flavors, brands and beverage types collected.

4.3.1.2 Food consumption data collection

Food consumption data were derived from the food consumption surveys. Information was collected using a structured self-administered questionnaire (Appendix 3). The questionnaire determined the frequency and amount of fruit-based non-alcoholic beverages consumed by different population groups in Nairobi County. The study's target groups included preschoolers aged 3 to 6 years, children aged 7 to her 18 years, and adults (ages 19 and older).

Participants were purposively sampled from the five major supermarket chains i.e., 30 participants from Tuskys, 30 from Naivas, 30 from Quickmatt, 30 from Carrefour and 30 from Chandarana food plus. The supermarkets provided a convenient approach for intercepting consumers of fruit based non-alcoholic beverages. The 150 participants were randomly selected and proportionately subdivided into 3 groups (Pre- school children, children & adolescents, and adults). Each group contained 50 people. Parents or guardians were requested to provide information for the preschoolers who could not communicate.

The self-reported body weight and age of participants was recorded, while a standardized weighing scale was used to measure the weights of those who did not know their body weight.

The daily intake of Fruit-based non-alcoholic beverages was determined using the cup/glass estimation method. The standard cup /glass was equivalent to 250 ml. The reported number of glasses of the beverages taken per day were then recorded and estimated using the following equation (Khan, Bruce, Naidu and Owens, 2009):

TDBI L person (L person-1 day -1) = BA × NG

Where,

TDBI = total daily intake of beverage (L/day/person)

BA = amount of beverage per glass

NG = number of glasses consumed in a day.

4.3.2 Analysis of total residual Sulphur dioxide content

The total Sulphur dioxide contents of the non –alcoholic fruit based beverages were determined according to Tanner method, as described by Kenya standard Method (KS 432, 1984) .In this method, the fruit beverage to be analyzed for total Sulphur dioxide is heated to boiling in a distillation flask in the presence of phosphoric acid and methanol while a stream of nitrogen as a carrier gas is passed. The Sulphur dioxide thus driven off is oxidized to sulphuric acid in a receiver containing neutral hydrogen peroxide; it is determined by titration with sodium hydroxide. Fifty (50) milliliters of fruit juice and 50 mL methanol are added to the distillation flask. To the distillation receiver are added 10 mL hydrogen peroxide solution and 60 mL water followed by a few drops of mixed indicator, then 0.01 N acid or alkali is added till the color changes to green. The receiver is then connected to the apparatus. At the beginning of the distillation the ground stopper above the receiver is removed while the phosphoric acid is run in. After replacing the stopper, a stream of nitrogen gas is passed through and the liquid in the flask is with a small burner to boiling and then brought to a gentle boil for exactly 15 minutes. When the distillation is complete the receiver is removed, the gas inlet tube being rinsed with water within (from the stopper) and without before finally detaching the flask. Sulphur dioxide which is trapped in the hydrogen peroxide solution and oxidized to form sulfuric acid is titrated with standardized 0.01 – N sodium hydroxide solution until a green color appears.

The total Sulphur dioxide was calculated by the following formula:

1 mL 0.01 N NaOH represents 0.32 mg SO_2 mg/L; SO_2 = a x 6.4,

Where a = mL 0.01 N NaOH used.

The Results were expressed as total Sulphur dioxide content in mg/l

4.3.3 Determination of exposure to Sulphur dioxide (SO_2) through consumption of fruit-based non-alcoholic beverages sold in Nairobi, Kenya

In Kenya, food Consumption Survey on fruit based beverages among different population groups has not been done. Therefore, the consumption data used in exposure assessment of sulfites in various fruit based beverages in this current study, was derived from a Food survey questionnaire (Appendix 3), where the average daily intake by different population groups was determined.

4.3.3.1 Determination of exposure to Sulphur dioxide (SO_2) through consumption of fruit-based non-alcoholic beverages sold in Nairobi, Kenya

The dietary exposure to SO_2 through the consumption of fruit based non-alcoholic beverages was calculated by using the deterministic method, as suggested in the previous study (Fanaike et al., 2019), using the formula below:

Exposure to SO_2 (mg/kg/day) = (∑ <u>(concentration of Sulphur dioxide × food consumption (kg/day)</u>
body weight (kg)"

The mean SO2 concentration for each sample category was used.

4.3.3.2 Determination of risk of Sulphur dioxide (SO_2) through intake of fruit-based non-alcoholic beverages sold in Nairobi, Kenya

The risk of Sulphur dioxide intake through consumption of fruit-based non-alcoholic beverages was calculated as % of ADI by dividing estimated exposure to SO_2 intake for each population group to respective daily Intake of 0.7 mg/kg body weight (JECFA, 1999) and expressed as percentage, using following equation (Fanaike et al., 2019):

$$\text{Risk of exposure to } SO_2 \text{ (\% ADI)} = \frac{\text{Estimated Dietary exposure (mg/kgBW)}}{\text{Acceptable Daily Intake (mg/kg BW)}} \times 100\%$$

4.3.4 Statistical Analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS) 16.0 software and Microsoft Excel 2016. Data were presented as mean ± standard deviation (SD) and the significant differences were explained at (P< 0.05).

4.4 Results

The levels of residual Sulphur dioxide in different fruit based beverages, expressed in µg/kg is shown in Table 3.

Table 3: Average Sulphur dioxide (SO_2) residue in fruit based beverages consumed in Nairobi, Kenya

Sample (Beverage/Drinks type category)	Total Number of Samples analyzed	Mean±SD	Range	Maximum permitted level (mg/kg)
Fruit Drinks	120	1.25±2.58a	0.00-9.00	10
Fruit Juices	100	0.56±1.71b	0.00-8.4	10
Fruit Nectars	80	0.49±1.47b	0.00-7.90	10
Dilutables	84	21.45±13.85c	0.00-43.60	10

The means with the same letter are not significantly different at 95% confidence interval (P> 0.05), while those with different letters are statistically significant.

There were no significant differences in residual SO_2 levels between the different types of ready-to- drink fruit- based beverages ($p > 0.05$).. However, dilutable fruit drinks had significant differences, with higher levels than other types of fruit-based drinks (fruit drinks, juices, and nectars)

Only 11(13.1%) out of 84 fruit juices, 12(12%) out of 100 fruit nectar and 27(22.5%) out of 120 fruit drinks detected Sulphur dioxide residues, which were all within the acceptable level. However, 69(86.3%) out of 80 dilutable drinks had Sulphur dioxide residues of which 57 (71.3%) of 80 were having Sulphur dioxide residues above the acceptable limit. The types of sulphites used as preservatives in in these products were sodium metabisulfite and SO_2. The highest and significant SO_2 residue levels were found in dilutable/concentrated drinks, which ranged from 0.00-43.60 with a mean of 21.52±13.85 mg/kg, followed by fruit drinks with mean SO_2 residue levels of 1.25±2.58, 0.56±1.71, while the lowest were found in fruit juices and nectars with mean sulphite level of 0.56±1.71mg/kg and 0.49±1.47 mg/kg, respectively. Most of the beverages that had SO_2 but not mentioned on the product packaging had levels below 10 mg/kg, except for one brand which had 14 mg/kg.

The Sulphur dioxide levels for all the categories of fruit based beverages were below the MPL of 10 mg/kg, except for the dilutables, which went as far as four times the acceptable levels. The highest Sulphur dioxide levels were detected in the dilutables fruit drinks at 44, 43, 42, 40 and 38 mg/kg in fruit punch squash, tropical squash, fizto drink, cocopine fruit drink and mango colado cordials respectively.

There was no significant difference in residual sulfur dioxide levels among ready-to-drink beverages, namely fruit juices, nectars and drinks ($p > 0.05$). Levels ranged from 1.6 to 9.0 g/kg in orange, red grape, apple, orange, tropical and lemon juices, drinks and nectars. About 4 out of the 5 brands found with added Sulphur dioxide residues had declaration label, while two brands that contained Sulphur dioxide residues had no mention of this on the label.

Statistically, SO_2 concentration in the fruit based beverages had no positive and significant correlation ($p>0.05$), with °Brix and pH content as presented in (Table 4).

Table 4: Correlation (r) of Sulphur dioxide (SO_2) residue levels with PH and °Brix in fruit based beverages consumed in Nairobi.

	PH		°Brix	
Sample	**Correlation (r)**	**P-value**	**Correlation (r)**	**P-value**
Fruit Juices	0.095	0.39	0.026	0.813
Fruit Drinks	0.129	0.159	0.05	0.589
Fruit Nectars	0.016	0.875	0.008	0.938
Dilutable	0.07	0.539	0.089	0.433

Overall, 84 percent of all the population groups surveyed (Table 5) consumed fruit based non-alcoholic beverages per day, with the highest frequency found among children aged 7-18 at 67 %, followed by adults at 65 % and preschoolers aged 3-6 at (46%) as the lowest consumers.

Table 5**:** % intake frequency of Fruit based non-alcoholic beverages by different population groups in Nairobi, Kenya

Population Group	Never, %	< Once per Day, %	2-4 times per week, %	5-6 times per week, %	Once per week, %
Preschool children (3-6 years)	1.8	30	45	20	3.2
Children (7 – 18 yrs)	1.1	36	49	10	3.9
Adults (19 years and above)	11.1	15	25	9	39.9

Daily intake of fruit based non –alcoholic beverages varied significantly among the different population groups ($P < 0.05$). Daily intakes were 125.2 ± 2.6, 229.8 ± 3.3 and 186.5 ± 2.5 for preschool children, ages 7 to 18 years and adults respectively (Table 6).

Table 6: **Average daily fruit based beverages intake and body weight for different population groups in Nairobi, Kenya.**

Characteristics	**Pre-school children (n = 50)**	**Children (7-18) adults (n = 50)**	**(19 years and above (*n* = 50)**
	Mean ± SD		
Weight (kg)	20 ± 2.1	45 ± 1.9	60 ± 2.1
Daily Intake (ml)	125.2 ± 2.6	229.8 ± 3.3	186.5 ± 2.5

The average distribution of body weight by age was 20 ± 2.1, 45 ± 1.9, 60 and ± 2.1 for pre-school children (3-6 years old), children (7-18 years old) and for adults (19 years' old and above) respectively

The mean daily exposure to SO_2 through the intake of fruit based beverages for preschool children, children (7-18 years) and adults were 0.032, 0.021, and 0.020 mg/kg body weight/day, respectively, while the corresponding daily exposures for the high end consumers were 0.086, 0.058 and 0.053 respectively (Table 7)

Table 7: **SO_2 exposure (mg/kg bw/day) from consumption of Fruit-based non-alcoholic Beverages and % ADI for different population groups in Nairobi, Kenya.**

Sample	**Age:3-6 daily intake (mg/kg bw/ day)**	**% ADI**	**Age : 7-18 daily intake (mg/kg bw/day)**	**% ADI**	**Age :19 and Above daily intake (mg/kg bw/ day)**	**% ADI**
Fruit Juices	0.004	0.5	0.002	0.34	0.002	0.31
Fruit Drinks	0.008	1.12	0.005	0.74	0.005	0.69
Fruit Nectars	0.003	0.44	0.002	0.29	0.002	0.27
Dillutables	0.134	19.15	0.089	12.77	0.082	11.74
Total	0.032	4.55	0.021	3.04	0.020	2.79

Determined risk of Sulphur dioxide (SO_2) through intake of fruit-based non-alcoholic beverages sold in Nairobi, Kenya, was 5 % (preschool children), 3 % (children aged 7 to 18) and 3 % (adults) (table 8), while the corresponding daily risk of exposure was 12, 8 and 7 % respectively (table 9)

High Consumers: The risk of exposure to high consumers was further determined using the 90th and 95th Percentile (Table 8 and 9).

Table 8 : SO2 exposure (mg/kg body weight/day) from consumption of Fruit-based non-alcoholic Beverages and % ADI for High-end consumers in Nairobi, Kenya, using 90th Percentile.

Sample	**SO2 Mg/Kg**	**Age:3-6 daily intake (mg/kg bw/ day)**	% ADI	**Age : 7-18 daily intake (mg/kg bw/ day)**	% ADI	**Age :19 and Above daily intake (mg/kg bw/ day)**	% ADI
Fruit Juices	2.1	0.013	1.88	0.009	1.25	0.008	1.15
Fruit Drinks	5.4	0.034	4.82	0.023	3.21	0.021	2.96
Fruit Nectars	4.1	0.026	3.66	0.017	2.44	0.016	2.25
Dilutable	40	0.25	35.71	0.167	23.81	0.153	21.9
Total	12.9	0.086	11.52	0.054	7.68	0.050	7.16

Table 9: **SO2 exposure (mg/kg body weight/day) from consumption of Fruit-based non-alcoholic Beverages and % ADI for High-end consumers in Nairobi, Kenya, using 95th Percentile**

Sample	**SO2 Mg/Kg**	**bw/**	% ADI	**Age : 7-18 daily intake (mg/kg bw/ day)**	% ADI	**Age :19 and Above daily intake (mg/kg bw/ day)**	% ADI
Fruit Juices	4	0.025	3.57	0.017	2.38	0.015	2.19
Fruit Drinks	8	0.05	7.14	0.033	4.76	0.031	4.38
Fruit Nectars	4.8	0.03	4.29	0.02	2.86	0.018	2.63
Dilutable	41.56	0.26	37.1	0.173	24.74	0.159	22.76
Total	14.59	0.10	13.03	0.06	8.69	0.056	7.99

4.5 Discussion

In Kenya, the maximum permissible level for Sulphur dioxide in fruit based beverages is 10 mg/kg. In this study, Sulphur dioxide residual levels (were detected in some fruit based beverages sold in Nairobi, Kenya. The highest amounts of sulphite were found in the dilutable fruit drinks followed by fruit drinks, while the lowest was found in fruit juices and nectars. 57 out of 84 (61.11%) dilutable beverages had SO2 levels above the maximum permissible limit (10 mg/kg) per Kenyan national law (CAP 254, 2021), whereas the levels in Fruit juices, nectars and drinks were all below the maximum permitted levels, with the highest level being 9 mg/kg. These levels are similar to those reported in a study carried out in Bosnia and Herzegovina to measure sulfite in fruit juices and diets for infants and toddlers (Marjanović et al., 2021).

The mean residual levels of SO_2 were significantly higher in dilutables than the fruit juices, nectars and drinks probably due to higher SO_2 dosage used during the processing of dilutable drinks, either due to lack of knowledge on the permitted dosage of SO_2, or to cover up of the inferior process. This could have also been attributed to the fact, SO_2 is restricted in fruit juices, nectars and drinks, but allowed in dilutables; though within the acceptable limits and conditions. The differences in SO_2 result$_s$ may indicate the varying use of sulphites in the fruit beverage industry.

When compared to the 21st ATDS FSANZ (2005) study conducted in Australia and New Zealand, the residual SO_2 levels were slightly lower (10 mg/kg) compared to the dilutable levels (21 mg/kg).Similar findings were also reported in some commercialized juices available on the Brazilian market (Machado & Toledo 2008; Leclercq *et al*., & Suh *et al.,* 2009). However, the findings reported by Arushi Jain & Pulkit Mathur (2016) in Delhi, India suggest that the presence of sulphites in ready -to -serve fruit based beverage was higher than the maximum levels allowed by the national and international laws. The slight differences between the findings of the current study and other studies might be due to the differences in PH content of the samples, sulphitation process or the methods of test used in determining SO_2 (Leclercq *et al*., 2000; Lou *et al*., 2017; Machado *et al*., 2008; Mischek & Krapfenbauer-Cermak, 2012; Soubra *et al.,* 2007).

In the present study, the average daily sulphite intake of fruit based beverages were 0.041, 0.034 and 0.031 mg/kg bw/day for preschoolers, ages 7-18, and adults, respectively which were lower than the figures established by FSANZ (2005) in study done in Australia and New Zealand for cordials as 0.12, 0.07, and 0.07 mg/kg bw/day for Australian preschoolers, adult females and males, respectively. The results show that there was a slight difference in SO_2 intake between the age groups. The intake increased slightly with the age. The intake could be attributable to the fact that an increase in food consumption increases with age. Among the different population groups, the SO_2 intake was between 5 to 7 % of their corresponding ADI. The intake of SO_2 intake for children aged 3 -6 years was notably greater at 7 % of their ADI. This is because children have higher intake of food per kilogram compared to adults, thus highly exposed, due to their low weights. Result further indicate that the main source of sulphite exposure for all population groups came from the dilutable drinks, which were two to four times higher than other beverages. It was also reported by the FSANZ (2005) 21st ATDS Assessment Study of Dietary Exposure of cordials, conducted in Australia and New Zealand. Despite high SO2 levels in dilutable beverages above the 10 mg/kg MPL allowed by Kenyan standards, ADIs for all population groups were below 0.07 ADI, with most fruit-based beverages containing levels within the levels set in legislation.

4.6 Conclusion

In general, SO2 use in most fruit-based beverages was within the respective acceptable residue levels and acceptable daily intake levels (ADIs) for all population groups, including high-end consumers, as per the Kenyan legislation. Although the risk of SO2 exposure was acceptable to Kenyan consumers, the presence of high levels of residual sulfur dioxide in dilutable beverages poses serious health risks and safety concerns, especially for sulfite-sensitive consumers.

4.7 Recommendation

The relevant government authorities should monitor and ensure that the SO_2 in food and drinks produced and sold in the country are safe and complies with the permitted levels, uses, and conditions established in the legislation. Furthermore, there is need for government to institute food recalls due to excess and undeclared Sulphites.

Excessive and frequent consumption of beverages, especially dillutable drinks should be avoided by individuals' sensitive to SO_2. The manufacturers should be made aware of appropriate labelling, to enable those people with allergies or sensitivities to certain food additives make informed choices.

CHAPTER FIVE: GENERAL CONCLUSIONS AND RECOMMENDATIONS

5.1 General Conclusions

SO2 levels in most fruit-based beverages are within the permissible safe limits permitted by Kenyan law, and therefore the use of SO2 as a preservative in most beverages does not pose a serious public health and safety concern. Non-alcoholic fruit-based beverages sold and consumed in Kenya also meet the quality, labeling and packaging requirements laid down in relevant Kenyan standards.

From this study, it can be concluded that his dietary exposure to SO2 from consumption of fruit-based soft drinks was below his corresponding Acceptable Daily Intake (ADI) in all population groups. However, frequent and excessive consumption of dilutables may exceed the ADI, raising health and safety concerns.

5.2 General Recommendations

There is need of a complete risk assessment more refined dietary exposure assessment and consumption data on the same and/or all other foods with added sulphites or other additives, this will help determine exposure in total diets.

Implementation of risk management measures applicable to Sulphur dioxide by government, manufactures and consumers could help in mitigating risk of exposure to SO_2 from consumption of fruit based beverages and other foods. Appropriate Process controls should be put in place to ensure that excessive amounts of SO_2 are not added to beverages.

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APPENDICES

Appendix 1: Self- Structured guide used in the Collection fruit based non-alcoholic beverage samples from the major supermarket chains in Nairobi, Kenya

Beverage Type	Brands /trade mark	Fruit Flavor	Fruit Juice content %	Type of packaging and Size	Ingredients declared	Country of Origin
e.g fruit nectar	e.g PEP	e.g Mixed/Tropical/punch Passion e.t.c	e.g 100 %	e.g plastic bottles of 1 litre etc	e.g Sugar, water e.tc	Local or import

Appendix 2: A list of Supermarkets Surveyed and Sampled

No.	Naivas Supermarkets	Carrefour	Tusky's	Quick Mart	Chandarana Foodplus supermaket
1	Westlands - In the Mall, Westlands Delta, Waiyaki Way	Sarit Center, karuna Rd	T-Mall, Langata Rd	Mombasa Rd, near Nextgen Mall	Yaya, Yaya Centre
2	Capital Centre - Capital Centre Mombasa Road	The Junction Mall, Ngong Rd	Imara, Accra Rd	Tom Mboya	Ngara, Parklands/Highridge
3	Lifestyle-In Hazina Trade Centre, Ground Floor	Two Rivers Mall, Off Limuru Rd	North View, Thika rd	Waiyaki Way	Head Office, 3rd floo, 197 Lenana, Lenana Rd
4	Ronald Ngala Street	TRM, Thika Rd	Beba Beba, Mondlane St.	Pipeline, Off Outer Ring Rd	Highridge Branch, Masari Road
5	Moi Avenue, Development House	Nextgen, Mombasa Rd	Karasha	Kilimani	Lavington Branch

6	Ruaraka	Galleria,	Southfield Mall	Buruburu	Ridgeways Mall, Kiambu Rd
7	CBD, Moi Avenue, Opposite Imenti House	The Hub Karen	Thigiri Ridge Rd	Fedha	The Well Karen, Langata Rd
8	South C, Mohoho Rd	Mega Mall	Adams Arcade	OTC, Ladhies Rd	ABC Place, Waiyaki Way
9	Eastgate, Outer Ring Rd	Village Market	Race Course Rd, Equity Bank OTC	Roasters	Karen, Ngong Rd
10	Kilimani, Tigoni Rd	Westgate Mall	Biioto, Langata Rd	Kikuyu Rd	Muithaiga, Mobil Plaza, Muthaiga Rd
11	Hazina, Checkers Pub, Plainsview Rd		Magic express, Ronald Ngala St. Starehe	Kahawa West	Rosslyn, Limuru Rd
12	Green House Branch		Pioneer, Moi Avenue	Jipange	James Gichuru, Rd
13	Komarock, Kariobangi South Komarock, Kayole Rd		OTC, Ladhies Rd, Oil Libya	Next to Eastmatt, Mfangano St.	Two Rivers
14	Langata, Free Heights Mall		Reli Co-op House, Mfangano St	Embakasi, Rd to Utawala Academy	
15	Kangemi, Kangemi Shopping Centre			Lavington, Westfield Mall	
16	Prestige, Prestige Plaza, Ngong Rd				
17	Tassia				
18	Muindi Mbingu St, Nairobi				
19	Mountain Mall				
20	Ciata Mall, Kiambu Rd				
21	Kasarani				
22	Riruta				

Appendix 3: Consumption Survey Questionnaire for consumers of fruit based non-alcoholic beverages in Nairobi County, Kenya

CONSUMPTION SURVEY OF FRUIT BASED ALCOHOLIC-BEVERAGES IN NAIROBI, COUNTY

The study was designed to determine beverage consumption patterns for different population groups in Nairobi County. The Quantitative food consumption data obtained will be used to conduct exposure assessment of the populations to SO_2 in beverages consumed.

1. Background information: General information

Interview Date:

Location of interview (Name of supermarket):

2: Respondent information

2. 1. Age (years)

3-6 yrs.

7-18 yrs.

19 yrs. and above

2.2. Estimated body weight (Kg)

3. Consumer Survey

3.1 In the past one week, how often did you drink fruit-based non-alcoholic beverages?

Fruit-based non-alcoholic beverages:	Daily	2-4 times a week	5-6 times a week	Once a week	Rarely/Never
Fruit juices					
Fruit drink					
Fruit Nectars					
Dilutables					

3.2 How many servings do you consume each time you drink the beverages

- 1/2 cup/glass = 125 mL
- 2/3 cup/glass = 150 mL
- 3/4 cup/glass = 175 mL
- 1 cup/glass = 250 mL
- 1 1/2 cups/glass = 375 mL
- 2 cups/glass = 500 mL
- 3 cups/glass = 750 mL
- 4 cups/glass = 1 liter
- More than 4 cups

Thank You.