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Formulation of functional beverage from a blend of baobab (*adansonia-digitata*), pineapple (*comosus ananas*) and black-plum (*syzygium cumini*) fruits

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**FORMULATION OF FUNCTIONAL BEVERAGE FROM A BLEND OF
BAOBAB (*Adansonia -digitata*), PINEAPPLE (*Comosus ananas*)
AND BLACK-PLUM (*Syzygium cumini*) FRUITS**

Tawakalt Omolara Adedokun

**A Dissertation Submitted in Partial Fulfilment of Requirements for the Degree of
Master's in Life Sciences of the Nelson Mandela African Institution of Science and
Technology**

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ABSTRACT

Several under-utilized tropical fruits have essential micronutrients and phytochemical composition with the potential to contribute to the nutrition of people in many poor communities where they are grown. This study was carried out to investigate the use of juice blends of baobab, pineapple, and black-plum fruits as functional beverages for human benefits. To understand potential consumers' unmet need for healthy drinks, a knowledge, attitude, and consumption pattern (KAP) survey was conducted and it was revealed that most (85%) of the 151 participants seek affordable healthy beverages from a blend of juices with moderate sweetness and flavor. Pasteurized juice blends of baobab, pineapple, and black-plum fruits were analyzed for physicochemical, antioxidant, sensory properties, mineral compositions, and storage stability at 4°C for 4 weeks. The results showed that the vitamin C contents of individual juices synergistically contributed to the high values observed in the blends (317.45-414.51 mg/L). Juice blends of baobab, pineapple, and black-plum fruits are good sources of calcium (57-153 mg/L), magnesium (71-130 mg/L), and antioxidants (ascorbic acid, total polyphenol contents (65-104 mg GAE/100 mL), scavenging ability (105.97-359.71 $\mu\text{mol TE}/100\text{ mL}$), and reducing potential (1376-1829 $\mu\text{MFe}^{2+}\text{ L}$) the consumption of which can promote human health. Physicochemical parameters of juice blends were stable at refrigeration temperature (4°C) in the first two weeks; however, color change was observed towards the end of the fourth storage week. The formulated ready-to-drink (RTD) beverages compared well with a known market sample for sensory parameters with improved taste and consumer acceptability and showed good antioxidant potential although there was a relative decrease in vitamin C content during storage at both refrigeration and ambient temperatures. These findings reveal that baobab fruit pulp, pineapple, and black-plum fruits can be major ingredients in producing an antioxidant-rich functional beverage that meets the preferences of consumers.

DECLARATION

I, Tawakalt Omolara Adedokun, do hereby declare to the Senate of The Nelson Mandela African Institution of Science and Technology that this dissertation is my original work and that it has neither been submitted nor being concurrently submitted for a degree award in any other institution.

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by The Nelson Mandela African Institution of Science and Technology, a dissertation titled “**Formulation of functional beverage from a blend of Baobab (*Adansonia -digitata*), Pineapple (*Comosus ananas*) and Black-plum (*Syzygium cumini*) fruits**” in partial fulfillment of the requirements for the degree of Master’s in Life Sciences of the Nelson Mandela African Institution of Science and Technology.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of Variance
BFCS	Baobab Fruits Company Senegal,
BPB	Baobab-pineapple-black plum juice blends
CMC	Carboxyl Methyl Cellulose
DNPH	2, 4- dinitrophenylhydrazine.
DPPH	2, 2 -diphenyl-1-picrylhydrazyl radical scavenging method
FRAP	Ferric Reducing Antioxidant Power assay.
GAE	Gallic Acid Equivalent
ICP	Inductively Coupled Plasma technique
KAP	Knowledge, Attitude and Consumption
MRPs	Maillard Reaction Products,
RDA	Recommended Dietary Allowances
ROS	Reactive Oxygen Species
RTD	Ready-to-Drink beverages
SOP	Standard Operation Procedure
TPC	Total Polyphenol Content
TSS	Total Soluble Solids
TTA	Total Titratable Acidity
USFDA	United States Food and Drugs Authority
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Recently, food and beverages are used as nutraceutical in disease prevention and management. Beverages are the most active functional food category because of the ease of dissolution of functional components and convenient method of consumption (Corbo *et al.*, 2014). Functional foods are foods or food components that provide a health benefit beyond basic nutrition. The awareness of consumers towards the association between food and health has increased their interest in healthy foods. The bioactive compounds present in these functional foods make them play a role in the prevention of several human diseases such as chronic degenerative diseases (Nazir *et al.*, 2019) thereby improving the quality of life. Frequent consumption of fruits and vegetables has the potential to contribute to good and healthy living, reduce the chance of cardiovascular disease, and have a protective role against diabetes and several non-communicable diseases (Kovačević *et al.*, 2020). These benefits of fruits are attributed to their natural compositions including vitamins such as B-vitamins, ascorbic acid, β -carotene, vitamin E, and folic acid; minerals like potassium, calcium, iron; dietary fibers, antioxidants, and other bioactive compounds essential for human health, constitute their functional attributes. These functional attributes of fruits make them qualify as functional foods.

Fruit-based functional beverages are important sources of vitamins, polyphenols, minerals, and dietary antioxidants that give protection against oxidative stress by increasing cell resistance to reactive oxygen species (ROS) in the system. They are also of significant health benefit for the human body (Siro *et al.*, 2008; Maria & Riccardo, 2020; Liu *et al.*, 2021; Londoño *et al.*, 2017). Pineapple (*Ananas comosus*) being one of the most commonly consumed tropical fruits although highly perishable is considered a good source of dietary fiber and phytochemicals such as carotenoids, flavonoids, phenolic acids, ascorbic acid and therefore a functional fruit (Ayala-Zavala *et al.*, 2011).

Africa is considered a treasure store of wild plants such as spices, herbs, roots, vegetables, and fruits. Although these fruits are under-exploited in most African countries, they contain essential nutrients. Under-utilized fruits have a considerable amount of nutrients and compounds resulting in their high medicinal and nutritional benefits. However, information on their nutrition composition is limited and fragmented (Stadlmayr *et al.*, 2013; Haule, 2016).

Edible wild fruits have been reported to be a good source of bulk micronutrient and bioactive compounds. They are commonly consumed during periods of food shortage or famine in the rural population (Akinnifesi, 2008), contribute to food security, and as well play vital roles in the nutrition of the people especially in the rural communities (Aworh, 2015; Stadlmayr *et al.*, 2010).

Baobab (*Adansonia digitata*), and black-plum (*Syzygium cumini*) fruits are widely distributed under-utilized fruits in tropical Africa and have recently attracted interest as functional fruits due to their exceptional compositions of bioactive compounds with the potential to contribute to food security (Ruffo *et al.*, 2002). Baobab is a naturally dry fruit that is high in pectin, dietary fiber, vitamins, and minerals. Baobab locally known in Tanzania as *Ubuyu*, and in Nigeria as *Kuka* or *Ose* (Sidibe & Williams, 2002) has ten times higher content in Vitamin C compared to orange (Kaboré *et al.*, 2011), high in mineral content such as iron and potassium (Osman, 2004). Vitamin C (ascorbic acid) has a very good anti-oxidant potential as it increases cell resistance to oxidative stress as well as aid the absorption of iron, consequently a natural remedy for anemic conditions (Naidu, 2003). The high potassium content of Baobab is important for regulating blood pressure its minimal sodium content is also good for a healthy heart (Houston, 2011).

Black-plum locally called *Zambarau* also has a significant amount of bioactive compounds, which have functional benefits and is used in the treatment of diabetes (Sharafeldin & Raza, 2015). Black-plum has been reported to have a high antioxidant capacity to reduce oxidative stress, inhibit growth and induce apoptosis of human breast cancer, have anti-inflammatory, anti-microbial, anti-bacterial, anti-fungal, free radical scavenging, gastro-protective and anti-diabetic properties (Tavares *et al.*, 2016; Baliga *et al.*, 2013; Pfuzia *et al.*, 2013).

Blending of fruits has previously been established to improve the nutritional and organoleptic qualities of the blends by synergistically contributing to human well-being when the benefits of all the fruits are combined (Shaheel *et al.*, 2015). The blending of these fruits has the potential to combine their functional characteristics to combat malnutrition, especially micronutrient deficiency among the most vulnerable groups in Africa. This study aims to formulate and investigate the effects of blends of pineapple with baobab fruit pulp and black plum extracts in order to obtain a functional beverage with optimal health benefits.

1.2 Statement of the Problem

Africa among other countries is faced with the double burden of malnutrition and food insecurity. Malnutrition forms an important health issue with micronutrient deficiency affecting key development outcomes with the health impacts which may not always be visible but significant therefore sometimes termed –hidden hunger. Micronutrient deficiency such as vitamin A inadequacy, and lack of vitamin C, iron, and calcium have been linked to diet-related non-communicable diseases such as diabetes, and degenerative diseases associated with oxidative stress (Nazir *et al.*, 2019). The World Health Organization (WHO) estimates that more than two billion people suffer from micronutrient deficiency globally. According to the Tanzania Demographic Health Survey (TDHS, 2015), micronutrient deficiencies are high among women of childbearing age, with 40% anemic, 36% iodine deficient, 30% iron deficient, and 37% vitamin A deficient.

Wildly grown fruits containing essential micronutrients and antioxidants are cheaply available and yet are underutilized despite their potential to contribute to the nutrition of people and also enhance food security. This could be a result of their repelling attributes to consumers such as; an increase in bulk of baobab powder in water, its dull and cloudy appearance, poor natural taste, and high astringency; a blunt taste of juice from *Syzygium cumini*. Therefore, this current study is meant to formulate a functional beverage with a sufficient amount of micronutrients and antioxidants. This product is expected to be high in phytochemicals such as polyphenols, and vitamin C which helps in the absorption of iron thereby overcoming the problem of anemia and iron deficiency and increasing cell resistance to oxidative damage.

1.3 Rationale of the Study

Wildly grown fruits containing essential micronutrients and antioxidants are cheaply available and yet are underutilized despite their potential to contribute to the nutrition of people and also enhance food security. This could be a result of their repelling attributes to consumers such as; an increase in bulk of baobab powder in water, its dull and cloudy appearance, poor natural taste, and high astringency; a blunt taste of juice from *Syzygium cumini*. Until now, the combination of baobab, pineapple, and black-plum fruit juices is unavailable globally especially in Tanzania markets as well as any know market in East Africa.

Therefore, this current study is meant to formulate a functional beverage with a sufficient amount of micronutrients and antioxidants. This product is expected to be high in

phytochemicals such as polyphenols, and vitamin C which helps in the absorption of iron thereby overcoming the problem of anemia and iron deficiency and increasing cell resistance to oxidative damage.

1.4 Objectives of the Study

1.4.1 Main Objective

To formulate and investigate the effects of blends of tropical fruits namely; pineapple, baobab fruit pulp, and black plum extract in order to obtain a novel functional beverage with optimum health benefits.

1.4.2 Specific Objectives

- (i) To establish consumers' perception, awareness of health benefits, and consumption patterns of under-utilized fruits in the current study.
- (ii) To evaluate the quality attributes of the blends of baobab, pineapple, and black-plum juices to determine their suitability for use as a functional beverage.
- (iii) To examine the quality of the formulated beverage during storage.

1.5 Research Questions

- (i) What is the knowledge, attitude, and practice of consumers of pineapple, baobab and black- plum fruits in the community where they are found?
- (ii) What combination of baobab-pineapple-black-plum juice/pulp will give the optimum health benefits?
- (iii) What are the quality changes in the formulated functional beverage especially vitamin C?

1.6 Significance of the Study

This study contributes to the scientific body of knowledge on functional foods specifically using *Adansonia digitata* and *Syzygium cumini* as functional ingredients to combat malnutrition.

The Juice blend of these under-utilized wild fruits will promote their utilization to access the available nutrients in the fruits thus meeting the needs and preferences of consumers. A novel

product produced plays a key role in food value addition, enhancing food diversification and reducing postharvest losses of fruits thereby overcoming the challenges associated with food insecurity in sub-Saharan Africa. The product formulated is rich in micronutrients which are essential for proper growth and development, therefore, solving the problem of micronutrient malnutrition.

1.7 Delineation of the Study

This study assessed the juice blends of baobab, pineapple, and black-plum fruits for use as functional beverages. A knowledge, attitude, and consumption pattern (KAP) survey was conducted to establish consumption patterns and awareness of health benefits of these fruits. This study conducted physicochemical, phytochemical and sensory properties, mineral compositions, and storage stability of the juice blends and the formulated ready-to-drink (RTD) beverages from the blends. Findings from this study inform people in the community and food industry to utilize the combination of baobab, pineapple, and black-plum fruits for their optimal health benefits.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Africa is considered a treasure store of wild plants such as spices, herbs, vegetables, and fruits which are underexploited despite their nutrient density. Wild fruits containing essential micronutrients and antioxidants are cheaply available, but underutilized despite their potential to contribute to the nutrition of people and also enhance food security. One of the ways to explore this potential is to develop a refreshing fruit beverage that is acceptable to consumers. Some of the previous research works related to the development of functional beverages from blends of fruits are discussed under the following headings: present status of edible wild fruits in Africa, physicochemical composition, functional and medicinal properties of baobab, black-plum and pineapples, extraction and thermal treatment of juice, blending of fruits, enhancing the stability of functional constituents in beverage, standard analytical method of characterization, the effect of processing on functional components of fruit-based beverages, perspective of functional foods and beverages development.

2.2 Present Status of Edible Wild Fruits in Africa

Wild fruits are indigenous fruits with edible parts which are found growing naturally on farms, fallow, or uncultivated land. They contribute to food and nutrition security, health, and income generation of rural communities in Africa and play important roles in the nutrition of people in the rural area (Stadlmayr *et al.*, 2010; Aworh, 2015). Prominent among wildy grown fruits in the Tabora region, Tanzania, and Miombo woodland savanna include: include Zambarau (*Syzygium cumini*), Mtonga (*Strychnos cocculoides*), Mkwaju (*Tamarindus indica*), Mtalali (*Vitex mombassae*) Mbula (*Parinari curatelifolia*) and Mfufu (*Vitex doniana*), Topetope (*Annona squamosa*).

Adequate consumption of fruits and vegetables has been proved by several epidemiological studies to reduce the risk of chronic diseases such as cancer, diabetes, and coronary heart diseases (ADA88, 2018). In a broad sense, African wild fruits and vegetables include African star apple (*Chrysophyllum albidum*), African mango (*Irvingia gabonensis*), hog plum (*Spondias mombin*), tamarind (*Tamarindus indica*), and roselle (*Hibiscus sabdariffa*), *Amaranthus cruentus*, water leaf (*Talinum triangulare*), Lagos spinach (*Celosia*

argentea), jute mallow (*Corchorus olitorius*), shea tree (*Vitellaria paradoxa*), African locust tree (*Parkia biglobosa*), African eggplant or garden egg (*Solanum aethiopicum*, *Solanum macrocarpon*), bitter leaf (*Vernonia amygdalina*), fluted pumpkin (*Telfairia occidentalis*) to mention but a few. Several kinds of research are recently conducted to promote and expand the utilization of these plants some of which include their conservation, domestication, and valorization to mention but a few.

2.2.1 Baobab

Baobab (*Adansonia digitata* L.) is a deciduous tree indigenous to Africa. It is an ancient tree commonly called African upside-down tree, monkey fruit tree, belonging to the plant family Bombacaceae sub-family Malvaceae. The tree is widely distributed in most of sub-Saharan semi-arid and sub-humid regions of Africa. It is among the prominent forest food resources available in the wild recently gaining recognition as a result of their nutritional composition and it is among the most edible forest trees encouraged to be conserved, domesticated and valorize as a result of its economic importance.

The commonly consumed parts of Baobab are leaves, seeds, and fruit pulp whereas timber, fodder, and fibers are good source of income to rural communities. The fruit pulp of Baobab is naturally dried, abundantly rich in vitamin C, calcium, potassium, magnesium dietary fibre and other phytonutrient beneficial to mankind (Osman, 2004). The dry fruit pulp is often indigenously chewed, sucked and can be eaten raw or made into light porridge, a refreshing drink (Chadare *et al.*, 2008). In Nigeria, the fermented seed is used as a sweetener for many local foods. In Tanzania, baobab fruit trees are found along the shores of Lake Malawi, Shire River and majorly in the central zone of Tanzania. The fruits are in season from April to September (Chadare *et al.*, 2009; Tembo *et al.*, 2017). Baobab fruits are locally processed into different products including juice, gruel, sour dough, oil, a coffee-like drink and dried as food reserves (Mborra *et al.*, 2008; Chadare *et al.*, 2008). Baobab is considered to have strong potential as a functional food (Braca *et al.*, 2018) as a result of its health-promoting constituents. Baobab fruit products are already gaining popularity on the international market including Baobab Fruits Company Senegal (BFCS), a company in the UK. Most western organic food and drug companies are realizing or becoming aware of its potential health benefit.

The baobab fruit has both nutritional and medicinal benefits. The major constituents of the fruit pulp are vitamin C and bio-accessible polyphenols. These contribute to the higher anti-oxidant

capacity of the pulp than that of other common fruits known as shown in Table 1. Several *in vivo* and *in vitro* studies have established the potential of baobab to reduce glycemic response (GR), improve carbohydrate-rich foods, its potential as prebiotic (Abdullahi *et al.*, 2014).

The prevalent phytochemicals that have been identified so far with Baobab pulp include: polyphenols (such as phenolic acid, procyanindins, tannins); organic acid such as (malic acid, tannic acid) which contributes to its tartness taste: vitamins (ascorbic acid); mineral elements (calcium, potassium, iron, magnesium). Reports on this nutritional composition varies, this is due to different geographical locations in which the plant is grown.

2.2.2 Pineapple

Pineapple (*Ananas comosus*) belongs to the genera *Ananas* and Bromeliaceae family. It is a highly perishable and most commonly consumed tropical fruits, considered as a good source of dietary fiber and phytochemicals such as carotenoids, flavonoids, phenolic acids, ascorbic acid (Ayala-Zavala *et al.*, 2011). Pineapple is one of the most common fruits in Tanzania after banana and citrus. The major pineapple growing area in Tanzania is Bagamoyo district in Coastal region. It is one of the world most widely grown and acceptable tropical fruit despite its high perishability. It is often included among the super fruits being a good natural source of macronutrient, micro nutrients and bioactive compounds that have positive effects in the prevention or treatment of many human diseases. Ascorbic acid, polyphenol compounds, carotenoids, dietary fiber, antioxidant, as well as Bromelain are the main bioactive compounds present in pineapple that have reported health benefits (Valderrain-Rodríguez *et al.*, 2017; Ngereza & Pawelzi, 2016). Although there are several varieties of pineapple fruits, 6-8 cultivars are generally commercially cultivated. The common varieties include 'Smooth Cayenne', 'MD2' (sweet, low-acid cultivar), 'Queen', 'Konasugarloaf' 'Smooth Cayenne', 'Red Spanish', 'Queen', and 'Abacaxi.

2.2.3 Black Plum

Syzygium cumini (syn. *Eugenia jambolana* (L.) SKEELS; *S. jambolana* DC; Family: Myrtaceae), commonly known as black plum or Java plum or Jamun is a plant native to India; it is called *Zamabarau* in Swahili. The cultivars commonly found in Tanzania are the wild varieties. Annually, the trees produce oblong or ellipsoid fruits berries. They are green when raw and purplish black when fully ripe. The ripe fruits are sweetish sour to taste and are used to prepare health drinks, squashes, juices, jellies and wine. Studies have shown that the black-

plums contain carbohydrates, pectin, minerals and the pharmacologically active phytochemicals like flavonoids, terpenes, and anthocyanins (Mukhopadhyay & Chaudhary, 2012). The main phenolic compounds in black plum abundant mainly in the edible part of the fruit are anthocyanins and hydrolyzable tannins (gallotannins and ellagitanins), flavanones, flavonols and flavan-3-ols (Tavares *et al.*, 2016).

The presences of these polyphenols, anti-oxidants and other phytonutrients in the pulp make it important in reducing the oxidative stress-induced diseases. The seeds and leaves are used in alternative medicines for digestive ailment, diabetes treatments, as anti-inflammatory, antipyretic, astringent, and antidiarrheal agents. Black plum has been reported to have good antioxidant, anti-inflammatory, anti-microbial, antibacterial, antifungal, free radical scavenging, gastro-protective and anti-diabetic properties (Baliga *et al.*, 2013; Tavares *et al.*, 2016).

2.3 Physico-Chemical Composition, Functional and Medicinal Properties of Baobab, Black-Plum and Pineapples

Baobab is a multipurpose wild fruit tree used primarily for its fruits, having all its part useful. It has been reported to be rich in dietary fibre, minerals (calcium, iron, magnesium, and sodium), vitamin C, organic acids, essential amino acids, sugars, sterols, saponins, triterpenes, flavonoids, high levels of procyanidin B₂ and (-)-epicatechin, cellulose, fibres and tannins (Kaboré *et al.*, 2011). The presence of flavonols and vitamin C provide evidence for its antioxidant properties.

Table 1: An overview of potential health-promoting constituents of Baobab, Pineapple, and Black-plum fruits

Black-plum	Pineapple	Baobab
Anthocyanin	vitamin C	Vitamin C
Fibre	Polyphenol compounds	dietary minerals
Ellagatanins	Dietary fibre	Polyphenols Flavonols
Glycoside.	Carotenoids	Minerals
Flavonoids	Bromelain	Tannins
Ellagic acid		Flavonoids Organic acids

2.4 Antioxidants in Fruits

Several studies have pointed out the importance of fruits and their association with reduced risk of developing chronic diseases. Frequent consumption of fruits and vegetables has the potential to contribute to good and healthy living, reduce the chance of cardiovascular disease, and have a protective role against diabetes and several non-communicable diseases (Bursac Kovačević *et al.*, 2020). The antioxidant potential of fruits results from their natural compositions including vitamins (ascorbic acid, beta carotene, alpha -tocopherol) carotenoids (carotenes, Xanthophyll, lycopene), polyphenols (caffeic acid, ferulic acid, anthocyanins), and other secondary metabolites such as glucosinolates (Martín-belloso *et al.*, 2016).

Antioxidant when consumed in sufficient amount can reduce free radical-induced oxidative stress, resulting from cellular toxic processes such as oxidation gene mutation which induce carcinogenesis, DNA damage, lipid oxidation. Antioxidant activity, TPC, and vitamin C (ascorbic acid) content are major parameters to evaluate the quality and potential health benefits of fruit juice.

2.5 Blending of Fruits

Blending has turn out to be an innovative and convenient way to utilize highly nutritive fruits and vegetables whose utilization is limited resulting from their shortcomings such as bitterness, high acidity, astringency, off-color and flavor. It has contributed to the economic utilization of the wild fruits in new product development which increases the availability of their nutritional

and medicinal benefits to meet the growing needs of the consumers nowadays. Blending of fruits has previously been established to improve the nutritional and organoleptic qualities of the blends by synergistically contributing to human well-being when the benefits of all the fruits are combined (Shaheel *et al.*, 2015). Fruits and vegetables can be blended to form smoothies, ready-to-serve (RTS) beverages, jelly, jam, juices, fruit drinks, nectar, squashes, and natural health drinks. Several studies have reported that several fruits juices/pulp may be blended together to improve organoleptic quality (taste, flavor and color) storability, nutritional quality and functional characteristics of the final blend (Bhardwaj & Pandey, 2011). It also has the potential to combine the individual functional characteristics of fruits to combat malnutrition.

2.6 Enhancing Stability of Functional Constituents in Beverages

The major concern of a newly formulated product is stability. Preservation usually prevents adverse changes in the nutritional and sensory characteristics of food. This is completed by controlling chemical, biochemical, physiological and microbiological activities using various techniques. Heat or cold handling, moisture removal, adding preservatives, sugar, salts and acids, and non-thermal preservation methods are the main techniques to maximize stability and maintain the quality of juices.

Thermal processing and the use of natural preservatives are also included because they are inexpensive and standard approaches to ensuring fruit juice preservation, (as used in this study). In developing countries, non-thermal treatments such as pulsed electric field (PEF), high pressure homogenization (HPH), and ultrasound (US) have a higher potential for fresh and healthy fruit juices, but they are very costly and not available.

The common approaches to ensuring the preservation of fruit juices are thermal processing and the use of preservatives. The effects of processing on the stability of bioactive compounds in foods vary between procedures, so it is very important to choose the right processing method for a specific food product for effective quality control (Aderinola, 2019). Several authors stated that due to the development of new compounds such as Maillard reaction products (MRPs), thermal processing increased antioxidant activity and total phenol content (Kedare & Singh, 2011; Tchuenchieu *et al.*, 2018). Fruit juices are also treated with chemical additives that are required to prolong the shelf life of fruit juices. Combined mild temperature treatments

with use of antimicrobial better preserved, antioxidant capacity, and vitamin C content, and color as well as increased total phenolic content of fruit juices (Tchuenchieu *et al.*, 2018).

These suppress the activity of oxidative enzymes such as polyphenol oxidases by altering their substrates or by restricting the availability of oxygen for microbial development.

Potassium sorbate and sodium benzoate are the preservatives widely found in commercial fruit juices. There is, however, a higher demand for the use of healthy natural antimicrobials with low toxicity levels. Food acids and preservatives (antimicrobials such as ascorbic acid, citric acid, malic acid and cinnamon bark oil) are widely used.

2.7 Standard Analytical Method of Characterization

2.7.1 Physicochemical Properties of Food

Generally, the physicochemical properties of food and beverages are measured using the recommended standard methods of Analyses. (AOAC, 2005). This includes the measure of hydrogen (H⁺) and hydroxide (OH⁻) ions in food-**pH**; the measure of soluble sugars in food-**total soluble solid**; the measure of total acid concentration in a food, -titratable acidity; the ratio of sugar to acid in food- sugar -acid ratio; the amount of water present-moisture content; the measure of flow ability of the sample-viscosity etc. The pH of food and beverages are measured usually with an instrument called pH meter which can be portable and movable/ bench-type. It is expedient that the meter is standardized using two buffers usually of pH 4, 7 and / 9 depending on the anticipated sample pH. pH is measured directly or potentiometrically (an electrochemical method of voltammetry) (Nielsen, 2010).

Titrate acidity is obtained by neutralizing the acid in food sample of a known quantity with a standard alkali (usually sodium hydroxide) using phenolphthalein as the indicator. A color change or a stable pH is usually an indication of the end point of the neutralization reaction. The common organic acids in food include citric, acetic, malic, lactic and tartaric acid. Food inorganic acids such as carbonic and phosphoric play important role in food acidulation while the organic food acids influence the flavor (tartness), color, keeping quality as well as microbial stability (resulting from sensitivity of various organism to pH). The titrate acidity is expressed in term of the dominant organic acid in the food sample such as (% citric acid) using the formula:

$$\% \text{ acid} = \frac{N \times V \times M}{S \times 10}$$

Where: N= Normality of standard NaOH solution, V= Volume of NaOH used (ml), M= Molecular weight of predominating acid in the sample, e.g., Citric acid=64.04, S= Sample size in Millilitres or grams

Total soluble solid is determined using an instrument called refractometer which can be bench or portable digital or analogue. The amount of dissolved sugar in the sample at 20 °C is measured as the brix content. Sugar/ acid ratio is important quality parameters as it determines:

Moisture content: This is an important quality factor in industry for a number of reasons: food preservation, food quality determination, and food resistance to deterioration. The dry matter remaining after removing moisture from food sample is called total solids.

Samples of known weight is measured into hot air oven and dried until a constant weight is reached. Percentage moisture is calculated using the formula below:

$$\% \text{ moisture} = \frac{\text{Weight of H}_2\text{O in sample} \times 100}{\text{Weight of wet sample}}$$

$$\text{Moisture (\%)} = \frac{(\text{weight of wet sample +pan}) - (\text{weight of dried sample +pan})}{(\text{Weight of wet sample +pan}) - (\text{weight of pan})} \times 100$$

2.7.2 Phytochemical Properties of Food

Vitamin C (Ascorbic acid) determination: There are several ways of determining vitamin C content in food and beverages, these include; titrimetric method, spectrophotometric method, and HPLC method. Ascorbic acid is determined titrimetrically using 2, 6 dichlorophenol-indophenol dye and expressed in mg/100ml (Tilman method). This is the official method of vitamin C determination for juices. This method may not be official for other types of food products; it is however used as a rapid, quality control test for a variety of food products.

Spectrophotometric method explains the determination of the total vitamin C (ascorbic acid + dehydroascorbic acid) in food samples using 2, 4-dinitrophenylhydrazine as described by Rahman *et al.* (2006) and Kapur *et al.* (2012).

HPLC method gives more rapid result for vitamin C determination but it is more capital intensive. Details of the equipment, sample and standard preparations, HPLC condition, expression and calculation of results are given in the prepared SOP.

Antioxidant capacity: In order to evaluate antioxidant potential of biological samples such as plasma, fruits beverages, several rapid methods are developed to measure antioxidant contents which connote their protection ability against oxidative damage. Using a single method is not suitable for all, it is therefore imperative to combine several methods to establish antioxidant activity of samples.

Results of these methods may vary depending on the specificity of the free radical used as well as the experimental conditions. All of the known methods include; radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging method, the oxygen radical scavenging absorbance capacity (ORAC) assay and the ferric reducing antioxidant power (FRAP) method, ABTS radical scavenging assay. DPPH assay applies to the overall antioxidant capacity of the sample and therefore has wide applications especially for food samples (Kedare & Singh, 2011). The DPPH assay method is based on the reduction of DPPH, a stable free radical. The free radical DPPH with an odd electron gives a maximum absorption at 517nm (purple color). When Antioxidants react with DPPH, which is a stable free radical becomes paired off in the presence of a hydrogen donor (e.g. a free radical scavenging antioxidant) and reduced the DPPH and consequently reduced to the DPPH-H form resulting in decolorization (yellow color) (Shekhar & Anju, 2014).

The ORAC assay measures the relationship between the antioxidants and the peroxy radicals, whereas the FRAP method measures the total reducing capacity of any compounds in the test materials. Principles of FRAP assay: At low pH, ferric Tripyridyltriazine (Fe^{III} -TPTZ) complex reduces to ferrous form with an accompanying intense blue color; this is monitored by measuring the changes in absorption at 593 nm.

Phenolic phytochemical are natural substances found in plant with great antioxidant capacity. Total polyphenol content is determined using the modified Folin-Ciocalteu spectrophotometric method described by Singleton *et al.* (1999) and reported as gallic acid equivalent (GAE).

2.8 Perspective of Functional Foods and Beverages Development

Functional foods/beverages are becoming significantly popular in the generation of today as consumers are becoming aware and more conscious of their health. Functional beverages provide potential health benefits including vitamins beyond the recommended daily intake, usual satisfaction of hunger (satiety), digestive health, immunity boosting, daily nutrient requirements, lowering cholesterol level, and providing energy.

The global market for functional beverages is on the increase. Sahar *et al.* (2019) reported the projection of functional beverage sales to be 135 billion USD as at 2017 and 185 billion USD by 2023. Wide varieties of acclaimed functional beverages are available in the global market, this includes; energy and sport drinks, dairy-based beverages, prebiotic-based beverage, fruit and vegetable-based beverages, cereal-based beverages, micronutrients-enriched drinks.

Innovation in functional food and beverages starts with the consumers (Sorenson & Bogue, 2009; Bleiel, 2010; Sahar *et al.*, 2019). Good consumer knowledge provides direction for the new product design and strategic marketing at the long run. Integrating the consumers need and preferences from the beginning of the product development process resulting from their requirements for healthy food with benefits to improve their health, wellness and quality of life can go a long way to enhance product success in the market. Consumer-oriented approach rather than technology-oriented strategies is the modern strategy to penetrate the functional food market. It is also important to have a good knowledge of consumers' problem; understand their behaviors, need and unmet desires, know their willingness to spend money for relevant functional benefits and have a technological know-how of how to solve such problems (Gruenwald, 2009; Bleiel, 2010; Granato *et al.*, 2020).

Several scientific advances made in the area of functional beverages include but not limited to: optimization of ingredient for the formulation of novel functional beverage, exploitation of microorganisms to enhance the functionality benefits, the use of natural ingredients, valorization of fruit by-products as a functional ingredients, use of non-digestible food ingredients which impact benefits to human in functional beverages formulations, application of non-thermal treatment to functional beverages to preserve their functional properties. (Gruenwald, 2009; Sun-waterhouse, 2011; Nazir *et al.*, 2019) The design of these beverages are to address several specific modern health challenges such as to reduce mental stress,

physical fatigue, enhance concentration, weight management, digestive health, detoxification, eliminate reactive oxygen species which can improve the overall quality of life.

There are salient features that need to be considered in designing novel beverage formulations. The ingredients have to be uniquely combined and synergistically formulated to serve the desired purpose without exhibiting any significant adverse effects. It is important to study the interaction that might occur as a result of the combinations of individual ingredients whether their functionality is reduced or lost especially at keeping temperatures/conditions (Sun-waterhouse, 2011)

A number of ingredients possessing functional properties are innovatively combined to meet the needs of consumers, these include standardized extracts from natural sources, marine nutraceutical, membrane stabilizers, selected amino acids, vitamins and antioxidant (Swaroop *et al.*, 2017). It is important to note that structural integrity of the combined ingredients should not be altered under the conditions of storage; however, a permitted additives/GRAS-affirmed constituents such as appropriate preservative, antioxidant, acidulants, stabilizers may be added in order to maintain the integrity of the beverage (USFDA, 2018).

CHAPTER THREE

MATERIALS AND METHODS

The description of materials used, experiments, and techniques employed during the investigation have been described under the following headings: sample collection, analytical reagent, other materials, experimental methodology, and analysis.

3.1 Sample Collection and Preparation

All the fruit samples namely: baobab, black-plum, and pineapples used in this study were obtained fresh from Arusha in the northern part of Tanzania. The indigenously grown pineapple variety (*smooth cayenne*) produced from the Tanga region of Tanzania was obtained from a local farmer's market. Wildly produced black-plum and baobab fruits were picked at commercial maturity during the April 2019 harvest season from the Babati community. The local varieties of these fruits were identified at the nearby research center, Tengeru Agricultural Research Institute (TARI), Tengeru, Arusha, Tanzania.

The dry pulp of baobab fruits was manually separated from the pod and fiber using mortar and pestle, sieved, and blended into a fine powder. Blemish-free thoroughly washed black-plum fruits were selected and treated according to the method of Rai *et al.* (2011), kept at the freezing temperature until used. Matured pineapple fruits were selected and thoroughly washed under running tap water and peeled using stainless steel knives.

3.2 Analytical Reagents and Other Materials

All the Chemicals used were of analytical grade and purchased from Sigma-Aldrich and Merck. These include; Folin- Ciocalteu reagent, Methanol, Trolox, Gallic acid, L-ascorbic acid standards, 1, 1- diphenyl-2-picrylhydrazyl (DPPH), and 2, 4- dinitrophenylhydrazine (DNPH).

3.2.1 Other Materials

Other materials used were of food grades obtained from local food chemical shops in Arusha, Tanzania. These include citric acid, granulated sugar, carboxyl methyl cellulose (CMC), E466, potassium sorbate, and sodium benzoate.

3.3 Experimental Methodology

3.3.1 Functional Beverage Knowledge, Attitude and Practices Assessment Survey

A baseline survey study was conducted to assess the consumers' perception, awareness of health benefits, and consumption pattern of under-utilized fruits under study. The need and preferences of potential consumers of (BPB) functional beverages in terms of taste, cost, consistency, availability, and health benefits were evaluated. This was achieved through interviews. The survey was conducted in 3 randomly selected communities namely: Babati, Nambala, and Tengeru in Arusha region of Tanzania to determine the consumption patterns of raw fruits and functional (health) beverages produced from the fruits under study.

The sample size was 50 in each community resulting in 151 participants altogether. It was calculated taking the type 1 error ($\alpha = 0.05$) into consideration. Respondents were randomly selected, based on consent, during visits to the market, homes, schools, and workplaces in the selected communities. A semi-structured/closed-ended questionnaire was used during the interviews to obtain information from customers on background characteristics of respondents, frequency of consumption, perceptions of functional (health) beverages consumption, desire for functional/healthy non-alcoholic beverages and to evaluate the needs they expect in juice and other beverages. The respondents' needs were translated into products in the next objective. The research was orally explained to the participants and a consent form was given to them while they filled out the questionnaire within 30 minutes.

3.3.2 Extraction of Pulp/Juice and Preparation of Baobab-Pineapple-Blackplum Fruit Juice Blend

The juice extraction of black-plum was done by the hot break pulping method (Lal *et al.*, 1986) described by Sharma (2016). Water was added to whole fruits (1:1), heated at 60 °C for 5 minutes, homogenized, and double-filtered through a sieve to remove the seed and fibers. Baobab fruit pulp was minimally processed by adding the powder to portable water (1:10), properly homogenized, filtered using a muslin cloth, and kept in a refrigerator prior to mixing. Pineapple juice was made using a juice extractor (Kenwood, JE680 series, China).

3.3.3 Fruit Juice Blending

Separate juices of baobab, pineapple, and black-plum fruits were blended in different ratios, in samples (F1-F7) while 100% Baobab juice, 100% pineapple juice, and 100% black-plum fruit juice were extracted in samples (F8-F10) without blending as shown in the mixing ratio given in Table 2. The juice blends were mixed in previously washed and sterilized bottles, pasteurized at 80°C for 5 min, cooled, and immediately stored at 4 °C for subsequent analyses.

Table 2: Blends of baobab, pineapple, and black-plum (BPB) fruit juices at different ratios (volume, %)

Fruit juices	F 1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Baobab	33.3	50	25	25	50	37.5	12.5	100	-	-
Pineapple	33.3	25	50	25	12.5	50	37.5	-	-	100
Black-plum	33.3	25	25	50	37.5	12.5	50	-	100	-

3.3.4 Development of Baobab, Pineapple, Black-Plum Based Health Drink

Two different blends from the previous experiments were chosen based on having higher phytonutrient composition and used as a base for the formulation of acceptable functional fruit beverages. Samples F7 and F5 were selected, and the total soluble solids (TSS) and pH were adjusted using sugar syrup and citric acid following the specifications from (CODEX STANDARD, 2005).

Sugar syrup was prepared by boiling calculated amounts of sugar and water and mixed with blended fruit juice following the Pearson Square methods described by Dr. Ali in Practical Action (see Appendix 2-a). The final formulation contained 40-50% fruit parts (mixed fruit juice content %), portable water, and other food additives (Appendix 2-b). In order to preserve the phytonutrient compositions of the juices and prevent microbial growth, permitted preservatives viz potassium sorbate and sodium benzoate at 100 ppm were added all together. No artificial color was used. Figure 1 shows the unit operations involved in the formulation of the baobab-pineapple- black plum juice blend functional drink. Similar commercial fruit beverages which were considered loved by consumers were purchased from local supermarkets in Arusha (names provided in Appendix 2-c) and served as a benchmark to evaluate consumer acceptability of the developed product and see whether it has a chance to be commercialized. The formulated beverages were then subjected to analysis to establish their contents.

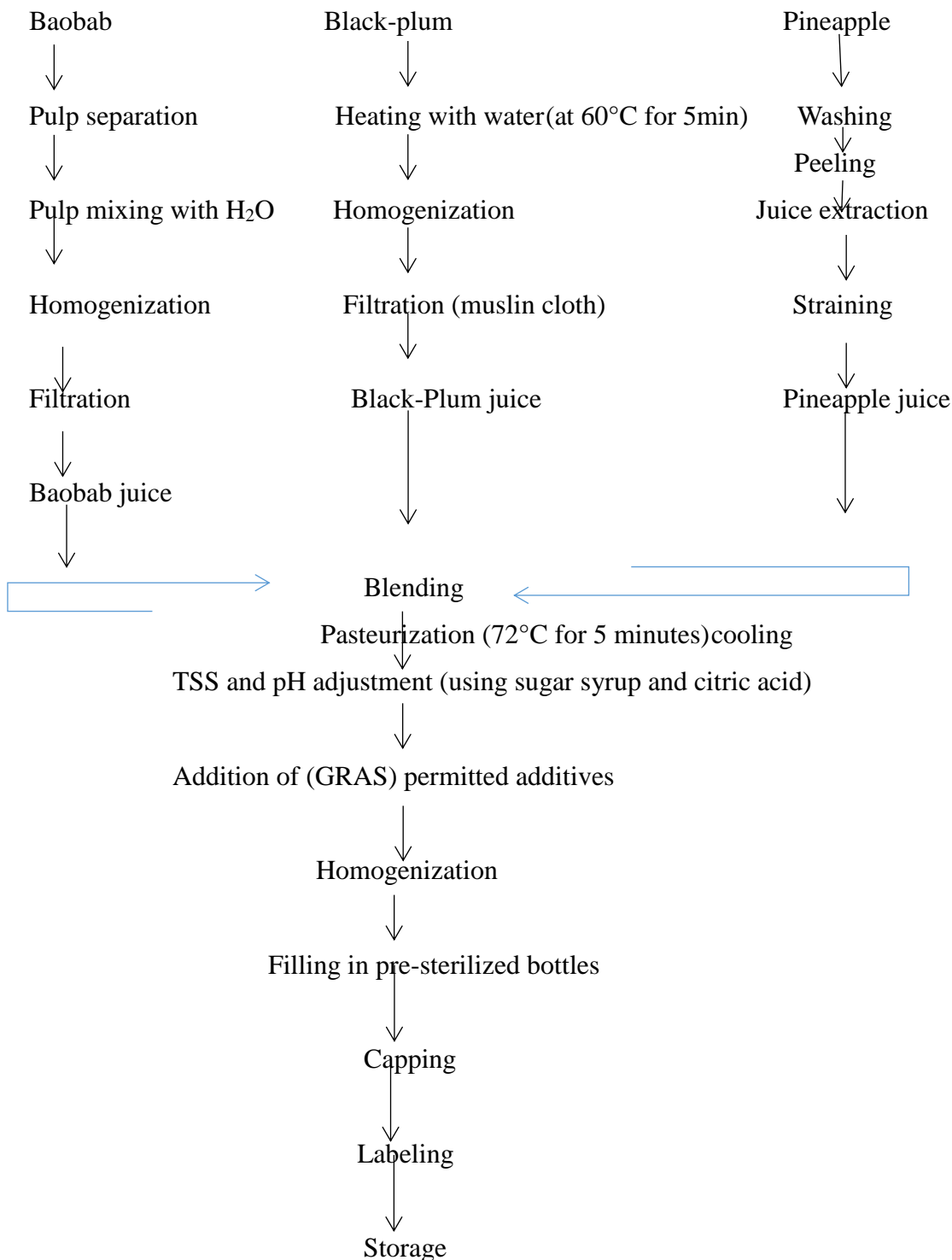


Figure 1: Flowchart showing unit operation for the formulation of BPB functional beverages

3.4 Analyses

Baobab, black-plum, and pineapple fruit juices/ juice blends and their developed functional beverages were analyzed for physicochemical, antioxidant, microbiological, sensory properties, mineral compositions, and storage stability. Standard methods employed in this study are described below:

3.4.1 Physico-Chemical Properties Determination

Physicochemical properties such as pH, total titratable acidity (TTA), total soluble solids, TSS ($^{\circ}$ Brix) and color of the juices were determined using the recommended standard method of analysis (AOAC, 2005). pH of the juices was measured using a digital pH meter (GMH Griesinger 3500 series, Germany) previously calibrated using 4 and 7 pH buffers. TTA of the juices was determined using a semi-titrator (Titronic basic, UK). Brix was measured using a hand-held refractometer (Model Erma, Japan) of range 0-32 $^{\circ}$ Brix at 20 $^{\circ}$ C/ bench refractometer (Atago, Japan). The color of the samples was read using a spectrophotometer (MetaVue, X-rite, VS3200, Switzerland).



A



B

Plate 1: A- bench refractometer (Atago) measuring brix of samples, and B Spectrophotometer (MetaVue) measuring color of samples

3.4.2 Phytochemical Properties Determination

The prominent phytonutrients in the juices tested in this study are total vitamin C (ascorbic acid and dehydro-ascorbic acid), total polyphenol compounds and the antioxidant capacities.

(a) Determination of vitamin C (ascorbic acid) content

The ascorbic acid content was determined using spectrophotometry method described by (Kapur *et al.*, 2012). Approximately, 3% bromine water (w/v) was added to 4 mL of centrifuged sample solution previously obtained from homogenizing 5 mL of juice with 25 mL of metaphosphoric acid - acetic acid solution, followed by the addition of 10% thiourea (w/v), and 1 mL of 2,4- dinitrophenylhydrazine. The mixture was incubated at 37 °C for 3 hours and 85% H₂SO₄ (v/v) was added before reading the absorbance at 521 nm using a microplate reader (Synergy HTX, multi-mode reader, Chicago, USA). Ascorbic acid (100-1000 mg/L) standard was used and quantification was done using the standard curve.

(b) Total phenolic content (TPC) determination

Total phenolic contents of the juice samples were determined using the modified Folin-Ciocalteu spectrophotometry method described by (Singleton *et al.*, 1999). One milliliter of the juice samples was mixed with 9 mL of distilled water; 1.0 mL Folin–Ciocalteu reagent was added to the mixture and shaken. After 5 min, 10 mL of 20% NaCO₃ (w/v) solution was added with mixing, the solution was immediately diluted to volume (25 mL) with distilled water and incubated for 23 °C for 90 minutes and absorbance was read at 750 nm. TPC was quantified by plotting the calibration curve using gallic acid (6.25-100 mg/L) as the standard and expressed as mg gallic acid equivalent (mg GAE/ mL) of the sample.

(c) Determination of antioxidant capacity

❖ *DPPH radical scavenging activity determination*

DPPH radical scavenging activity of juice blends was determined using the method described by Shekhar & Anju (2014) with some modification. About 4 ml of 0.1 mM methanolic DPPH solution was added to 200 µL of the juice sample and left in the dark at room temperature for 30 min. Absorbance was read at 517 nm using a microplate reader and standard curve generated using Trolox standard (50-1000 µM).

❖ *Ferric ion reducing antioxidant power (FRAP) assay*

Reducing power of the juice was determined using FRAP assay following the method of (Benzie & Strain, 1999) with some modification. Ferric ion reducing antioxidant power reagent was added to 100 µL test samples and standards in 15 mL falcon tubes, vortex mixed and kept

at 37 °C for 4 min. Absorbance was read at 593 nm using a microplate reader. Standard curve calibration was made using FeSO₄.7H₂O as the standard ranging from 100-1000 µM.

3.5 Analysis of Mineral Content

The mineral content of the juices/ juice blends was determined using (ICP) Inductively Coupled Plasma technique (iCAP7200 Duo, Thermo scientific, China) according to the method described by Akubor (2017).

3.6 Anti-Nutritional Factor Test

A preliminary screening for the presence of tannin was done on the formulated beverage (Kumar *et al.*, 2009). About 3 drops of 1% lead acetate was added to 5 mL of the samples. The formation of faint yellow precipitate indicated the presence of tannin which was quantified by using Folin Ciocalteu method (Makkar, 2003).

3.7 Microbial Analysis of Fruit Juices

The final developed beverage was examined for microbiological safety using total plate count method (AOAC Microbiology, 1984). One ml of the beverage after serial dilution (10^{-2} , 10^{-4} , 10^{-6} , 10^{-8} , and 10^{-10}) was aseptically inoculated into disposable sterile plates containing total plate count agar (10-15 mL) under a sterile environment. This was followed by incubation at 37 °C for 72 hours. The total plate count was expressed as log cfu/ mL of sample.

3.8 Storage Study

The fruit juice blends contained in 50 mL bottles and bottled formulated beverage samples were stored at refrigeration temperature (4 °C) and tropical room temperature (30 °C). Changes in the physicochemical properties were evaluated in the juice blends weekly at interval for 4 weeks while the final beverages were evaluated for physicochemical properties and changes in the vitamin C content at 3 days interval for 12 days.

3.9 Sensory Evaluation

Sensory evaluation of the juice blends was conducted using 15 semi-trained panelists (trained for 3 hours with blank labeled commercial juices) consisting of members of laboratory staff and post graduate students of NM-AIST, Tanzania using a nine-point hedonic scale as

described in Appendix 1-a. The test was also repeated for the final developed products using additional 15 panels to evaluate the sensory parameters such as taste, mouthfeel, flavor, color and overall acceptability in comparison with commercial fruit beverage as shown in Appendix 1-b. Nearly the same panelists were used throughout the entire period of study. Water and cracker biscuits were provided for each panelist to clear and rinse their mouth after tasting each sample.

3.10 Statistical Analysis

All determinations were done in triplicate and data were subjected to Analysis of Variance (ANOVA) at $\alpha = 0.05$ and mean separation was done with Tukey's Studentized Range test where the model has a significant effect on the variability of the result, using SPSS statistical program (version 21.1 IBM SPSS). Graphs were plotted using GraphPad Prism 8 and Microsoft Excel 2010 packages.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Functional Beverage Perception, Awareness of Health Benefits and Consumption Pattern among the Consumers

Data about knowledge, attitude and consumption pattern (KAP) of functional beverages from under-utilized fruits covered in this study among the consumers where these fruits could be found in the parts of Tanzania are presented and discussed in this section. Knowledge from this survey helped the next objective of formulation to identify the consumer knowledge gaps, beliefs, and behavioral patterns toward the fruits under study in order to provide baseline data that may help plan product formulation-related decisions. This helped to identify consumers' needs as well as their top wellness priorities and preferences regarding beverages.

This study administered a total of 151 questionnaires through an interview guide to the respondents. All 151 questionnaires were completed hence making the study achieve a 100% response rate. Figure 2 presented the demographic information among 151 participants, 47% were male and 53% were female. The majority of the participants were between the age of 19 and 25 years (25%), single (53%), were educated to secondary (27%) and tertiary school levels (28%), and were gainfully employed (50%). The majority of participants frequently consume fruits at least once a week (69%) and mostly after a meal (52%) according to Fig. 3. The participants are familiar with the fruits under study and they have consumed them at one time or the other, although the frequency of consumption varies as they are available only in seasons, especially pineapple and black-plum. Baobab fruit is available and accessible from the forest and in the market resulting from its low perishability which makes it storable for a long time and available throughout the year.

The consumers' consumption frequency of fruits is 71% at least once a week. Nearly 89% of the participants have processing knowledge of these fruits as they know the fruits can be processed into fruit juice, drinks, and smoothies (Fig. 4). It was found that 98% of the respondent had no knowledge of the term 'functional drink' but have a moderate idea of its meaning- health-providing drinks. According to this survey, most consumers seek health-providing non-alcoholic drinks with added benefits of improving their health rather than just quenching thirst. This agrees with a similar survey where consumers are not familiar with the term 'functional' foods but have an understanding of the concept (Derkyi *et al.*, 2018). Increased

consumer awareness of the relationship between food and health might also have influenced their interest in health-promoting drinks. Major health and wellness interest of consumers in this survey were cardiovascular disease (8.6%), high blood pressure (23.2%), cancer (33.8%), diabetes (22.5%), and stress (Table 4). In similar studies, consumers' primary health concerns are stress, immunity, indigestion, aging, fatigue, weight gain, and cognitive disability (Sahar *et al.*, 2019).

The study finding showed that the most preferred fruit is pineapple because of its taste and characteristic flavor (Table 3). This is followed by black-plum fruit for its sweet taste and bright color. Baobab is the least preferred resulting from its sharpness, flavor, and taste. This justifies the reasons behind the underutilization of baobab and black-plum fruits despite their nutritive value. The majority of the consumers (80.1%) expected to get nutrients from the juice when consumed especially vitamins, minerals, and energy, they have little knowledge of the other health benefits contained in these fruits and juices from them (Table 3). Eighty-five and four tenths' percent (85.4%) of them are very interested in purchasing a healthy drink from these fruits with special preferences for moderate sweetness in taste and providing wellness benefits of interest to them. Consumers have more interest in a beverage from a combination of these fruits if they know it has the potential to give them more health benefits.

It is not enough for a product to be nutritious for it to be successful in the market, understanding the potential consumers' unmet needs is equally important. The functional ingredients should be adequately and innovatively combined in product design in order to meet consumers' needs and be acceptable to them in terms of taste, flavor, and health advantages. These products are not merely to provide basic nutritional benefits to consumers, but also to serve as disease-preventing remedies, and to improve their health and wellness. Therefore, one of the first steps of product development is to explore consumers' needs and preferences so that the product could be successful in the market (Sorenson & Bogue, 2009; Bleiel, 2010).

From the survey results, it can be deduced that consumers need fruit drinks with health benefits (majorly preventing their predisposition to cancer and other modern diseases), affordable, sweet taste, and flavor. In the next study, the negative attributes in the fruits with the least acceptance (baobab and black-plum) were innovatively combined with the most preferred fruit to maximize their benefits while masking those negative attributes.

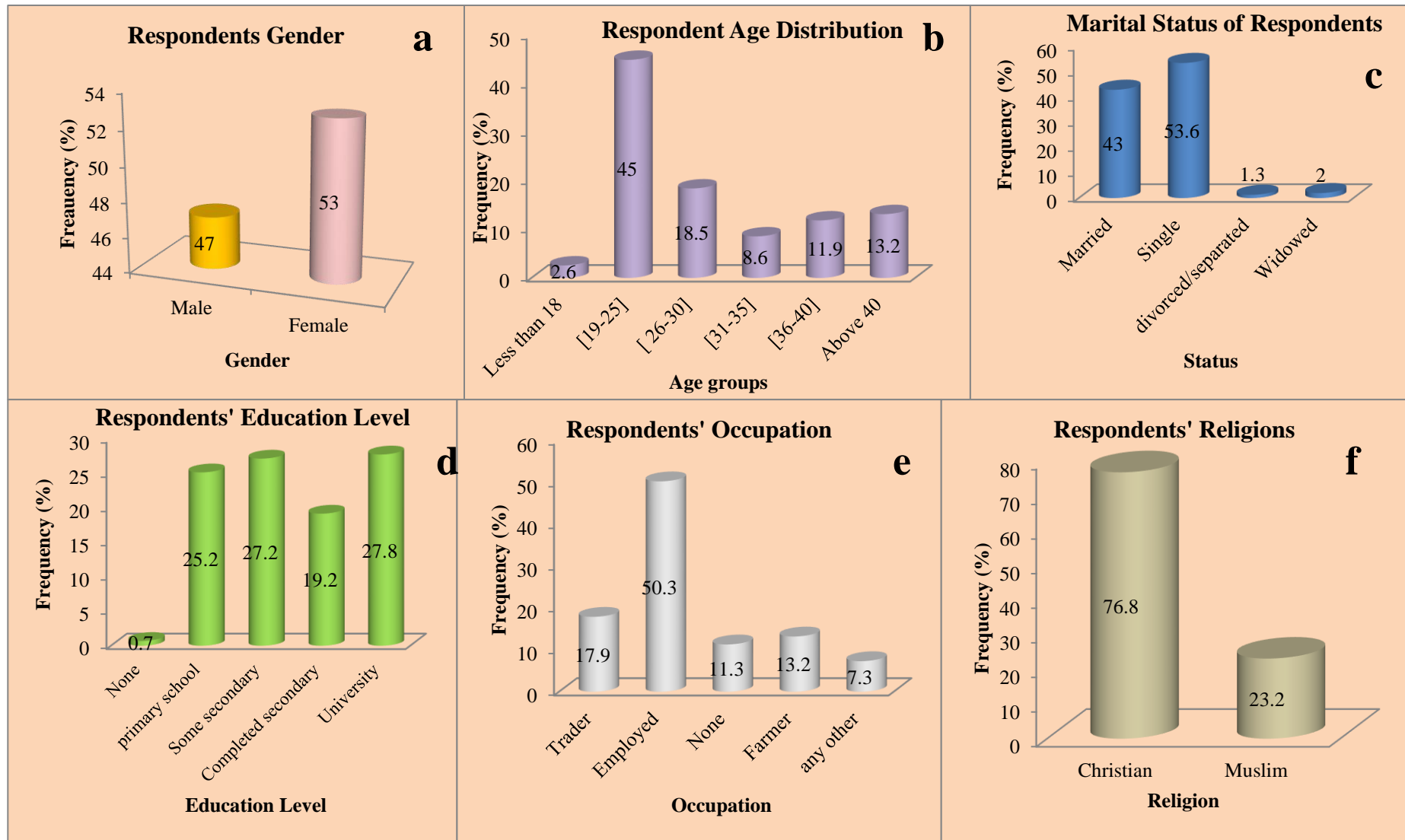


Figure 2: Demographic characteristics of respondents

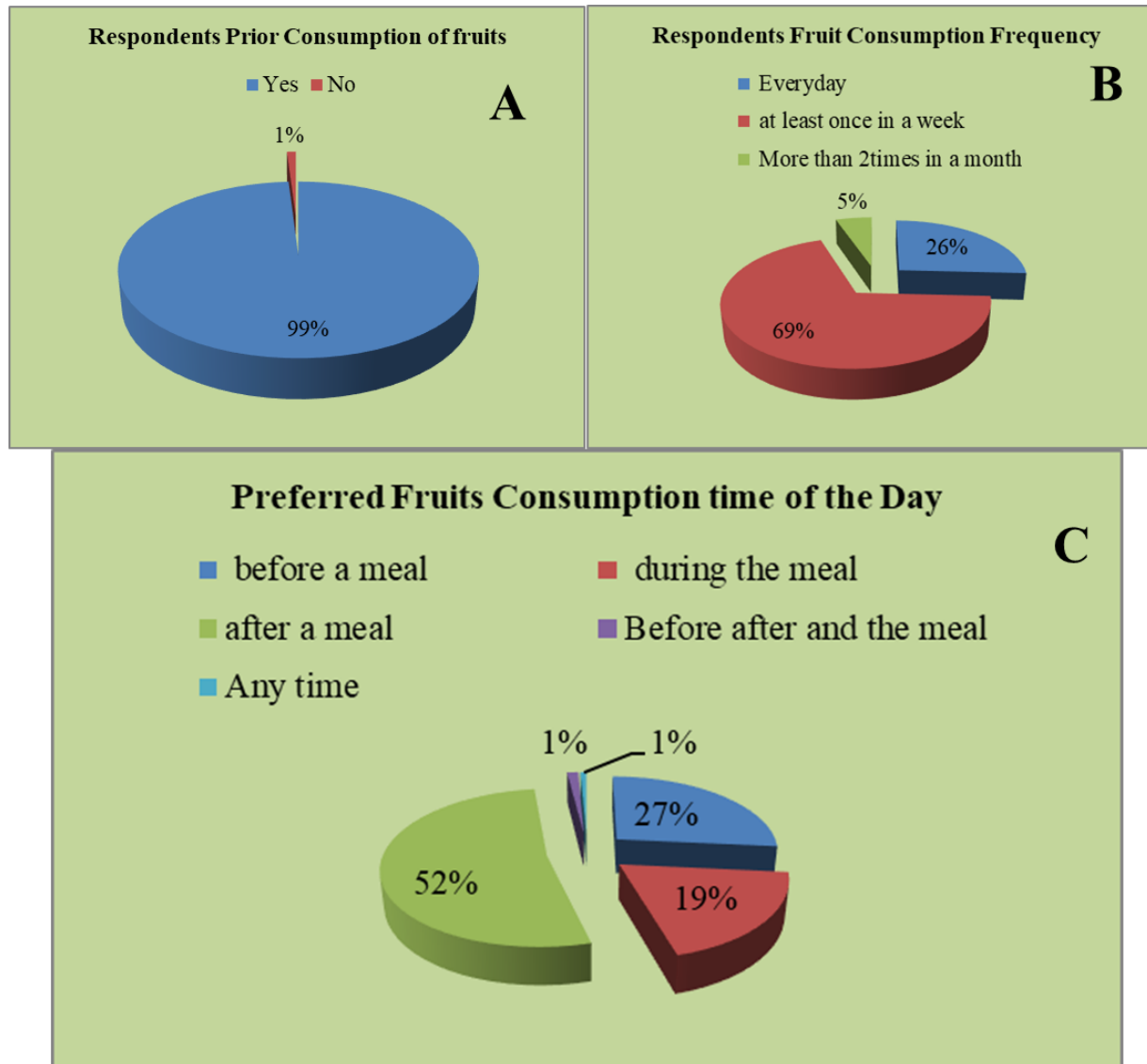


Figure 3: Information on respondent’ prior fruit consumption experience, frequency and preferred consumption time

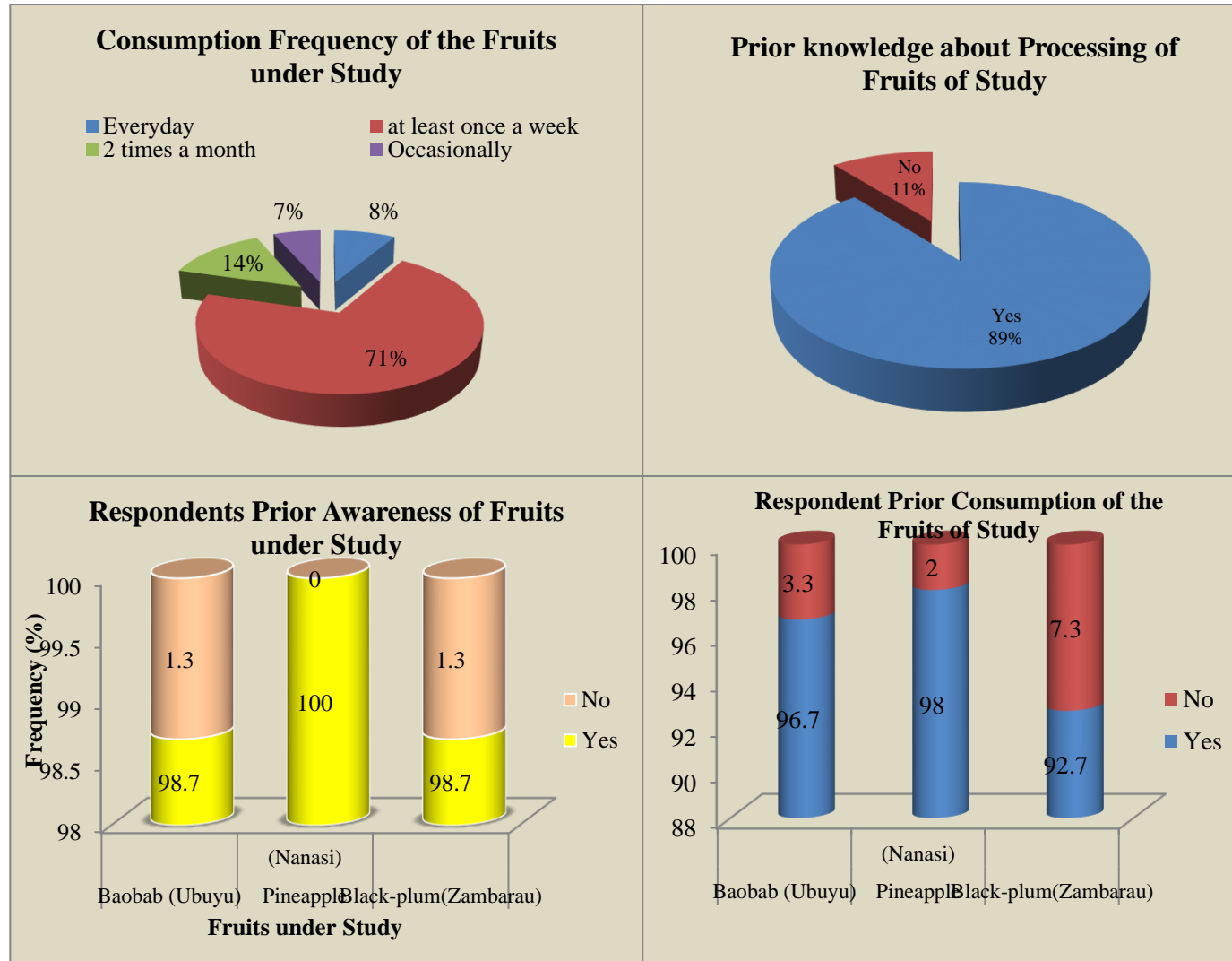


Figure 4: Prior knowledge of the fruits under study

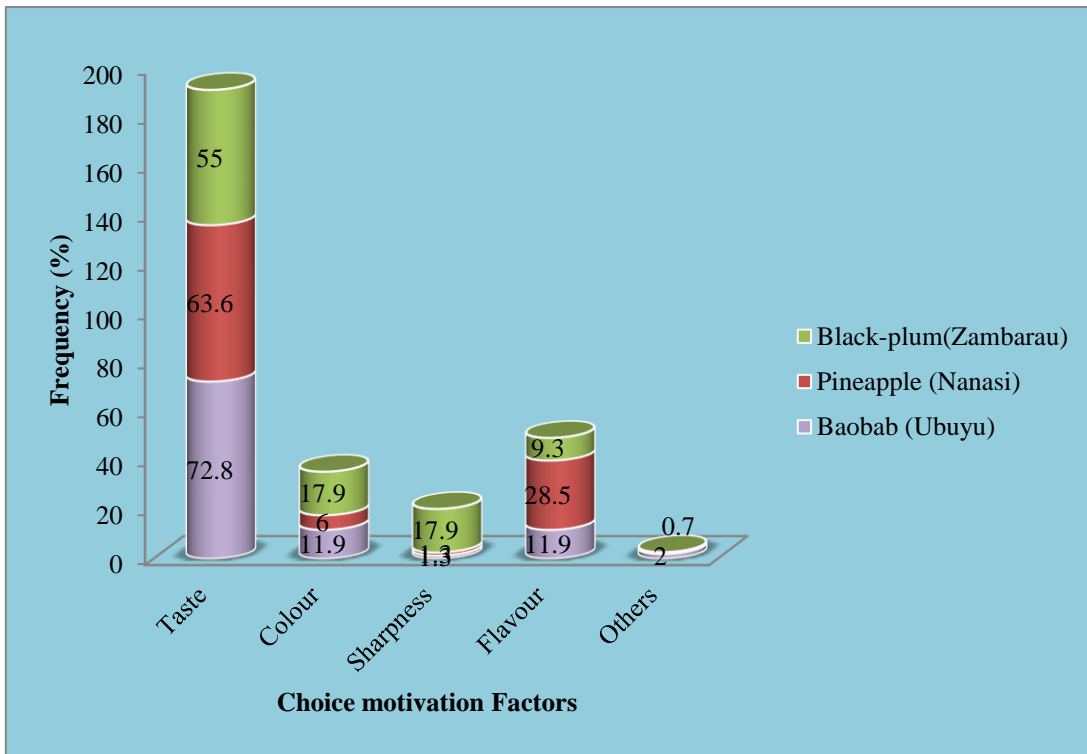


Figure 5: Respondent motivating factors for the individual fruit preferences

Table 3: Knowledge related questions and percentage of correct and incorrect responses

Benefit of Drinks		Frequencies %	
Prevents the risk of diseases		39.1	
Prevents frequency of diseases		55.6	
I don't know		4.6	
Others		0.7	
Knowledge of fruit nutrient			
Minerals		11.3	
Vitamins		86.8	
Anti -cancer bioactives		1.3	
I don't know		0.7	
Preference to buy / processed			
Yes, I prefer to buy		54.3	
No, I can process myself		45.7	
Knowledge of health drinks			
Yes		98.0	
No		2.0	
Preference of fruits under study	Baobab	Pineapple	Black-plum
Like most	19.9	55.6	24.5
Like average	40.4	41.7	16.6
Like least	35.1	27.8	38.4
Motivation to take juice			
To quench thirst		12.6	
For health reason		76.8	
For pleasure		9.3	
For taste		0.7	
Others		0.7	
Consumption of fruits last months	20.5	30.5	6.0

Table 4: Attitude related questions and percentage of correct and incorrect responses

Reasons for Preferences	Baobab	Pineapple	Black-plum
Primary health concern			
High blood pressure		23.2	
Diabetes		22.5	
Stress		0.7	
Cardio vascular diseases		8.6	
Cancer		33.8	
Obesity		5.3	
Others		4.6	
None		0.7	
Expectation when taken juice			
To provide nutrients		80.1	
To boost your energy		19.9	
Interest to buy health drinks			
Yes		85.4	
No		14.6	
Interest to buy combined fruits in the product drinks			
Yes		60.3	
No		28.5	
It depends		5.3	
I don't know		6.0	
Sweetness preference			
Very sweet		24.5	
Moderately sweet		40.4	
Naturally sweet		35.1	

4.2 Physico-Chemical Characteristic of Fresh Baobab, Pineapple and Black-Plum Fruits Pulp/Juice

Fresh baobab, pineapple and black-plum fruits used in this work were analyzed for various physicochemical characteristics as shown in Table 5. Baobab fruit pulp contained 10.84% moisture content, 4.79 Brix, 0.65% TTA, 3.3 pH, and 610.25 mg/L ascorbic acid. The low moisture content helps in the natural keeping ability of the fruit. These results are in close range with the ones reported by Osman (2004) and Adam *et al.* (2016). The results of 105 mg GAE/100 g TPC also conform with the findings of (Ismail *et al.*, 2018; Braca *et al.*, 2018).

Black-plum fresh pulp is rich source of total phenolic (120.97 mg GAE/100 g). It contained 84.18% moisture content, 12.52 Brix, 0.28 % TTA, 3.62 pH, 380.05 mg/L ascorbic acid while pineapple fruit pulp had 89.28% moisture content, 15.02 Brix, 0.32 % TTA, 3.80 pH, 250.67 mg/L ascorbic acid. The high moisture content of these fruits explains why they are suitable for juice making so as to quench thirst. The moisture content results in this study is similar to the findings of Masamba (2013) for pineapple and baobab. The slight variation in physicochemical characteristics can be attributed to the difference in cultivars, variation in climatic conditions, stage of maturity of the fruits, and geographical variation of the soil where these fruits are grown.

Table 5: Composition of fresh Baobab pulp, pineapple and black-plum fruits

Parameters	Baobab	Pineapple	Black-plum
Moisture content (%)	10.85	89.28	84.18
Total soluble solids (°Brix)	4.79	15.02	12.52
pH	3.30	3.80	3.62
Titrateable acidity (%)	0.65	0.32	0.28
Vitamin C (mg/L)	610.25	250.67	380.05
TPC (mg GAE/100g)	105.02	30.05	120.97
FRAP	ND	ND	ND

ND-Not determined Values are means of triplicates (n=3)

A) Fresh fruits



Pineapple



Baobab



Black-plum

B) Juices



Pineapple Juice



Baobab Juice



Black-plum Juice

Plate 2: A) Fresh Pineapple fruit, Baobab fruit pod/ pulp and Black-plum fruits and B) Pineapple, Baobab and Black-plum juices

4.3 Evaluation of Quality Attributes of the Blends of Pineapple, Baobab, and Black-Plum Juice

The blending of fruits has the potential to combine the individual functional characteristics to combat malnutrition, especially micronutrient deficiency among the most vulnerable groups in Africa. The result of the evaluated quality attributes and storage stability of the juice blends from pineapple, baobab fruit pulp, and black-plum fruits are discussed below. The best blends based on the evaluated results were then selected to develop final functional antioxidant rich beverage.

4.3.1 Physicochemical Properties of Baobab-Pineapple-Black Plum Juice Blends

The physicochemical properties of the individual juice and juice blends from baobab, pineapple, and black-plum juices are shown in Table 6. The pH values of the samples ranged

from 3.12 to 3.94. Although the pH of the blends registered acidic values with a standard deviation not greater than 0.01, analysis of variance showed that there is a significant effect ($P < 0.05$) of the model on the variability that is shown on the pH. The low pH of baobab juice contributed to the lower pH of all juice blends and may be attributed to the high concentration of organic acid present, predominantly citric acid (Tembo *et al.*, 2017). The pH value obtained in this study is relatively comparable to the pH of 3.15 reported for *Adansonia* (Adam *et al.*, 2016), 3.79 for pineapple juice (Ngereza & Pawelzik, 2016), and 3.84-3.92 for pineapple-carrot-orange juice blends (Hossain *et al.*, 2016). Low pH is an important indicator of the microbial stability of food; the lower the pH, the more microbiologically stable the fruit juice (Nwachukwu & Ezeigbo, 2013).

Total soluble solid (TSS) is a measure of soluble sugars in the juices. The TSS in the samples ranged between 4.83 (for 100% baobab juice) and 12.3°Brix (for 100% pineapple juice) (Table 5). The effect of blending and type of fruits significantly affected the Brix values of the blends and pure juices. The TSS values (6.35-8.87) for the blends fall between the ranges for the pure juice as expected. The lower TSS in the juice blends could be attributable to baobab juice with the least amount of sugar content of the pure juices. Pineapple juice has the highest Brix (12.3°B), and this may be due to a high amount of sucrose naturally present in it (Ngereza & Pawelzik, 2016; Akubor, 2017). Juice blend with high pineapple juice (F3, F6, and F7) had the correspondingly high TSS. A similar result was reported by Hossain *et al.* (2016) and Begam *et al.* (2018).

The titratable acidity of the samples ranged between 0.22% and 0.62% (Table 5). Baobab juice had the least pH of 3.12, and the highest acidity of 0.62%. The expectation was that low pH should correspond to high acidity (Bamidele & Fasogbon, 2017), which the results from this study confirm. The predominant organic acid (citric acid) present in baobab may be responsible for this high acidity value. The effect of baobab juice high acidity is seen in samples F2, F5, and F6.

Color is an important quality parameter of beverage contributing to organoleptic properties and subsequent consumer acceptability. The color parameters of the samples presented in Table 6 show the lightness values (L^*) range from 14.08 to 41.22. Sample F9, 100% black-plum juice had the lowest ($L^* = 14.08$) as expected from the dark pigmentation of the fruit, while sample F8, 100% baobab juice had the highest ($L^* = 41.22$). The highest redness values (a^*) was found in sample F9 ($a^* = 15.24$) and lowest in sample F10 ($a^* = 1.28$). The blending of the fruit juices

resulted in a significant ($P < 0.05$) change in colorimetric values in all the samples. The significantly high value of (a^*) in juice blends (F1, F4, and F5) may have resulted from high polyphenol content especially anthocyanin compound in black-plum juice. Yellowness (b^*) values of the juice samples ranged from 6.42 to 19.74 with sample F10 having the highest. A similar result was observed by Zaman and Shamsudin (2016) for pineapple and mango juice blends that the color of the juice samples varies with different juice concentration.

Table 6: Physicochemical characteristics of juice blend from Baobab (*Adansonia digitata*), Pineapple (*Comosus ananas*) and Black-plum (*Syzygium cumini*) fruits

Samples	pH	TSS (°Brix)	TTA (% citric acid)	Color		
				L*	L*	L*
F1	3.47 ± 0.01 ^c	7.80±0.14 ^c	0.35 ±0.01 ^c	24.40±0.30 ^c	14.33±0.25 ^a	14.15±0.49 ^b
F2	3.30 ±0.01 ^c	7.30±0.07 ^c	0.41±0.00 ^b	29.67±0.05 ^c	11.59±0.01 ^b	12.95±0.08 ^b
F3	3.53 ±0.01 ^b	8.87±0.04 ^b	0.30 ± 0.00 ^c	29.65±0.18 ^c	9.32±0.09 ^c	12.38±0.24 ^b
F4	3.58 ±0.01 ^b	7.83±0.04 ^b	0.34 ±0.00 ^c	22.42±0.05 ^c	14.23±0.09 ^a	9.59±0.16 ^c
F5	3.34 ±0.01 ^c	6.35±0.07 ^d	0.40 ±0.00 ^b	25.83±0.09 ^c	14.22±0.05 ^a	11.28±0.15 ^b
F6	3.44 ±0.01 ^c	8.05±0.07 ^b	0.40 ±0.00 ^b	22.76±0.08 ^c	15.79±0.02 ^{*c}	9.80±0.13 ^c
F7	3.66 ±0.01 ^b	8.23±0.04 ^b	0.30 ±0.00 ^c	24.15±0.12 ^c	11.85±0.06 ^b	12.67±0.29 ^b
F8 100% Ba	3.12 ±0.00 ^d	4.83±0.04 ^e	0.62 ±0.00 ^a	41.22±0.04 ^a	4.31±0.06 ^d	25.37±0.09 ^a
F9 100% Bp	3.88 ±0.01 ^a	6.05±0.07 ^d	0.22 ±0.00 ^d	14.08±0.11 ^d	15.24±0.08 ^a	6.42±0.33 ^c
F10 100% P	3.94 ±0.02 ^a	12.3±0.07 ^a	0.30 ±0.01 ^c	37.92±0.09 ^b	1.28±0.02 ^d	19.74±0.20 ^a

Ba=Baobab juice, P=Pineapple juice, Bp=Black-plum juice, TSS=Total Soluble Solids, TTA = Titratable acidity.

F1= 33.3%Ba: 33.3%P: 33.3%Bp; F2= 50%Ba: 25%P: 25%Bp; F3= 25%Ba: 50%P: 25%Bp; F4= 25%Ba: 25%P:50%Bp; F5=

50%Ba:12.5%P:37.5%Bp; F 6= 37.5%Ba: 50%P: 12.5%Bp; F7=12.5%Ba: 37.5%P:50%Bp; F 8= 100% Baobab juice; F 9 =100% Black-plum juice; F 10 = 100% Pineapple juice.

Values are means of triplicates (n=3) ± standard deviations. Mean with different letter superscripts in the same column are significantly different (P < 0.05).

4.3.2 Phytochemical Properties of Baobab-Pineapple-Black Plum (Bpb) Juice Blends

Figure 6 presents the phytochemical properties of the baobab-pineapple-blackplum juice blends. Vitamin C content, total polyphenol content, and antioxidant capacities were determined in this study. Figure 1A showed the vitamin C content of the juice samples with 100% baobab (sample F8) having the highest (571.52 mg/L) value. The significantly high ($P < 0.05$) vitamin C content of the blends could be attributed to their baobab content since baobab fruit pulp is reported to be a good source of vitamin C (Osman, 2004; USDA, 2018). Sample F8 ascorbic acid content differs from sample F9 and sample F10 at $P < 0.05$. This confirms that black-plum and pineapple juices are fair sources of vitamin C (Bukya, 2018; Masamba, 2013). The synergistic combination of all vitamin C in these individual juices contributes to the high vitamin C observed in the blends with blends having a lesser amount of baobab juice having lower vitamin C content. The amount of vitamin C observed in the juice blend samples could cover about 60% of the recommended dietary allowances (RDA) based on the recommendation that dietary intake of 90-100mg ascorbic acid /day could reduce the risk of non-communicable diseases (Carr & Frei, 1999). A similar trend was observed in the total polyphenol content (TPC) values as in vitamin C content. The TPC contents of all the samples ranged from 29.81 to 104.65 mg GAE/100 mL with the highest value found in 100% baobab juice (sample F8) and sample F5. Vitamin C is an important nutrient that performs several biological functions in the human body such as preventing free radical damage to DNA and providing supports to the immune system (Naidu, 2003).

The reducing potential and DPPH radical scavenging capacity of juice samples are shown in Figure 1(C-D). Black-plum juice showed the highest ability to reduce Fe^{3+} to Fe^{2+} (1929 μMFe^{2+} /L) followed by baobab juice (1391.81 μMFe^{2+} L). Among the juice blend, the reducing power is significantly high, showing the capability of the juice blends to donate electrons in order to terminate chain reactions resulting from free radical oxidation. The presence of free radical scavenging ability in the juice samples was significant thus the juices demonstrated high anti-oxidant properties despite their variations. There was a significant difference ($P < 0.05$) in the DPPH radical scavenging ability of the samples, with samples F2 and F6 having the highest values. Baobab and black-plum have been reported to have high antioxidant properties and so can prevent the risk of disease such as cancer, diabetes resulting from the free radical-induced oxidative reaction (Braca *et al.*, 2018; Baliga *et al.*, 2013).

The synergetic effect resulting from the combined relatively high scavenging ability, high reducing potential, high ascorbic acid content, high polyphenol contents of the juice blends observed in this study, translates into increased antioxidant capacity thus its potential benefits of reducing free radicals when consumed in sufficient amount. Similarly, Aderinola (2019) and Olagunju and Sandewa (2018) reported increased antioxidant content of cucumber and carrot juice; soursop juice and milk respectively.

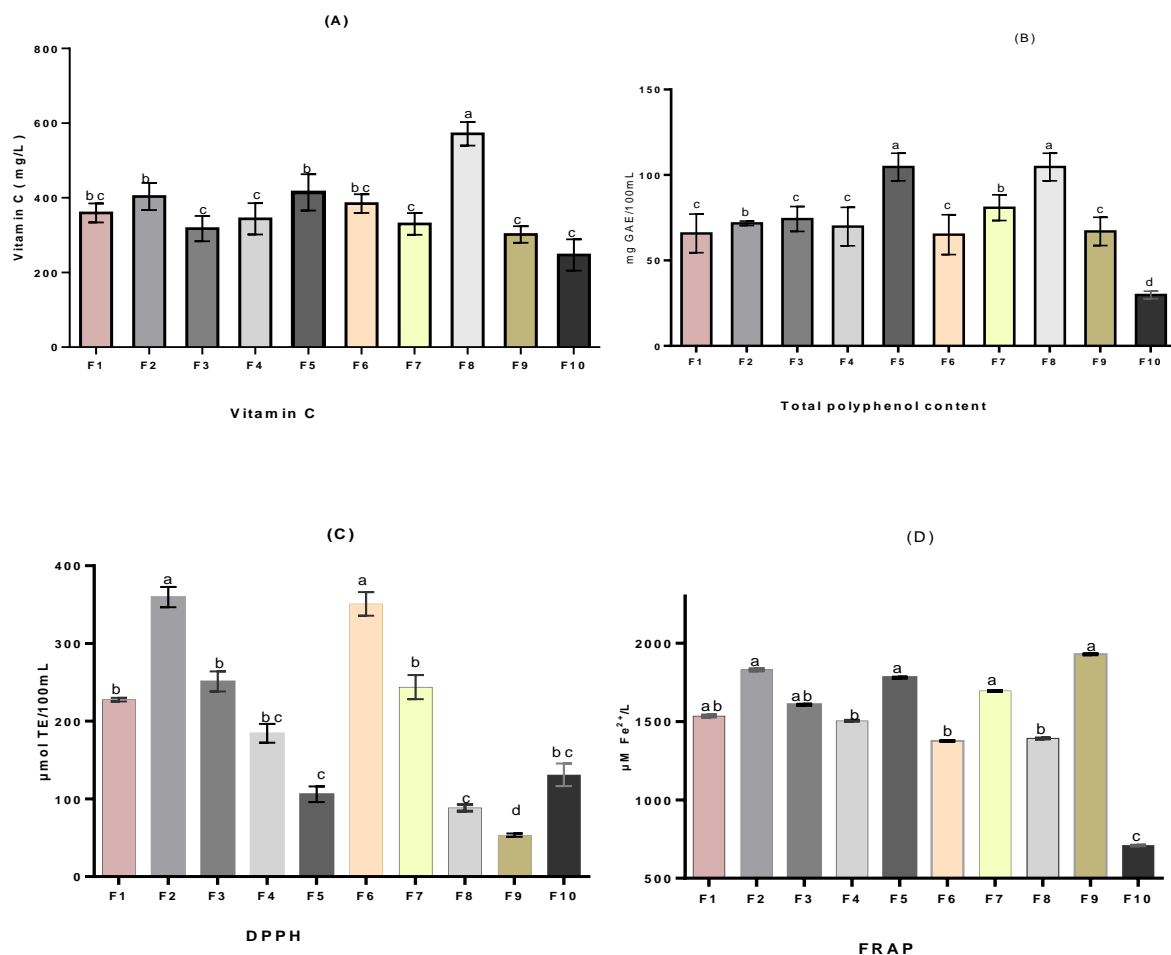


Figure 6: The vitamin C content, total phenolic content and antioxidant capacity of juice blends from Baobab, Pineapple, and Black-plum fruits

Ba=Baobab juice, P=Pineapple juice, Bp=Black-plum juice, FRAP=Ferric ion reducing antioxidant power, DPPH=1,1-diphenyl-2-picrylhydrazyl

F1= 33.3%Ba: 33.3%P: 33.3%Bp; F2= 50%Ba: 25%P: 25%Bp; F3= 25%Ba: 50%P: 25%Bp; F4= 25%Ba: 25%P: 50%Bp;

F5= 50%Ba: 12.5%P: 37.5%Bp; F 6= 37.5%Ba: 50%P: 12.5%Bp; F7=12.5%Ba: 37.5%P: 50%Bp; F 8= 100% Baobab juice: F 9 =100% Black-plum juice F10 = 100% Pineapple juice.

Values are means of triplicates (n=3) ± standard deviations. Significant differences between formulations (F1 to F10) are indicated by different letters (P < 0.05).

4.3.3 Mineral Content of Juice Blends

The results of the mineral contents of the samples are shown in Table 7. The juice blends showed high content of all the minerals tested, particularly magnesium, potassium, calcium, and phosphorus. The concentration of calcium is high (57-153 mg/L) when compared to the presence of other dietary minerals in the samples. Other elements ranged between (71-130 mg/L) for magnesium, potassium (22-32 mg/L), phosphorus (4-43 mg/L), and sodium (0.79-1.97 mg/L). Similar high calcium content (80.3 mg kg⁻¹) was reported for orange juice (Simpkins *et al.*, 2000) and 282 ppm for baobab fruit pulp (Adam *et al.*, 2016). Calcium is an important mineral for muscles and bone health (Pravina *et al.*, 2013). This makes these blends a good source of calcium supplements for the lactating women and children. Potassium is also an essential component of body cells and fluid while low sodium is ideal for a healthy heart.

4.3.4 Sensory Properties of Baobab-Pineapple-Black Plum (BPB) Juice Blends

The results of sensory properties such as taste, mouthfeel, flavor, color, and overall acceptability of the juice samples are shown in Table 8. Sample F8 was rated lowest for all the evaluated parameters except for the color that was rated high. This may be due to the high acidity of the juice resulting in its astringency and sourness. This sample coincidentally has the highest value of the phytonutrients tested (Fig. 5). A similar low rating for samples with better antioxidant properties was observed in the blend of an equal volume of carrot and cucumber juice (Aderinola, 2019). Sample F10 rated highest for taste, mouthfeel, flavor, color, and overall acceptability. This may be due to the high sugar content reflected in the high Brix value of the sample (Table 5) and the familiar color of the juice to the consumers (Akubor, 2017). Sample F9 rated high only for color but low for other parameters. This may be due to the attractive color (light purple) resulting from high anthocyanin content of the juice. The low overall acceptability of this juice may be due to the pungent smell and watery taste resulting from low Brix value. Samples F1, F3, F4, F6, and F7 were rated high for overall acceptability among the juice blends. This may be due to the high ratio of pineapple juice above 25% in the blends and baobab juice, not more than 25%, especially in sample F3 and F7. This implies that blending baobab with pineapple and black-plum can complement and improve consumers' acceptability. Although there was no significant difference ($P > 0.05$) in the ratings among the juice blends, sample F5 showed better phytonutrient properties but was poorly rated by consumers. Consumer acceptance could be improved upon in the final formulation for a ready to drink functional beverage.

Table 7: Mineral content determination for the juice blends (mg/L)

Samples	Magnesium	Potassium	Calcium	Iron	Zinc	Phosphorus	Sodium
F1	80.20±10.65 ^b	25.11±1.83 ^b	70.35±10.59 ^{bc}	0.04±3.73 ^c	1.15±0.01 ^b	24.11±1.11 ^b	1.97±0.02 ^c
F2	73.50±9.19 ^c	24.08±2.31 ^b	77.23±7.41 ^{bc}	0.04±6.30 ^c	1.11±0.01 ^b	17.12±0.15 ^c	1.56±0.01 ^c
F3	98.23±10.79 ^b	29.45±3.81 ^{ab}	72.36±10.58 ^{bc}	0.04±0.45 ^c	1.15±0.02 ^b	25.15±1.01 ^b	2.23±0.01 ^b
F4	85.15±10.02 ^b	26.04±1.45 ^b	67.08±9.62 ^c	0.05±8.51 ^c	0.49±0.01 ^c	28.01±1.01 ^b	1.51±0.02 ^c
F5	73.12±9.57 ^c	32.54±2.82 ^a	89.45±10.05 ^b	0.05±7.29 ^c	1.08±0.03 ^b	19.24±0.02 ^c	1.32±0.20 ^c
F6	76.19±6.46 ^c	25.12±1.46 ^b	57.03±5.84 ^c	0.01±3.02 ^c	1.08±0.02 ^b	27.21±0.09 ^b	1.61±0.05 ^c
F7	92.13±5.59 ^b	27.49±2.40 ^{ab}	119.02±4.87 ^a	0.07±2.15 ^c	0.51±0.02 ^c	30.32±0.03 ^b	1.36±0.02 ^c
F8 100%Ba	71.07±3.18 ^c	22.02±2.54 ^c	153.42±2.21 ^a	0.18±1.69 ^b	1.01±0.01 ^b	4.00±0.04 ^d	0.79±0.01 ^d
F9 100%Bp	83.14±1.73 ^b	28.31±1.66 ^{ab}	19.24±0.03 ^d	0.09±4.84 ^c	1.22±0.02 ^a	43.46±2.03 ^a	1.53±0.03 ^c
F10 100% P	130.23±5.53 ^a	30.06±2.20 ^a	65.09±6.11 ^c	0.32±1.02 ^a	1.21±0.02 ^a	28.09±2.01 ^b	3.60±0.20 ^a

Ba=Baobab juice, P=Pineapple juice, Bp=Black-plum juice.

F1= 33.3%Ba: 33.3%P: 33.3%Bp; F2= 50%Ba: 25%P: 25%Bp; F3= 25%Ba: 50%P: 25%Bp; F4= 25%Ba: 25%P:50%Bp; F5= 50%Ba:12.5%P:37.5%Bp; F 6= 37.5%Ba: 50%P: 12.5%Bp; F7=12.5%Ba: 37.5%P:50%Bp; F 8= 100% Baobab juice; F 9 =100% Black-plum juice; F 10 = 100% Pineapple juice.

Values are means of triplicates (n=3) ± standard deviations. Means values with the same letter in a column are not significantly different (P > 0.05).

Table 8: Sensory attributes of the juice blends from Baobab, Pineapple and Black-plum fruits

Samples	Taste	Mouthfeel	Flavor	Color	Overall acceptability
F1	6.93 ±1.34 ^b	7.00 ±1.36 ^b	6.87 ±0.99 ^{bc}	7.40 ± 1.18 ^b	6.93±1.22 ^{bc}
F2	6.07 ±1.39 ^c	6.00 ±1.00 ^c	6.33 ± 0.90 ^c	7.20 ± 0.68 ^b	6.20±1.08 ^c
F3	7.47 ±0.99 ^b	7.53 ±0.99 ^{ab}	7.47 ±0.92 ^b	7.53 ± 0.99 ^a	7.47 ±0.95 ^b
F4	7.07±1.22 ^b	7.00 ±0.85 ^b	6.80 ± 1.04 ^{bc}	7.67 ± 0.90 ^a	7.13 ±0.92 ^{bc}
F5	6.00 ± 1.31 ^c	6.33 ±1.05 ^c	6.13 ± 0.99 ^c	6.93 ±1.49 ^c	6.40 ± 0.74 ^c
F6	7.20 ±1.27 ^b	7.33 ±1.11 ^b	7.07±1.16 ^b	7.07 ±1.03 ^{ab}	7.07± 1.10 ^{bc}
F7	7.53 ±0.92 ^b	7.20 ±1.08 ^b	7.07±1.39 ^b	7.60 ± 0.74 ^a	7.60± 0.83 ^b
F8 100%Ba	4.00 ±1.89 ^d	4.33 ±2.19 ^d	5.02±2.04 ^d	6.80 ±1.86 ^c	4.80±0.19 ^d
F9 100%Bp	5.00 ±2.45 ^d	5.07 ±2.34 ^d	4.93±2.31 ^d	7.07±1.75 ^{ab}	5.33±2.19 ^d
F10 100% P	8.13 ±0.99 ^a	8.13 ±0.74 ^a	8.33 ±0.82 ^a	7.60 ±0.91 ^a	8.27 ± 0.46 ^a

Ba=Baobab juice, P=Pineapple juice, Bp=Black-plum juice.

F1= 33.3%Ba: 33.3%P: 33.3%Bp; F2= 50%Ba: 25%P: 25%Bp; F3= 25%Ba: 50%P: 25%Bp; F4= 25%Ba: 25%P:50%Bp; F5= 50%Ba:12.5%P:37.5%Bp; F 6= 37.5%Ba: 50%P: 12.5%Bp : F7=12.5%Ba: 37.5%P:50%Bp); F 8= 100% Baobab juice; F 9 =100% Black-plum juice; F 10 = 100% Pineapple juice.

Values are means of triplicates (n=3) ± standard deviations. Mean with different letter superscripts in the same column are significantly different (P < 0.05).

4.3.5 Storage Studies of the Juice Blend

Figure 7 shows the effect of storage at refrigeration temperature (4°C) for 4 weeks on pH, acidity, and TSS of baobab-pineapple-black plum juice blends. There was no significant change in the pH of the juice blends at the first 2 weeks of storage but a slight decrease in pH occurred after week 2 until week 4 of storage. This may be due to biochemical reactions occurring within the juice samples. The relatively unchanged low pH (3.01-3.86) observed in all the samples is an indication of shelf-stability at 2 weeks under refrigeration temperature even though the color became less intense at the end of the storage studies. This observation was supported by the report of Nwachukwu and Ezeigbo (2013) that pasteurized fruit juices at acidic pH under refrigeration temperature are less susceptible to contamination and growth of microorganisms. Moreover, the acidity of the juice blends showed no significant change in the first 2 weeks of the storage period except for a slight decrease towards the end of week 4. The presence of natural antioxidants and organic acids with pasteurization and low temperature are important useful factors in extending the shelf-life of fruit juices. There was a slight increase in the TSS towards the end of the storage period (Fig. 7III). This could be attributed to the hydrolysis of polysaccharides to sugar. Bhardwaj and Pandey (2011) also reported an increase in TSS value as storage time and temperature increased. Therefore, it can be concluded from this study that juice blends of baobab, pineapple, and black-plum kept well without significant physicochemical changes at low temperatures (4 °C) for 2 weeks even as the color become less intense.

From the above, it can be concluded the studied blends of baobab, pineapple and blackplum fruits are good source of calcium, magnesium and antioxidants (ascorbic acid, total polyphenol contents, scavenging ability, and reducing potential) the consumption of which will promote human health.

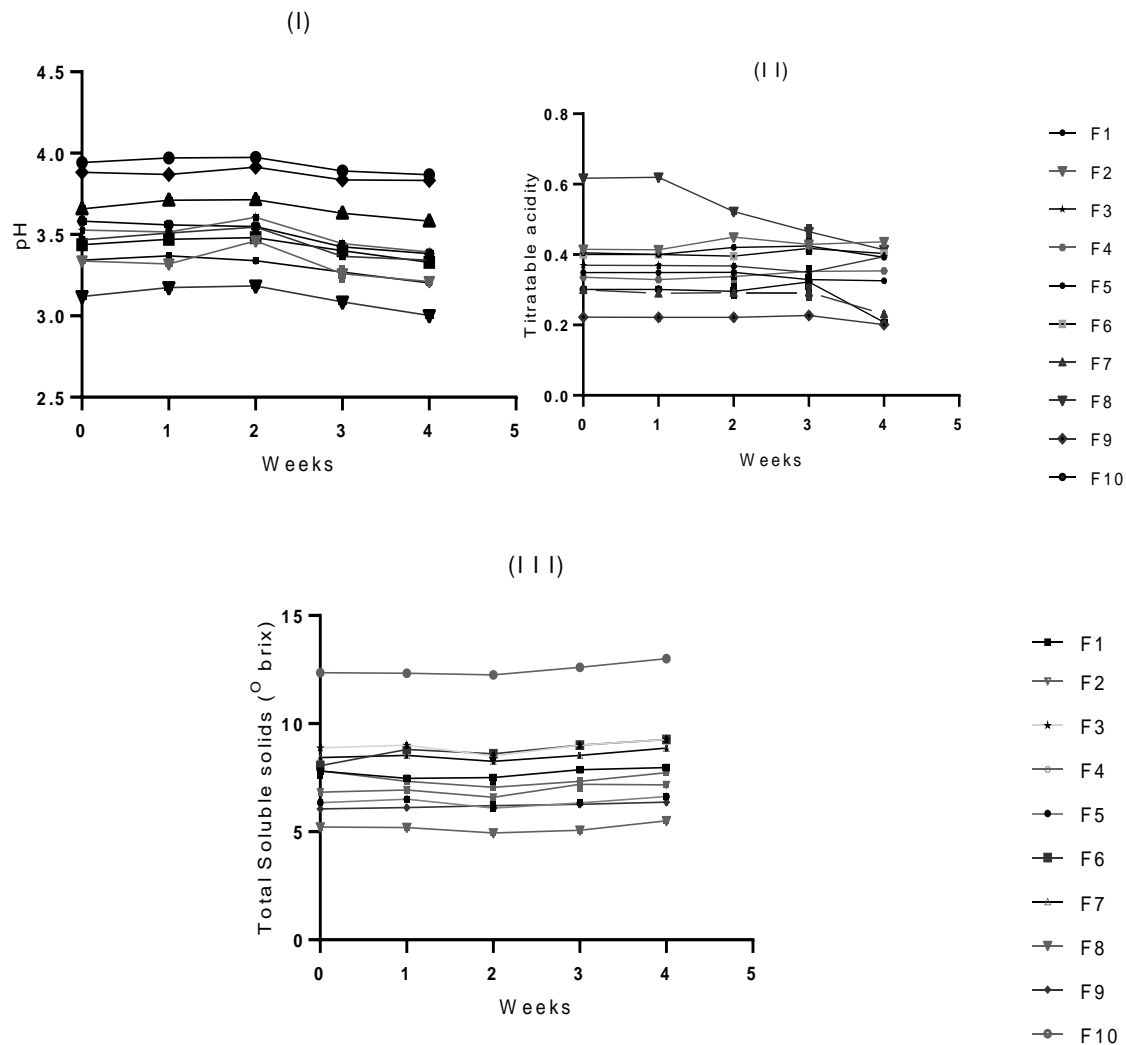


Figure 7: Storage effects on physicochemical characteristics of juice blends from baobab, pineapple and black-plum fruits

F1= 33.3%Ba: 33.3%P: 33.3%Bp; F2= 50%Ba: 25%P: 25%Bp; F3= 25%Ba: 50%P: 25%Bp; F4= 25%Ba: 25%P: 50%Bp;
 F5= 50%Ba: 12.5%P: 37.5%Bp; F 6= 37.5%Ba: 50%P: 12.5%Bp; F7=12.5%Ba: 37.5%P: 50%Bp; F 8= 100% Baobab juice: F 9 =100%
 Black-plum juice F10 = 100% Pineapple juice. Values are means of triplicates (n=3) ± standard errors

4.4 Development of Ready-to -Drink Functional Beverages

In an effort to see the possibility of commercializing the juice blend of BPB to formulate a ready-to-drink beverage available to all at all seasons, guidelines from Codex were followed. From the above-evaluated juice blend results (objective 2), the best blends based on functionality were selected. The selected fruit blends were formulated to be ready to drink and the composition of the BPB beverage giving in Table 9 /Appendix-II. Sample Beverage 1

contained 50% baobab juice, 12.5% pineapple juice, and 37.5% black-plum juice; Beverage 2 contained 12.5% baobab juice, 37.5% pineapple juice, and 50% black-plum juice.

All formulations were adjusted to 12% TSS and 0.3% acidity and kept constant in both samples. Stabilizers were added to enhance uniformity and prevent separation during storage. The formulated RTD beverage was then filled in clean 200mL capacity plastic bottles and kept at refrigeration and ambient temperature for storage. BPB beverage in this work is referred to as mixed fruit juice nectar from baobab pineapple and black-plum fruits.

Table 9: Physico-chemical and anti-oxidant properties of BPB formulated beverages

Properties	Beverage 1	Beverage 2
Color	ND	ND
Total soluble solids	12.45	(Constant)
pH	2.35	-
Titrateable acidity	0.38	(Constant)
Vitamin C	420.52±4.12	337.51±9.80
Total phenolic content	105.56±2.02	85.82±3.26
FRAP	1780±32.31	1705±2.18
DPPH	110.24±5.06	105.79±5.05

ND- Not determined. Values are means of triplicates (n=3)

The formulated BPB beverage has high amounts of ascorbic acid, total phenol, and significantly high antioxidant properties therefore qualify as a functional fruit beverage. These parameters of the beverage are within the quality specifications specified by USFDA for beverage/health drinks. Potential consumers also rated the formulated drink high with high interest to purchase and intend to offer 2.50 Tshillings for its 1L as compared to 2.95 Tshillings of the market sample. (Appendix). The tannin content of BPB beverage measured 0.315 mg tannic acid (TA) which is within the non-toxic limit. This measures the astringency of the juice and its tendency to discolor during storage (Bhardwaj & Pandey, 2011). Therefore it is possible to produce BPB fruit drinks and sell them in the market; this will improve the economic value of the fruits and increase income generation.

4.4.1 Sensory Evaluation of Ready-To-Drink BPB Formulated Beverage in Comparison with Known Commercial Beverage

The formulated ready-to-drink (RTD) BPB beverages were compared with known commercial beverages for the sensory parameters as shown in Table 10. The differences in flavor and overall acceptability between the market sample and the formulated beverages were not significant ($P > 0.005$). The formulated beverages were within the acceptable range for taste, color, and mouthfeel (beverages 1&2) by the consumers except for beverage 1 consumers rated the color a little lower (6.80). This confirms that the acceptability of BPB formulated beverages at different concentrations was high and shows baobab fruit pulp, pineapple, and black-plum fruits can be major ingredients in producing a consumer-acceptable antioxidant-rich functional beverage for optimum human health.

Table 10: Sensory evaluation of ready-to-drink BPB formulated beverage compared with fruit-based commercial beverage

Formulated beverages	Sensory scores				
	Taste	Color	Mouthfeel	Flavor	Overall acceptability
Beverage 1	7.35±0.18 ^b	6.80±0.31 ^b	7.30±0.25 ^b	7.50±0.26 ^a	7.35±0.17 ^a
Beverage 2	7.40±0.20 ^b	7.05±0.20 ^b	7.45±0.19 ^b	7.45±0.17 ^a	7.50±0.17 ^a
Market Sample	8.20±0.17 ^a	8.20±0.19 ^a	8.10±0.24 ^a	7.80±0.31 ^a	8.15±0.18 ^a

Values are means of triplicates ($n=3$) ± standard deviations. Mean with different letter superscripts in the same column are significantly different ($P < 0.05$).

4.4.2 Effect of Storage Temperature and Time on BPB Beverage

The results of the formulated functional beverage samples stored at tropical room temperature (30°C) and refrigeration (4°C) and the effect of storage temperature on pH, acidity, TSS and Vitamin-C content observed for 12 days is presented in Table 11.

A slight decrease in pH was observed during storage at 4°C and 30 °C in the beverage. This was due to increase in acidity of the beverage resulting from the organic acid present. Hussein *et al.* (2017) observed similar results in pH over a period of 9 days of storage at ambient

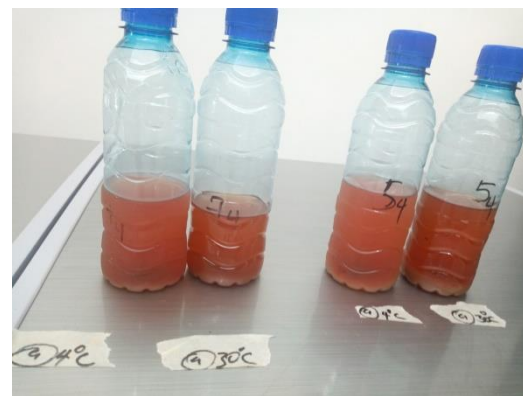
temperature in blends of Kiwi fruit and pineapple juice nectars. No significant ($P>0.005$) change was observed in TSS of BPB beverage at both 4°C and 30 °C.

Visually, no color change was observed during the 12 days of storage in BPB beverage at refrigeration temperature. However, there was a slight loss in visual color in the beverage stored at 30°C at the end of the storage period. Moreover, there was sedimentation of particles at the bottom of the bottles in the beverages stored at both temperatures. This implies that the stabilizer used in this experiment may not be ideal or sufficient in amount to enhance uniformity in the beverage. This result is also similar to that of Mgaya-kilima *et al.* (2014) who observed minimal color change in Roselle fruit blends at ambient temperature.



Fresh BPB beverage

A



Stored BPB beverage

B

Plate 3: A- Fresh Baobab-Pineapple-Blackplum (BPB) juice blend beverage B- BPB beverages stored @ 4°C and 30°C

Vitamin C content of all BPB beverages decreased during storage at 4°C and 30°C, although the decrease at 4°C was not significant. This shows that the storage condition has a greater influence on the ascorbic acid retention of fruit beverages as confirmed by Singh and Sharma (2017). The changes observed in ascorbic acid content probably could be due to the sensitivity of vitamin C to temperature, oxygen, light, as well as method of processing. Mgaya-kilima *et al.* (2014) also reported a significant decrease in ascorbic acid content of Roselle-fruit blend due to processing, exposure to light and storage duration. Since the loss in Vitamin C and color change was more noticeable at 30°C, storage at 4°C is therefore highly recommended if the product (BPB beverage) needs to be stored for a long time.

Table 11: Physico-chemical & vitamin C content of BPB functional beverage stored 0-12 days at 4°C & 30°C

Temperatures	4°C					30°C					
	Days	0	3	6	9	12	0	3	6	9	12
Parameters											
Vitamin C (mg/L)		420.52 ^a	418.05 ^a	415.97 ^a	413.23 ^a	409.29 ^b	420.52 ^a	415.69 ^b	409.48 ^c	397.09 ^d	366.67 ^d
TSS (%)		12.45 ^a	12.45 ^a	12.46 ^a	12.48 ^a	12.50 ^a	12.45 ^a	12.47 ^a	12.50 ^a	12.52 ^a	12.54 ^a
pH		2.35	2.37	2.35	2.32	2.31	2.35	2.37	2.38	2.40	2.41
Titratable (%)		0.38	0.36	0.38	0.39	0.40	0.38	0.37	0.39	0.40	0.45

Values are means of triplicates (n=3)

4.4.3 Microbial Population of BPB Beverage

Microbiological analysis of formulated functional beverage of baobab pineapple and black-plum juice blends showed the absence of potentially pathogenic contaminants viz. bacteria, molds and yeast immediately after preparation of the juice and it increased slightly at the end of the storage period (0.07 log cfu/ml and 0.11 log cfu/ml). This microbial load was far below the safe level both at 4°C and 30°C. This might be due to the inhibitory effect of the contained phenolic compounds and preservatives on micro-organisms. Hossain *et al.* (2016) also observed a low initial total no of viable count in Pineapple: Papaya: Banana: Orange juice blends health drink which increased slightly during storage but within acceptable limits whereas Batra *et al.* (2018) reported initial contamination with a large variety of bacterial and mold species. There was no presence of yeast and E.coli in the beverage, it is therefore considered safe for consumption up to the period of storage from the day of preparation. It is expected that the total colony count will increase as the storage period increases, especially at room temperature; therefore, accelerated storage stability study may be conducted to check the stability for a longer period.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the current investigation, the KAP survey helped to explore the unmet need and preferences of potential consumers of functional non-alcoholic drinks from the area of study so that the product could be successful in the market. The survey revealed that consumers need non-alcoholic fruit beverages with health benefits that could prevent them from cancer and other modern diseases, and that which are equally affordable with sweet taste and flavor. The negative attributes in the fruits with the least acceptance (baobab and black-plum) were innovatively combined with the most preferred fruit (pineapple) to maximize their benefits.

Blending of the fruit juices improved the sensory attributes and subsequently consumers' acceptance. Baobab-pineapple-black plum juice blends showed a high amount of micronutrients and phytochemicals that establish their potential to improve health when consumed. Juice blends of baobab, pineapple, and black-plum fruits synergistically increased the anti-oxidant potential and mineral contents.

The present study revealed that pasteurized baobab-pineapple-black-plum juice blends kept well at a low temperature (4°C) until 2 weeks with no significant change in physicochemical quality attributes. The best blends based on functionality contained 50%baobab juice, 12.5%pineapple juice, 37.5%black-plum juice and 12.5%baobab juice, 37.5%pineapple juice, and 50%black-plum juice were selected for the preparation of an acceptable and palatable ready-to-drink functional beverage. The formulated beverage contained high amounts of ascorbic acid, and total phenolic, and had shown significantly high antioxidant properties as well as acceptability, especially when compared with commercial mixed beverages.

Therefore, this study allows us to conclude that baobab, pineapple, and black plum can be successfully utilized to develop beverages that can substantially improve the health of the consumers, especially increase cell resistance to oxidative changes when consumed in a sufficient amount. The health drink from the blend of baobab-pineapple-black plum fruits also has a tendency to aid the absorption of iron thus preventing anemic conditions as well as a good source of calcium resulting from the high vitamin C and calcium contents.

This study provides important information highlighting the quality attributes of blends of baobab, pineapple, and black plum juices which can contribute to reducing micronutrient deficiency and improving the nutritional status of people in the rural communities in sub-Saharan Africa. It also provides a guide to the food industry in the development of new functional beverages improving the utilization of these fruits and becoming a source of income generation for the producers and retailers.

5.2 Recommendations

However, the absorption of vitamin C in this functional beverage especially in the vulnerable groups in Tanzania can be a new research area. Replacing sucrose as a sweetener with other low-calorie substitutes such as stevioside, sucralose and aspartame can also be considered which can substantially reduce the calorie content of the beverage which will make it amenable to diabetes patients. Furthermore, consumers' interest to purchase BPB functional beverages will improve the economic value of the fruits and become a source of income generation for the entire community. The availability of BPB functional beverages in the market will benefit the health-conscious consumers.

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APPENDICES

Appendix 1-a: Hedonic Rating Test Evaluation for Sensory Quality of Baobab-Pineapple-Black Plum (BPB)

BLENDED BEVERAGES

Name:	Product: BPB
Panelist No:	Date:
<p>Instructions:</p> <ul style="list-style-type: none"> ▪ Before you taste each sample, take a sip of water. ▪ Taste these samples and then check with this mark (√) on the point in the scale which best describes your feelings about the sample. ▪ Please give a reason for choosing this option, remember you are the one who can tell us what you like. Your honest expression of your opinion will help us . <p>Please notify the evaluator once you are done with a sample, so another one can be served.</p>	

SCORE*	SAMPLE CODE				
(9) Like extremely					
(8) Like very much					
(7) Like moderately					
(6) Like slightly					
(5) Neither like nor dislike					
(4) Dislike slightly					
(3) Dislike moderately					
(2) Dislike very much					
(1) Dislike extremely					
Reason:					

SCORE*	SAMPLE CODE				
(9) Like extremely					
(8) Like very much					
(7) Like moderately					
(6) Like slightly					
(5) Neither like nor dislike					
(4) Dislike slightly					
(3) Dislike moderately					
(2) Dislike very much					
(1) Dislike extremely					
Reasons:					

Please evaluate each of quality parameters as given below: Write the code of each sample given

S/ N	Parameters Treatments	Taste	Mouthfeel	Flavor	Color	Overall Acceptability
		1.				
2.						
3.						
4.						

5.						
6.						
7.						
8.						
9.						
10.						

Nine-point Hedonic scale

9=Like extremely
8=Like very much
7 =Like moderately
6 =Like slightly
5 = neither like nor dislike

1=Dislike extremely

4=Dislike slightly
3=Dislike moderately
2=Dislike very much

Signature of Evaluator.....

Please turn -over

SCORE*	SAMPLE CODE				
(9) Like extremely					
(8) Like very much					
(7) Like moderately					
(6) Like slightly					
(5) Neither like nor dislike					
(4) Dislike slightly					
(3) Dislike moderately					
(2) Dislike very much					
(1) Dislike extremely					
Overall impression:	<p>.....</p> <p>.....</p> <p>.....</p>				
Would you ask for more?					
What would be your intention to PURCHASE this product? ("X" ONE BOX BELOW)					
SCORE*	SAMPLE CODE				
Certainly, would buy					
Probably would buy					
Certainly, would not buy					
Probably would not buy					

How much would you like to offer (Tsh) for this product if it were to be packed in 1Litre?

3500					
2500					
1000					
500					

Please provide any additional remarks about this evaluated product.

.....
...
.....
.....

THANK YOU FOR YOUR VALUABLE INPUTS AND TIME.

Appendix 2-a: Calculation of Sugar Syrup (500mL)

60% sugar syrup=6g in 4ml of water=10mL

60% of 500mL = $60/100 \times 500 = 300\text{g}$

That is to say 500m L syrup= 300g of solid sugar dissolved in 200mL of H₂O.

Appendix 2-b: The composition of the formulated BPB functional beverage (1L)

Ingredients	Amount
Mixed fruits	40-50%
Sugar syrup (60% TSS)	Was added until the 12° Brix
Citric acid	Adjusted as specified
Sodium benzoate	50ppm
Potassium sorbate	50ppm
Carboxymethyl cellulose	0.1%
Additional water	made up to volume

Appendix-II-c Commercial fruit beverages

Commercial fruit beverages bought from supermarkets (Rushida super store, Arusha Tanzania) are Azam Tropical mixed fruits juice containing pineapple and other tropical fruits.

Appendix 3: Functional Beverage KAP Community Assessment Questionnaires

Informed consent and confidentiality of interviews

Good morning/afternoon, Mr/Mrs _____

We are from Nelson Mandela African Institution of Science and Technology. We are working on a project concerned with under-utilized fruits and health drinks in which you could participate.

Now, the project is just starting and we are completing a survey among participants to know more about their knowledge, attitudes and practices to do with consumption of these locally available fruit: Baobab (Ubuyu), Black-plum (Zambarau), Pineapple (Nanasi).

The interview will take about 30minutes of your time. All the information we obtain will remain strictly confidential and your answers and name will never be revealed. Also, you are not obliged to answer any question you do not want to, and you may stop the interview at any time.

The objective of this study is to evaluate the need and preferences of potential consumers of (BPB) functional/ health beverage/drink in terms of taste, cost consistency, availability, health benefits i.e. to evaluate consumption of these fruits and beverage/drink from them.

This is not to evaluate or criticize you, so please do not feel pressured to give a specific response and do not feel shy if you do not know the answer to a question. I am expecting you give a specific answer and would like you to answer questions honestly. Feel free to answer questions at your own pace.

Do you agree to participate in this interview?

Yes ___ No ___ *If yes, continue to the next question; if no, stop the interview.*

Do you have any question before we start? (*Answer questions*).

May I start now?

Interview Date: ___ / ___ / ___ (DD/MM/YYYY) ---- ----

Interviewer Name: _____

Community: _____ Enumeration area: _____

DEMOGRAPHIC INFORMATION

[CORE] : Please answer every question in this section as accurate as possible

- 1) What is your name? ----- Code:
- 2) Gender of respondent Male Female
- 3) What is your age? <18 19-25
 26-30 31-35
 36-40 >40 others

4) What is the highest level of education you have completed? (Choose one only.)

- None Primary
 Some secondary Completed secondary or higher
 Other Specify (-----) University

5) What is your occupation?

- Farmer Trader Employed None
Any other.....

6) What is your religion?

- Muslim Christian Others

7) What is your marital status?

- Married Single Divorced /separated
 Widowed Any other

Functional Beverage KAP Community Assessment Questionnaires

KNOWLEDGE

Question K.1: Consumption pattern of fruits

I would like to ask you about particular fruits you may eat on their own or as part of a dish in raw or processed form. Please tick on the most appropriate option

1. Do you in general consume fruits (common/uncommon) such as Orange, pineapple, Apple, Grape, Baobab(Ubuyu), Black-plum (Zambarau)

- Yes
 No
 Don't know/no answer

If Yes:

Every day?

- Yes
 No
 Don't know/no answer

2. How often?

- Every day
 At least once in a week
 More than 2times in a month

Other (*specify*) _____

3. When do you usually eat fresh fruits? (*Read the following options to the respondent*)

Before a meal

During the meal

After a meal

Other (*specify*) _____

Don't know/no answer

4. Have you ever seen/heard of any of these fruits?

a- Baobab (*Ubuyu*) Yes No

b- Black-plum (*Zambarau*) Yes No

c- Pineapple (*Nanasi*) Yes No

5. Have you ever consumed any of these fruits?

a- Baobab (*Ubuyu*) Yes No

b- Black-plum (*Zambarau*) Yes No

c- Pineapple (*Nanasi*) Yes No

6. How often do you eat these fruits? (*Refer to the options in (5) above*)

Every day

At least once a week

2times a month

Other (*specify*) _____

Occasionally

7. Have you ever eaten any of these fruits processed?

Baobab (*Ubuyu*) Yes
No

Black-plum (*Zambarau*) Yes No

Pineapple (*Nanasi*) Yes
No

Don't know/no answer

8. How do you like any of these fruits for your consumption?

- Raw/ fresh form
- Processed into juice
- Processed into smoothies

Preliminary analysis	
Knowledge about fruits consumption	
Number of correct responses	<input type="text"/>

Can you list some common available fruits in this community that you know? -----

9. Do you prefer to buy the processed form of these fruits in the market /you make it yourself?

- Yes, I prefer to buy
- I don't prefer to buy, can process myself.

Question K.2: Benefits associated with fruit-based health drinks consumption

10. Have you heard of drinks that promote health states?

- Yes
- No

11. What are the benefits you can think of when you consume fruits /drinks from them?

- Prevents the risk of diseases such as cancer
- Prevents frequent occurrence of ailment /diseases
- Don't know
- Others

12. Are you aware of any risk associated with lack of fruits consumption?

- Risk of developing micronutrients deficiency
- Imbalance recommended daily nutrient consumption
- Don't know
- Others

13. What nutrients do you know can be found in fruits?

- Minerals
- Vitamins
- Anti-cancer bioactives

- Don't know
- Others

14. What health problem would you like to be solved through fruit/health drink?

-
-

15. Can you list uncommon fruits locally available in this community?

mbuyu, zambarau, pineapple and

- Add other locally available fruits not common
.....

PRACTISE

Question P.1: Fruit-intake practises of mbuyu, zambarau, and pineapple

16. What motivate your interest to take a juice or fruit made drink?

- To quench thirst
- For health reasons
- For pleasure
- For the taste
- No, I don't know
- Others

17. Have you taking any of these fruits in the last 1 month?(*mark as appropriate*)

- Ubuyu
- Zambarau
- Pineapple (nanasi)

18. What form did you take any of *the options in 17 above*?

- Raw fruit
- Watery form,
- Dried

- Smoothies (thick juice)
- Others.....

19. what is your expectation when you take juice?

- To provide nutrients
- To boost your enery
- No expectations
- Others.....

20. How do you like your juice

- Very sweet (sugary)
- Moderately sweet
- Naturally sweet
- Un-sweetened
- Others

Reasons for your answer in (20) above?

.....

21. What color of juice would you prefer?

- Brightly colored of fresh Zambarau
- Dull color of Ubuyu
- Mixed color
- No color
- Don't know

Question P.2: knowledge about local processing and availability of products from these fruits.

22. Do you know any local product from any of these fruits: Ubuyu, pineapple and Zambarau?

- Yes
- No

If yes, name the product(s).....

23. Which of the products is available in your local area?

.....

24. What is the main fruit (s) in other most liked fruit drink products in this locality?

.....

Preliminary analysis
<input type="checkbox"/>
<input type="checkbox"/>

Question A.1: Attitudes towards an ideal or desired nutrition-related practice

25. How good do you think it is to eat more fruits at every meal or more frequently?

- 1. Not good
- 2. Good
- 3. Not sure

Perceived barriers

26. How difficult is it for you to eat more fruits at every meal or more frequently?

- 1. Not difficult
- 2. Very difficult
- 3. Difficult

27. Reasons for your answer if *difficult*?

- Too expensive
- Not available
- Other reasons

Preliminary Analysis
<input type="checkbox"/>
<input type="checkbox"/>

Question 1: Market analysis

28. Have you ever bought a raw form of Baobab (Ubuyu) /Zambarau fruits?

- Yes
- No

29. Which of these do you prefer most: Baobab(Mbuyu) , Zambarau, ? Nanasi fruits?

Mark the order of likeness 1- like most 2-like average
3-like least

Give reason why you like Ubuyu?

Taste Colour Sharpn Flavour
Others.....

Give reason why you like Zambarau?

Taste Colour Sharpn Flavour
Others.....

Give reason why you like Nanasi?

Taste Colour Sharpn Flavour
Others.....

30. If there is a product containing the combination of Ubuyu Zambarau? Nanasi would you taste?

- Yes
- No
- It depends/.....on what?
- I don't know

Please give reasons for your answer.....

31. Will you buy a fruit drink with claims of having health benefit?

- Yes No

32. Which of these is primary health concern to you?

High blood pressure diabetes
stress
Cardiovascular diseases, cancer
obesity others

33. Please mark what you would be looking for in a health -fruit drink

Cheap price affordable price sweet aroma sweet
taste

Health benefits thick/sticky watery nutrient
 dense Others.....

Preliminary Analysis
 Potential determinant of consumers' acceptance of BPB functional fruits drink

Question 2: Observation

Please write what you are able to observe in the area of study here using these guidelines

34. Is there a tree of any of these fruits in your area?

- Yes
- No
- Unable to observe

35. Which of these fruits is planted/grown in this area?

- Ubuyu
- Zambarau
- Pineapple (Nanasi)

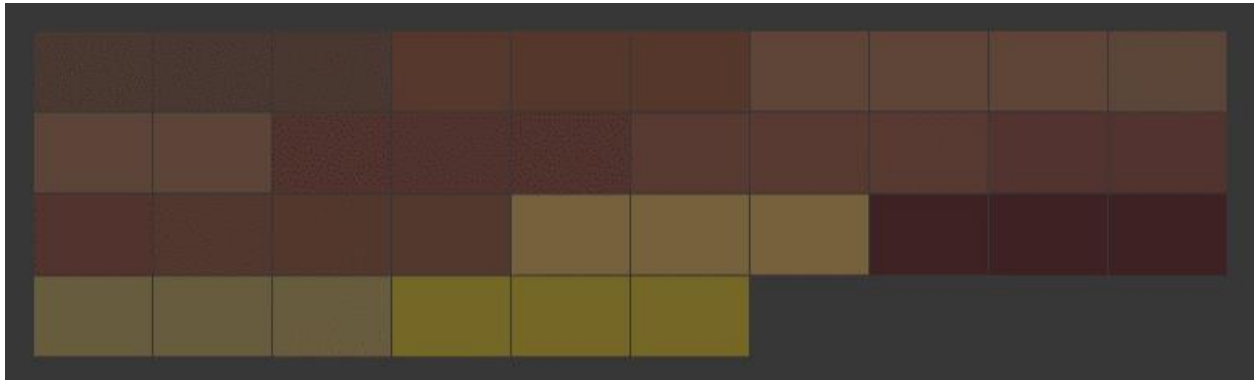
35a. What is the varieties of the fruits mentioned in () above?

35b. What is the evidence of consumption of any of these fruits you see around?(*to be filled by the interviewer*)

Appendix 4: Color Measurement Using Spectrophotometer

Samples from left to right (3 measurements)

F1 ; F2 ; F3 ; F4 ; F5 ; F6 ; F7 ; F8 ; F9 ; F10 ; F10b



Samples	L	a	b	C	h
F1	24.4±0.30	14.33±0.25	14.15±0.49	20.14±0.052	45.11±0.13
F2	29.67±0.05	11.59±0.01	12.95±0.08	17.38±0.07	46.00±0.04
F3	29.65±0.18	9.32±0.09	12.38±0.24	15.50±0.24	47.09±0.08
F4	22.42±0.05	14.23±0.09	9.59±0.16	17.16±0.13	42.51±0.11
F5	25.83±0.09	14.22±0.05	11.28±0.15	18.15±0.12	43.54±0.07
F6	22.76±0.08	15.79±0.02	9.80±0.13	18.58±0.09	41.86±0.08
F7	24.15±0.12	11.85±0.06	12.67±0.29	17.34±0.18	45.69±0.20
F8	41.22±0.04	4.31±0.06	25.37±0.09	25.73±0.10	55.69±0.02
F9	14.08±0.11	15.24±0.08	6.42±0.33	16.53±0.09	39.90±0.25
F10	37.9±0.09	1.28±0.02	19.74±0.20	19.78±0.20	55.89±0.06
Europeanpineapple F10b	42.58±0.02	-1.22	38.93	38.95	62.06

RESEARCH OUTPUTS

Output One: A research Paper

Adedokun, T. O., Matemu, A., Höglinger, O., Mlyuka, E., & Adedeji, A. (2022). Evaluation of functional attributes and storage stability of novel juice blends from baobab, pineapple, and black-plum fruits. *Journal of Heliyon*, <https://doi.org/10.1016/j.heliyon.2022.e09340>.

Output Three: 2 Poster Presentation

Poster Presentation



FORMULATION OF FUNCTIONAL BEVERAGE FROM A BLEND OF BAOBAB (*Adansonia -digitata*), PINEAPPLE (*Comosus ananas*) AND BLACK-PLUM (*Syzygium cumini*) FRUITS

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ABSTRACT
Several under-utilized tropical fruits have essential micronutrients and phytochemical composition with the potential to contribute to the nutrition of people in many poor communities where they are grown. This study was carried out to investigate the use of juice blends of baobab, pineapple, and black-plum fruits as functional beverages for human benefits. Pasteurized juice blends of baobab, pineapple, and black-plum fruits were analyzed for physicochemical, antioxidant, sensory properties, mineral compositions, and storage stability at 4°C for 4 weeks. The results showed that the vitamin C contents of individual juices synergistically contributed to the high values observed in the blends (317.45- 414.51 mg/L). Juice blends of baobab, pineapple, and black-plum fruits are good sources of calcium (57-153 mg/L), magnesium (71-130 mg/L), and antioxidants (ascorbic acid, total polyphenol contents (65-104 mg GAE/100 mL), scavenging ability (105.97-359.71 µmol TE/100 mL), and reducing potential (1376-1829 µMFe²⁺-L) the consumption of which can promote human health. Physicochemical parameters of juice blends were stable at refrigeration temperature (4°C) in the first two weeks; however, color change was observed towards the end of the fourth storage week. The formulated ready-to-drink (RTD) beverages compared well with a known market sample for sensory parameters with improved taste and consumer acceptability and showed good antioxidant potential although there was a relative decrease in vitamin C content during storage at both refrigeration and ambient temperatures. These findings reveal that baobab fruit pulp, pineapple, and black-plum fruits can be major ingredients in producing an antioxidant-rich functional beverage that meets the preferences of consumers.

CONCLUSIONS
Baobab-pineapple-black plum juice blends showed a high amount of micronutrients and phytochemicals that establish their potential as functional beverages vital in disease prevention and health promotion. The blending of the fruit juices improved the sensory attributes and subsequently consumers' acceptance. This study highlights the quality attributes of blends of baobab, pineapple, and black plum juices which can contribute to reducing micronutrient deficiency and improving the nutritional status of people in the rural communities in sub-Saharan Africa. It also provides a guide to the food industry in the development of new functional beverages improving the utilization and economic value of these fruits and becoming a source of income generation for the producers and retailers.

RECOMMENDATIONS
The absorption of vitamin C in this functional beverage especially in the vulnerable groups in Tanzania can be a new research area. Replacing sucrose as a sweetener with other low-calorie substitutes can also be considered which will make it amenable to diabetes patients.

INTRODUCTION
Several studies have pointed out the importance of fruits and their association with reduced risk of developing chronic diseases. Frequent consumption of fruits and vegetables has the potential to contribute to good and healthy living, reduce the chance of cardiovascular disease, and have a protective role against diabetes and several non-communicable diseases (Bursac' Kovacevic et al. 2020). The benefits of fruits are attributable to their natural compositions which include vitamins such as ascorbic acid and folic acid; minerals like potassium, calcium, iron; fibers, anti-oxidants. They also contain other bio-active compounds essential for human health which are responsible for their functional attributes (Martin-belloso et al., 2016). These attributes in fruits make them qualify as functional foods. Functional foods are foods providing benefits beyond basic nutrition. They contain substances that have the potential to improve human physical and mental wellness as well as have the capacity to prevent nutrition-related diseases (Gibson and Williams, 2001). Beverages are the most active functional food category as a result of their ease of dissolution of functional components and convenient method of consumption (Corbo et al., 2014). Functional beverages have become the recent interest of consumers as their awareness of fruit benefits increases and that of the food industry as it comes at the center of research and development (Cong, Bremer, & Mirova, 2020). Fruit-based functional beverages are important sources of vitamin C, polyphenols, minerals, and dietary antioxidants that give protection against oxidative stress by increasing cell resistance to reactive oxygen species (ROS) in the system and are also of significant health benefit for the human body (Siro et al., 2008; Maria & Riccardo, 2020; Liu et al., 2021). To maximize the benefits from the base ingredients used in functional beverages, they have to be uniquely combined and synergistically formulated to address several modern health challenges such as eliminating reactive oxygen species which can improve the overall quality of life. Under-utilized wild fruits widely distributed in tropical Africa particularly Baobab (*Adansonia digitata*) and black-plum (*Syzygium cumini*) fruits have a considerable amount of essential nutrients and compounds. They have recently attracted interest as functional fruits due to their exceptional compositions of bioactive compounds with the potential to contribute to food security as well as play vital roles in the nutrition of the people especially in the rural communities (Avorh, 2015; Akimfesi, 2000). The blending of fruits has previously been established to improve the nutritional and organoleptic qualities of the blends by synergistically contributing to human well-being when the benefits of all the fruits are combined (Shahel et al., 2015). Blending these fruits has the potential to combine their individual functional characteristics to combat malnutrition, especially micronutrient deficiency among the most vulnerable groups in Africa. This study aimed to formulate and investigate the juice blends of pineapple, baobab fruit pulp, and black-plum fruits in order to obtain a functional beverage with optimal health benefits.

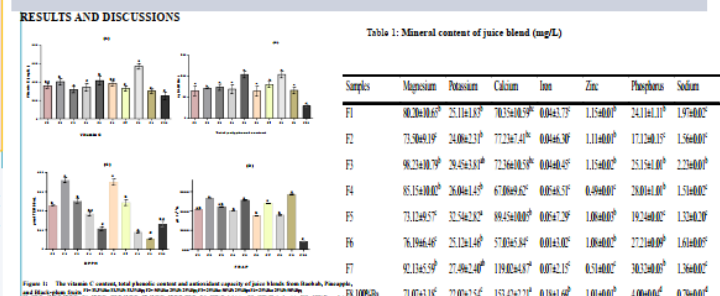


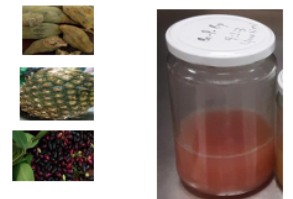
Figure 1A showed the vitamin C content of the juice samples with 100% baobab (F1) (sample F1) having the highest (771.52 mg/L) value. The significantly high (P<0.05) vitamin C content of the blends could be attributed to their baobab fruit pulp content since baobab fruit pulp is reported to be a good source of vitamin C (Omanu, 2004; USDA, 2015). Sample F5 ascorbic acid content differs from sample F9 and sample F10 at P<0.05. This confirms that black-plum and pineapple juices are fair sources of vitamin C (Bulya, 2018; Masamba, 2013). The synergistic combination of all vitamin C in these individual juices contributes to the high vitamin C observed in the blends with blends having lower amount of baobab juice having lower vitamin C content. The amount of vitamin C observed in the juice blend samples could cover about 60% of the recommended dietary allowances (RDA) based on the recommendation that dietary intake of 90-100mg ascorbic acid/day could reduce the risk of non-communicable diseases (Carr & Frei, 1999).

OBJECTIVES OF THE STUDY

- To establish consumers' perception, awareness of health benefits, and consumption patterns of under-utilized fruits in the current study.
- To evaluate the quality attributes of the blends of baobab, pineapple, and black-plum juices to determine their suitability for use as a functional beverage.
- To examine the quality of the formulated beverage during storage.

EXPERIMENTAL METHODOLOGY

- Functional beverage knowledge, attitude and practices assessment survey - Achieved through an interviews in 3 randomly selected communities namely: Babati, Nambala, and Tengeru in Arusha region of Tanzania.
- Fruit juice blending
- Physico-chemical properties determination such as pH, total titratable acidity (TTA), total soluble solids, TSS (°Brix) and color of the juices using the recommended standard method of analysis (AOAC, 2005).
- Phytonutrients determination such as total vitamin C, total polyphenol compounds and the antioxidant capacities.
- Mineral contents and Anti-nutritional factor determination.
- Storage and sensory studies of the blends and ready-to-drink beverages from the juice blends



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