# DEVELOPMENT AND QUALITY EVALUATION OF A FUNCTIONAL FOOD FROM CULTURED MILK SUPPLEMENTED WITH BAOBAB (*Adansonia digitata l.*) FRUIT PULP

**BY**

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This thesis is my original work and has not been submitted for the award of a degree in any other University:

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# DEDICATION

I dedicate this work to, my dear daughters Chloe and Loretta. You have made my life more purpose driven and fulfilled. You were such an inspiration towards the completion of this work. I love you, *cupcakes*

## LIST OF ACRONYMS

**AOAC**- Association of Official Analytical Chemists

**ANOVA-** Analysis of Variance

**CFU**- Colony Forming Units

**CGM-** County Government of Makueni

**CHO-** Carbohydrates

**COVID-19**- Corona Virus

**DNA**- Deoxyribonucleic acids

**DPPH**- 2,2-diphenyl-1-picrylhydrazyl.

**EPS**- Exopolysaccharides

**FAO**- Food and Agriculture Organization

**GNP-** Gross National Product

**IOM**- Institute of Medicine

**ISO**- International Organization for Standardization

**KNBS**- Kenya National Bureau of Statistics

**KEBS**- Kenya Bureau of Standards

**LAB**- Lactic Acid Bacteria

**LSD**- Least Significant Difference

**MOALF**- Ministry of Livestock, Agriculture and Fisheries

**PCR**- Polymerase Chain Reaction

**PET**- Polyethylene terephthalate

**MSME**- Micro, Small and Medium Enterprise

**TBE**- Tris-borate ethylenediaminetetraacetic acid

**UV**- Ultraviolet

**VRBA**- Violet Red Bile Agar

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# GENERAL ABSTRACT

The baobab tree exists in areas characterized by high poverty levels, increased food insecurity and low resilience to climatic changes. In such areas, the tree is vital in complementing staple diets of the rural poor by serving as an alternative source of nutrition during lean seasons. However, in East Africa particularly Kenya, parts of the tree remain underutilized compared to other West-African communities. This study therefore assessed the status of utilization of baobab tree in Kenya with an overall aim to develop and evaluate the quality of a selected functional food that will serve to increase utilization of the fruit part of the tree. The selected study site was Makueni County, a drought prone area with baobab trees being vastly dominant. A survey was conducted using semi structured questionnaires for data collection on production, consumption, processing, and marketing of baobab products involving 250 purposively sampled households, using a cross-sectional study design. Five Focus Group Discussions and ten Key Informant Interviews were also conducted to triangulate the data obtained from the survey. Descriptive statistics for mean, frequency and percentages were used to analyze the data. The survey findings indicated that the tree was accessible to majority of the respondents with the fruit pulp being widely consumed by 72% of the respondents. Small scale processing of pulp/seed sweets was done by 47% of the respondents and at least 8875 KGs of this commodity was processed annually. Rural processors however face several challenges such as financial constraints (41%), limited number of customers (25%) and limited market space (12%) all which account for minimum returns of less than KES 5000 (USD 41.21) per month. Various products processed from the baobab fruit i.e., jam, toffees, juice, pulp/seed sweets and fruit powder were identified including those prepared traditionally at household level. However, incorporation of baobab fruit pulp in innovative formulations remains limited. Hence, a new innovative product was developed form the baobab fruit pulp through modern processing techniques that ensure safety while delivering adequate nutrition. The innovative baobab product under study involved cultured milk supplemented with baobab fruit pulp and was tested for micronutrient composition, physicochemical, sensory, shelf life and microbial characteristics using standard methods. Micronutrient composition of baobab tree products was also studied. The data was analyzed using STATA version 12, inferential statistics done using ANOVA and means separated using Bonferroni's method. Findings on micronutrient composition of baobab tree products, indicated that baobab fruit pulp contained vitamin C level of 195.06±0.70 mg/100g. Compared to the pulp, the leaves contained highest calcium (2061.77±4.69 mg/100g) and iron (10.47±0.07 mg/100g) content while kernels possessed the highest amount of zinc (7.67±0.01 mg/100g) at $p<0.05$. Additionally, the baobab fruit pulp displayed a higher antioxidant activity (60.79±0.16%) compared to the leaves (32.74 ± 0.25%) and kernels (51.5 ± 0.36%). On the other hand, developed baobab formulations showed statistically significant differences at $p<0.05$, in vitamin C (2.47 ± 0.10-10.09± 0.10 mg/100g), Calcium (14.92 ± 0.03-36.95± 0.03 mg/100g), Iron (0.25 ± 0.02-1.51± 0.02 mg/100g) and Zinc (0.67 ± 0.01-1.19 ±0.01 mg/100g) content. The microbial analysis also showed that the developed baobab product was safe for human consumption since *Staphylococcus aureus* was not detected in all formulations. Acceptable formulations selected for shelf-life study exhibited a high shelf stability when subjected to 4 °C storage for 14 days, while packaged in glass and white pigmented PET plastic containers. The study concluded that cultured milk supplemented with baobab pulp has a high potential for commercialization ultimately improving livelihoods and nutrition among communities living along baobab regions.

# CHAPTER ONE: GENERAL INTRODUCTION

## 1.1 Background information

The baobab tree endemic to the arid and semi-arid regions of Sub-Saharan Africa, offers an array of economic, medicinal, and nutritional benefits (Sabina et al., 2020). In rangeland communities, the indigenous baobab tree can capably support the rural communities through the supply of inexpensive nutrients (Assogba et al., 2022). This is particularly evident when food security is jeopardized by unpredictable changes in climatic conditions that render staple food crops unavailable (Cousins and Witkowski, 2015). All parts of the tree are edible, but the fruit pulp, seeds and leaves are the most commonly utilized for food and nutrition (Assogbadjo et al., 2021) The tree is therefore considered vital in reducing vulnerability in marginalized communities since its products could be utilized to supplement diets or generate income (Kaimba et al., 2020). The nutritional profile of parts of the baobab tree in the supply of essential nutrients is reportedly better than staple food crops (Stadlmayr et al., 2020). This has resulted to appreciation of the baobab tree in international markets thereby putting pressure on baobab pulp exportation to European Union and United States (USA) markets (Fischer et al., 2020). Rapid development of the baobab fruit pulp market has been triggered by the declaration of the fruit pulp as a novel food, by the European Commission (Meinhold et al., 2022), consequently resulting to its promotion as a superfood and its application as a natural ingredient in over 300 formulations (Gebauer et al., 2014). Although baobab fruit pulp exportation seems an exciting opportunity for economic growth, it may not necessarily bring forth rural developments, due to the likelihood of inequalities that may occur in the distribution of accrued benefits (Buchmann et al., 2010). Further, increased attention towards exportation of the baobab fruit tends to undermine the local subsistence utilization of baobab products (Meinhold and Darr, 2022). This will therefore have a negative impact on the rural livelihoods in terms of reduced nutrient intake and limited access rights (Buchmann et al., 2010).

Baobab products when incorporated into the local diets are capable of increasing the nutritional value as they possess high amounts of carbohydrates, dietary fiber, calcium, vitamin $B_1$, niacin and vitamin C (De Caluwé et al., 2010). For instance, the leaves and seeds form a major part of the West African culinary dishes, soups, and beverages (Rahul et al., 2015; De Caluwe et al., 2009; Chadare et al., 2009). The fruit, leaves and stem bark part of the baobab tree contain phytochemicals that largely contribute to their antioxidant activities (Ndiaye et al., 2021; Braca et al., 2018; Lagnika et al., 2012). Therefore, consumption of these parts, particularly the pulp and leaves, is said to confer anti-inflammatory, antidiabetic, antipyretic, analgesic, and anticancer activity to the human body (Braca et al., 2018). The tree can therefore be termed as an iconic tree that can be utilized as a dietary source and for income generation (Muriungi et al., 2021) since products generated by the baobab tree have great potential to support marginalized communities and reduce their vulnerability in the face of harsh climatic conditions (McMullin, 2015).

In Kenya the most common consumed part among the rural communities living along the baobab growing regions is the fruit pulp (Kwamboka, 2020). The fruit pulp is processed into sweets locally known as *mabuyu* (Jackering et al., 2019) and vended to school going children (Kinuthia, 2018). In addition, baobab fruit pulp is also blended traditionally with milk to hasten spontaneous fermentation to form a local beverage known as *maziwa lala.* This is a similar practice in Nigeria among Hausa and Fulani communities during *nono* production where baobab pulp emulsion is used to impart a characteristic taste (Bello et al., 2020). Similarly, in Zimbabwe and Zambia baobab fruit pulp is blended with raw cow milk to form local preparations known as *mutandabota* and *chivalavati* without necessarily subjecting the milk to fermentation (Moonga et al., 2019; Mpofu et al., 2014). Milk contains substantial amount of nutrients comprising of all macro elements such as carbohydrates, proteins, lipids, energy as well as trace elements (Guetouache at al., 2014). Fermenting milk has been shown to produce milk products that are nutritious, convenient, and palatable by even people with lactose maldigestability (Nduko et al., 2016). Previous studies have shown that organic acids present in baobab fruit pulp and lactic acid produced during milk fermentation are capable of inhibiting both spoilage and pathogenic bacteria (Zumunta et al., 2021) in these products. Spontaneous fermentation of milk is a common practice in rural communities. In spontaneously fermented products exists a broad diversity of natural microbiota involved in the fermentation process (Teshome, 2015). However, spontaneously fermented dairy products have limited shelf life and inconsistent in terms of quality and organoleptic properties (Nduko et al., 2016). Modern interventions such as the use of starter cultures consisting of a definite microbial composition result in high quality food products with a prolonged shelf life (Marco et al., 2017; Teshome, 2015). One product manufactured using starter cultures is cultured milk, whereby the mesophilic LAB are typically incorporated into the milk at room temperatures. The mesophilic bacteria hydrolyze milk proteins, lower pH and secrete bacterial metabolites resulting to sour taste and increased viscosity (Aisha et al.,2017). This study therefore embarked on the development of a functional food in this case cultured milk product supplemented with baobab fruit pulp, a product that will offer health benefits beyond basic nutritional value (Lee and Foo 2014). Owing to phytochemicals present in the baobab fruit pulp which can decrease the effects of harmful environmental impacts to the human body (Gorelik et al., 2017) amongst other benefits. Moreover, having seen the nutritional benefits of baobab fruit pulp (*Adansonia digitata l.*), the functional food product under study can be used to combat micronutrient deficiencies in particularly populations living in abject poverty who are incapable of purchasing biofortified foods and mineral supplements to meet their recommended diet requirements (Kinuthia et al., 2018) and in turn increase the utilization of this fruit.

## 1.2 Statement of the problem

Successful utilization of the baobab fruits is impeded by several socio-cultural factors comprising of multiple beliefs within Kenyan communities on the sacrosanctity of the baobab tree. This is particularly evident along the coastal areas where strict restrictions exist since special rituals are carried out under the baobab tree by the religious leaders. Some communities also believe that the tree is a host for evil spirits and eating the pulp will result to weakness of bones and joints (Wanjeri et al., 2020). In addition, negative perceptions such as the tree often being termed as ‘poor man’s food’, ‘monkey food’ or ‘children food’ has strongly devalued the tree (Kinuthia, 2018). This therefore creates a need to disseminate knowledge on the nutritional importance of baobab products to promote consumption of these products, reduce vulnerability and boost nutrient uptake during lean seasons.

In addition, much attention has been geared towards the production of staple foods which are more prone to losses during adverse climatic conditions with minimum efforts being directed towards high ecological tolerance indigenous foods (Mc Mullin and Kehlenbeck, 2015). One of the ways to enhance utilization of baobab tree products is through processing of high-quality value-added products which consequently overcomes overreliance on existing traditionally processed products whose returns are meagre, and consumption associated with a particular group of people i.e., school going kids, poor people, or monkeys.

In addition, the authorization of importation baobab fruit as a novel food under regulation EC258/97 by the European Commission (Vassilou, 2008), has resulted in energy being directed towards exportation to acquire income, rather than the development of high value baobab products that can be used as a source of income and nutrition among the vulnerable communities in the baobab belt which in turn has negatively influenced utilization and processing by the local communities. This implies that effort is required to promote incorporation of baobab products in the day to day diets, to reduces pressure on export and increases dietary diversity while boosting micronutrient intake, consequently reducing incidences of malnutrition during lean seasons.

Further, scarcity in research and innovation towards successful development and value addition of baobab tree products has largely resulted to a gap in development and commercialization of substantial high-quality baobab products for consumption by the general population. This has resulted to limited production of innovative high value products from baobab thereby causing the full potential of baobab products not to be tapped both as nutritious food and an income generation venture. Currently, the most commonly vended baobab product is *mabuyu* sweets whose production involves inferior processing techniques and consumption associated with school going children (Omotayo and Aremu, 2020). Incorporation of the baobab pulp as a food ingredient in various formulations remains limited and this study seeked to develop an innovative dairy formulation which besides excellent nutritional value, increases the consumption and commercial value of the highly underutilized baobab fruit.

## 1.3 Justification

Exploring how one can use parts of the baobab tree which possess nutraceutical and functional properties to promote a healthy lifestyle is vital for vulnerable populations living in abject poverty who from time to time suffer the consequences of adverse climatic conditions. Whereas the baobab tree has a high ecological tolerance and information on how parts of the tree can be integrated into the local diets will serve to increase the dietary diversity and reduce vulnerability during lean seasons (Meinhold and Darr, 2020).

Indigenous crops such as baobab (*Adansonia digitata L.*) when utilized as a dietary source have the capacity to address diverse nutrient deficiencies and improve food security in the country (Momanyi et al., 2019). Therefore, utilization of the baobab tree products is a feasible strategy in combating food and nutrition security issues since their nutritional profile in the supply of essential nutrients is better even than staple food crops (Stadlmayr et al., 2020).

Development of cultured bovine milk supplemented with baobab fruit pulp is a worthwhile venture consisting of locally accessible raw materials. The functional product has the potential to foster economic development among rural communities living along baobab regions and inevitably increase utilization of the baobab fruit pulp. Further, this project provides vital information to processors on the fermentation process and baobab fruit pulp levels that yield quality, consistent and shelf stable supplemented cultured milk.

### 1.4 Main objective

The main objective of the study was to develop and evaluate the quality of a functional food made from cultured milk and baobab fruit pulp powder for improved nutrition and economic empowerment among vulnerable communities.

### 1.5 Specific objectives

I. To assess the status of utilization and processing practices of the baobab fruit by small holder farmers in Makueni County.

II. To determine the and microbial quality characteristics of cultured milk supplemented with baobab fruit pulp for rural populations.

III. To determine the physicochemical and micronutrient composition of the cultured milk supplemented with baobab fruit pulp for rural populations.

IV. To evaluate the overall consumer acceptability of the cultured milk supplemented with baobab fruit pulp for rural populations.

V. To conduct a shelf-life study of the cultured milk supplemented with baobab fruit pulp for rural populations.

## 1.6 Hypotheses

I. There will be significant utilization, production, and commercial processing of the baobab fruit in Makueni County.

II. The developed cultured milk product supplemented with baobab fruit pulp will have acceptable physicochemical properties as well as high microbial quality as that of similar products.

III. The developed cultured milk product enriched with baobab fruit pulp will be acceptable to consumers.

IV. The developed cultured milk product enriched with baobab fruit pulp will be shelf stable.

# CHAPTER TWO: LITERATURE REVIEW

## 2.0 Introduction

This chapter provides an overview of previous research studies on baobab utilization, nutritional importance of baobab products and marketing potential of processed baobab products. Therefore, a synthesis of previous research work on a local, regional, and global scale was used to provide insights on the research topic and data collection requirements for the primary research.

## 2.1 Food Security and Role of Baobab tree

According to the GNP (2017), African countries record the fastest growth in population and in most of these countries agricultural ventures are the main sources of livelihood. However, there are several threatening environmental factors such as climatic impacts, crop failure and low agricultural productivity (Kiprotich et al., 2019). All these render a threat to agricultural activities. One of the ways to mitigate these climatic change impacts is through utilization of drought tolerant crops such as the baobab tree which is vital to majority of the rural populations particularly residing in the marginalized areas in Kenya (Gebauer et al., 2016). The tree is well resistant to harsh climatic conditions and can capably serve vitally in the nutrition and food security at household level (Business, 2014) by diversifying diets during lean seasons of famine and crop failure (Kwamboka, 2020). Considering food security objectives, parts of the tree are capable of offering an opportunity to increase nutrient intake and address various micronutrient deficiencies, due to the abundance of micronutrients and phytochemicals (Gabaza et al., 2018). The leaves, fruits, flowers, and seeds of the baobab tree are traditionally consumed during lean seasons (Darr et al., 2020). For instance, the leaves of the tree can be consumed during periods of famine and scarcity as a substitute for spinach and kales (Chadare, 2010) and in making soups

(Zahar'au et al., 2014), the fruit pulp can be eaten like a snack, used to make porridge, hard gruel ('ugali') or other different foods in times of scarcity (Wanjeri et al., 2020). Incorporation of baobab tree products therefore increases the nutritional quality of the local diets and promotes individual nutrient adequacy in households (Momanyi et al., 2019). Non-food utilization of baobab parts such as barks, branches and fruit shells could be a venture in boosting welfare and income through making of ropes, beehives, rat traps, bush meat traps for sale (Wanjeri et al., 2020). Commercialization of such non- food baobab products by small holder farmers can be a vital source of income that can be used to buy food, access health care services or education while indirectly contributing to food security objectives (Meinhold and Darr, 2021).

### 2.2 Distribution of the Baobab (Adansonia digitata l.)

Outside Africa, baobab tree has been reported to exist along the Arabian Peninsula, North Yemen, Sri Lanka, and Oman (Wickens, 2008; Rahul et al., 2015). The tree has been domesticated in Cairo, Mauritius, Malaya, Java, New Caledonia, Hawaii, Philippines, West Indies, the Antilles, and Guyana (Wickens, 2008). In Africa, baobab trees are mainly distributed in the Savannah regions where they provide vital non-timber forest products to the rural communities living along these areas (Assogbadjo et al., 2015). It is an indigenous fruit tree species endemic to the semi-arid regions of Sub-Saharan Africa where each tree part is considered useful (Petignat, 2016; Kabore et al., 2011). West African countries like Mali, Malawi, Senegal, and Nigeria maintain huge populations of the baobab trees (Schumann et al., 2010). The baobab tree is also evident in the coastal plains of Ghana, Togo and Dahomey in areas receiving between 700 - 800 mm rainfall per annum and in the south of the equator on the coastal plains of Congo, Kubango and Kunene in Namibia (Wickens, 2008). In Namibia baobabs mainly occur in the Northern regions in the hot and dry woodlands (Lisao et al., 2017). In the Northeast of Africa, baobab trees are densely populated towards the southern parts Sudan, where they thrive in both short grass and deciduous savanna woodlands (Wickens,2008) while in Ethiopia, the trees occur in the lowlands of Eritrea and some in the Coastal plains of Somalia (Wickens, 2008). In East Africa, the tree is found in the Tanzanian border east of Mt. Kilimanjaro (Gebauer et al., 2016) and coastal regions of Kenya (Kiprotich et al., 2019; Kinuthia, 2018). In Southern Africa, the tree occurs in the poorly drained soils of the valleys of Zambezi, dry woodlands of Malawi, Savannah vegetation of the Central Angolan plateau and in South Africa along the Limpopo basin in the hot and dry frost- free sandy soil (Wickens, 2008).

### 2.3 Characteristics of the baobab tree

The African baobab tree belongs to Kingdom: Plantae, Phylum: Tracheophyta, Class: Magnoliopsida, Order: Malvales, Family: Malvaceae, Genus: Adansonia, Species: Dagitata (Carvalho-Sorbrinho et al.,2016; Kinuthia, 2018). The baobab tree (*Adansonia digitata l)* is a massive and deciduous plant whose height is between 20-30 meters with a vast and robust root system that can grow up to 2 meters (Rahul et al., 2015). The roots can absorb up to massive amounts of water making the tree have high ecological tolerance (Lisao et al., 2017). The tree is widely adapted to a variety of soils (either sandy, stony or clay soils) while tolerating high temperatures and low rainfall (Buchmann et al., 2010). The trunk is stout, either tapering, cylindrical or bottle shaped consisting of irregularly distributed branches (Gebauer et al., 2002). The baobab tree produces simple leaves that are alternate and foliate in nature having a diameter of 20 centimeters (Rahul et al., 2015). Towards the end of the dry season flower buds arise from the tree and are either ovoid or globose (Sidibe and Williams, 2002). The fruit consists of a hard, red brownish seeds upon which the dry white pulp is embedded on (Nnam and Obiakor, 2003).

All these parts of the tree are vital in many parts of Africa where they are utilized in treating various ailments or in preparation of various foods (Kabore et al., 2011).

**Figure 2.1: Baobab tree**

Source: Angela Mwangi

### 2.4 Utilization of Baobab Plant Products

Parts of the baobab tree are used to supplement diets of rural poor or serve as a hunger survival strategy in times of food scarcity or crop failure while addressing the various human nutritional needs (Legwaila et al., 2011). For instance, in West African countries, meals incorporated with baobab parts are consumed daily with the surplus either being stored or sold in local markets (Buchmann et al., 2010) indicating that baobab-based meals are staple in these countries. In Southern Africa, multiple uses of baobab have been reported with the most useful part being the fruit pulp which forms a vital part of the nutrition of these rural communities (Munyebvu et al., 2018). In these local dishes the baobab fruit pulp majorly serves as a seasoning and a substitute to cream of tar tar (Sabina et al., 2020) On the other hand, in Eastern Africa some parts of the tree like the leaves are rarely consumed (Gebauer et al., 2016). In Kenya and Tanzania, immense benefits of baobab are particularly derived from the fruit pulp, which is either consumed fresh, or incorporated into various traditional delicacies (Gebauer et al., 2016). For instance, in Tanzania, the fruit of the sausage tree, baobab fruit pulp and sugar cane juice are used to come up with a traditional alcoholic beverage (Tembo et al., 2017). When consumed, parts of the tree are reported to be greatly nutritious as it contains substantial amounts of vitamins, minerals, phytochemicals and amino acids (Sabina et al., 2020). In various parts of Sub-Saharan Africa, the fruit pulp, leaves, bark and seeds have traditionally been used to treat various infections such as diarrhea, dysentery, smallpox, measles and hiccough (Diop et al., 2006; Sidibe and Williams, 2002). Previous studies have shown that parts of the baobab tree possess anti-pyretic activities, antimicrobial activity (particularly against *Salmonella*, *Bacillus* and *Streptococcus* species), analgesic and antiviral activities (Kabore et al., 2011) therefore proving useful in combating various diseases. According to Van Damme 2015, the ash generated from burning baobab fruit shells is used in disinfecting wound. Ethnopharmacological uses of parts of the tree are mainly attributed to the abundance of bioactive components that contribute to the treatment of intestinal disorders, diarrhoea and dysentery (Silva et al., 2023). Despite the baobab tree being a source of food and medicine, it also offers a wide range of economic benefits, since fibers from the baobab tree bark are used in making clothes, ropes, and baskets (Chadare, 2010). In East Africa the roots and bark of the baobab tree are useful in dye manufacture (Zahra'u et al., 2014). Despite the wood derived from baobab being a poor source of fuel, the fruit covers have been reported to be superior sources of fuel in Tanzania (Zahr'au et al., 2014). Further to that, in Kenya the fruit shells are utilized in the manufacture of curio items, souvenirs and pots for food and drink (Gebauer et al., 2016; Zahra'u et al., 2014). Interestingly, in Southern Africa, baobab tree trunks have been utilized as storehouses, prisons, bus stations as well as dwelling places that can house up to fifty people inside (Adensina and Zhu, 2022).

## 2.5 Baobab Leaves

### 2.5.1 Production and Consumption of Baobab leaves in Sub-Saharan Africa

Consumption of baobab leaves is common in the central and most notably in Western regions of Africa. Young leaves and shoots of the baobab tree have been reported to provide a tasty vegetable resembling spinach (Wickens, 2008). At the start of the rainy season, the leaves are soft and are consumed green leafy vegetables or used in salad preparation (Wickens, 2008; Rashford, 2018). Assogbadjo et al. (2008), reported a distinguishing trait among baobab leaves for consumption in West Africa whereby, there are baobab trees that yield bitter leaves while others yield delicious leaves. In a review by Rashford, (2015), he noted that the distinction between the palatable and non-palatable baobab leaves has not received much attention in literature. Most assumptions according to this review characterize taste as a function of age and morphological variation since the old leaves are thick, hairy, tasteless, and bitter. In Africa, there is a much greater preference in young baobab leaves for consumption and the highly mucilaginous nature of the cooked leaves does not affect the desirability of the leaves in African countries in which the leaves are consumed (Rashford, 2015). In a study conducted by Nordeide et al. (1996), over fifty percent of rural households consume the baobab leaves during lean seasons. The baobab leaves tend to be harvested during the rainy season since during such time they are tender (Gebauer et al., 2002). In Mali and Benin, the cash sale of such dried baobab leaves product is used to augment household incomes (De Caluwe and Van damme, 2011). Sundried leaves are powdered and reconstituted into a sauce that is incorporated into soups, porridges or thick gruels (Abioye et al., 2014; Sidibe and Williams, 2002), for thickening and flavoring purposes (Rashford, 2018). Leaves are used in Mali to prepare *Lalo* a sauce in which other vegetables are incorporated into (Nordeide et al., 1996). Similarly, in Nigeria, the leaves are used in preparing *Miyan kuka*, a soup consumed among the Hausa community of Nigeria (Sabina et al., 2020). In Zimbabwe the fresh leaves are used as substitutes for local green vegetables (Zah'rau et al., 2014). In Sudan, young tender leaves are used in salad preparation in conjunction with peanuts (Gebauer et al., 2002). In the same West African communities, the leaves are also utilized as livestock fodder (Rashford, 2018). In Gambia, fresh ground leaves are cooked together with meat, fish, onions, vegetables and hot pepper, to form a local dish known as *soupa lalo* (Wickens, 2008). In Kenya, very low consumption of baobab leaves has been reported in communities living along the baobab growing regions (Wanjeri et al., 2020). In a study conducted in Taita Taveta and Kitui counties, consumption of leaves was unknown to the people (Fischer et al., 2020). However, in another study conducted in Kilifi County in Kenya, the leaves were reported to be a part of some local household diets with most of them consuming the leaves one to three times in a month (Wanjeri et al., 2020). In these communities where the baobab leaves are consumed in Kenya, they are prepared like spinach or mixed and cooked with other vegetables (Achigan-dako et al., 2011).

**Figure 2.2: Baobab leaves**

Source**:** Angela Mwangi

### 2.5.2 Nutritional Importance of Baobab leaves

Baobab leaves contains appreciable amounts of protein with five of the eight essential amino acids being present (De Caluwe et al., 2010). Protein content in the leaves has been reported to be better than that present in cereals like barley, rice, wheat, and sorghum (Habte et al., 2021). It has also been reported that once baobab leaves are consumed together with such cereals the leaves are able to also compensate for deficiencies in micronutrients (Hyacinthe et al., 2015). The leaves are also excellent sources of both macro and micro elements such as Calcium, Potassium, Iron and Zinc among others (Zahr'au et al., 2014). Carbohydrate in leaves range from 60-70%, fat 4-10%, the fiber and ash is approximately 11% and 16% respectively (De Caluwe et al., 2010). It has been reported that once baobab leaves are consumed together with other cereals such as rice, maize or millet, the leaves are able to compensate for deficiencies in iron and zinc micronutrients such as (Hyacinthe et al., 2015; Chadare et al.,2009). According to Arowora et al. (2018), the sodium and potassium levels present in the baobab leaves qualifies them to be used in the management and treatment of diseases associated with the Central Nervous System as well as their prevention. Therefore, in these West African communities where the leaves are consumed as a staple diet, they provide a significant amount of proteins and minerals particularly zinc, iron and calcium to children, pregnant women, and lactating mothers (Zahr'au et al., 2014). In addition, the baobab leaves also contain provitamins A and C. Provitamin A is particularly high in young leaves and the high concentration of Vitamin A in the young leaves is particularly considered to be beneficial to women and children (Assogbajo et al., 2012). The leaves also possess a significant level of antioxidant activity due to the presence of glycosides, saponins, steroids and flavonoids (Gbaguidi et al., 2020). The leaves possess high levels of anti-nutrient factors such as phytates and tannic acid (Habte et al., 2021). However, baobab leaves are not eaten raw but are boiled in water and antinutrient factors are significantly reduced during the cooking process (Olajide and Baiyeri, 2022). Further, fermentation of leaves increases bioavailability of nutrients, consequently improving the eating qualities of baobab leaves (Mahanu and Mariod,2022). **Table 2.1** and **Table 2.2** below indicates the nutrient composition of baobab leaves based on different authors.

**Table 2.1: Nutritional composition of fresh leaves per 100g dry weight based on different authors**

| **Chemical constituent** | **Value 1** | **Value 2** | **Value 3** | **References** |
|---|---|---|---|---|
| Moisture (g/100g) | 78.2 | 9.86 | | Abiona et al., 2014; Arowora et al., 2018 |
| Crude fat(g/100g) | 2.71 | 3.72 | 1.16 | Abiona et al., 2014; Arowora et al., 2018; Abioye et al., 2015 |
| Crude protein(g/100g) | 13.6 | 19.84 | 12.28 | Abiona et al., 2014; Arowora et al., 2018; Abioye et al., 2015 |
| Crude Ash(g/100g) | 4.08 | 8.66 | 8.01 | Abiona et al., 2014; Arowora et al., 2018; Abioye et al., 2015 |
| Crude Fiber(g/100g) | 2.45 | 4.16 | 8.0 | Abiona et al., 2014; Arowora et al., 2018; Abioye et al., 2015 |
| Carbohydrates(g/100g) | 53.76 | 17.49 | | Arowora et al., 2018; Abioye et al., 2015 |
| Energy (KJ/100g) | 415.63 | | | Abioye et al., 2015 |
| Calcium (mg/100g) | 415.63 | 900 | | Arowora et al., 2018; Abioye et al., 2015 |
| Magnesium(mg/100g) | 15 | | | Abioye et al., 2015 |
| Potassium(mg/100g) | 30 | | | Abioye et al., 2015 |
| Sodium(mg/100g) | 2.5 | | | Abioye et al., 2015 |
| Iron(mg/100g) | 15 | | | Abioye et al., 2015 |
| Vitamin A(mg/100g) | 11.5 | | | Abioye et al., 2015 |
| Vitamin C(mg/100g) | 14.98 | | | Abiona et al., 2014 |

**Table 2.2: Nutritional composition of dry leaves per 100g dry weight based on different authors.**

| **Chemical constituent** | **Value 1** | **Value 2** | **References** |
|---|---|---|---|
| Moisture (g/100g) | 7.82 | | Ogbaga et al., 2017 |
| Crude fat(g/100g) | 2.29 | | Abioye et al., 2015; |
| Crude protein(g/100g) | 11.99 | 11.55 | Abioye et al., 2015; Ogbaga et al., 2017 |
| Crude Ash(g/100g) | 9.17 | 3.92 | Abioye et al., 2015; Ogbaga et al., 2017 |
| Crude Fiber(g/100g) | 8.05 | 2.97 | Abioye et al., 2015; Ogbaga et al., 2017 |
| Carbohydrates(g/100g) | 17.49 | 52.23 | Abioye et al., 2015 |
| Calcium (mg/100g) | 1801 | 915 | Abioye et al., 2015; Hyacinthe et al., 2015 |
| Magnesium(mg/100g) | 941 | 8.1 | Abioye et al., 2015; Hyacinthe et al., 2015 |
| Potassium(mg/100g) | 1739 | 27 | Abioye et al., 2015; Hyacinthe et al., 2015 |
| Sodium(mg/100g) | 1.6 | 1.6 | Abioye et al., 2015; Hyacinthe et al., 2015 |
| Copper(mg/100g);’ | 0.36 | 5.405 | Hyacinthe et al., 2015; Ogbaga et al., 2017 |
| Iron(mg/100g) | 11.6 | 26.0 | Hyacinthe et al., 2015 Abioye et al., 2015 |
| Zinc (mg/100g) | 7.353 | | Ogbaga et al., 2017 |
| Manganese(mg/100g) | 10.11 | | Hyacinthe et al., 2015 |
| Phosphorus(mg/100g) | 457 | 2.5 | Ogbaga et al., 2017; Hyacinthe et al., 2015 |

## 2.6 Baobab Seeds

### 2.6.1 Production and Consumption of Baobab seeds in Sub-Saharan Africa

The Baobab seeds are embedded in the sour acidic pulp and the kernels can be roasted or eaten raw (Sidibe and Williams 2002, Sabina et al., 2020). In other communities, the seeds are roasted, cooled, and ground into powder after which the ground powder is dissolved in boiling water and consumed like coffee (Tembo,2016). Seed powder can be used in thickening soups (Braca et al., 2018) or can be used as a flavoring agent after their fermentation (Danbature et al., 2014). Baobab seeds are prepared for eating by steeping the whole seeds, roasting/prolonged boiling/fermentation after which the seeds are dried and crushed to give a fine coarse meal that can either be used as a spice or a thickener in stews or a condiment to intensify the flavor (Wickens, 2008; De Caluwe et al., 2010). Studies have indicated that better protein quality in the seeds is yielded through fermentation as opposed to roasting (Wickens, 2008). The fermentation of seeds is a practice evident particularly in the West African communities, for instance in Burkina Faso, the seeds are boiled and kept in the dark to ferment for 96 hours and the resulting product is referred to as '*maari*' which is used in flavoring dishes (Parkouda et al., 2010). In Senegalese communities, baobab seeds are pounded together with millet and sorghum to prepare a local gruel (Wickens, 2008). In some communities particularly in Sudan, the baobab seeds are roasted and ground into fine powder that is used as a coffee substitute (Salih and Yahi, 2015). A study conducted by Wanjeri et al. (2020) reported the practice of roasting baobab seeds in the coastal areas of Kenya after which they are consumed as a snack or oil pressed from the seeds for cosmetic use.

### 2.6.2 Nutritional Importance of Baobab Seeds

Baobab seeds are high in nutritional value, (Zahr'au et al., 2014) as indicated in **Table 2.3**. Furthermore, when the seeds are consumed in sufficient quantities, they have been reported to provide Dietary Reference Intake of most minerals (Sabina et al., 2020). Baobab seeds contain high percentage of protein and can be used together with low protein foods to supplement protein quantities or can be used together with cereal based flours to improve the protein quality for better nutrition (Danbature et al., 2014). The seeds also contain high levels of lysine which could result in the improvement of the protein quality of cereal-based flours when blended with the baobab seeds (Kinuthia, 2018). In addition, baobab seeds and seed oil contain fatty acids such as linoleic, oleic and palmitic acids as well Omega 3, 6 and 9 (Ofori and Addo, 2023). On the other hand, baobab seeds contain antinutritional factors such as trypsin inhibitors and phytic acid which have a negative implication on protein utilization and availability in the diet (Sabina et al., 2020). However, different processing techniques reduce the antinutritional content of the seeds thereby improving accessibility, bioavailability and acceptability of nutrients present in baobab seeds (Ofori and Addo, 2023).

**Figure 2.3: Baobab seeds**

Source: Angela Mwangi

**Table 2.3: Nutrient composition of baobab seeds per 100g dry weight based on different authors.**

| Chemical constituent | | | | | | | | References |
|---|---|---|---|---|---|---|---|---|
| Moisture (g/100g) | 7.01 | 4.3 | 25.45 | 5.37 | 6.47 | | | Muthai et al., 2017; Osman, 2004; Nnam& Obiakor, 2003; Danbature et al., 2014; Affo and Akande, 2011 |
| Crude fat(g/100g) | 14.43 | 17.50 | 12.2 | 18.87 | 24.72 | 7.8 | | Muthai et al., 2017; Osman, 2004; Ezeagu, 2005; Nnam& Obiakor, 2003; Danbature et al., 2014; Affo and Akande, 2011 |
| Crude protein(g/100g) | 12.41 | 16.60 | 18.4 | 20.13 | 15.5 | 18.4 | | Muthai et al., 2017; Osman, 2004; Ezeagu, 2005; Danbature et al., 2014; Affo and Akande, 2011 |
| Crude Ash(g/100g) | 3.92 | 5.5 | 3.8 | 7.61 | 7.36 | 3.9 | | Muthai et al., 2017; Osman, 2004; Ezeagu, 2005; Nnam& Obiakor, 2003; Danbature et al., 2014; Affo and Akande, 2011 |
| Crude Fiber(g/100g) | 23.31 | 14.94 | 16.2 | 7.89 | 6.57 | | | Muthai et al., 2017; Osman, 2004; Ezeagu, 2005; Danbature et al., 2014; Affo and Akande, 2011 |
| Carbohydrates(g/100g) | 20.00 | 60.40 | 45.1 | 48.07 | 39.90 | 60.48 | | Muthai et al., 2017; Osman, 2004; Ezeagu, 2005; Nnam& Obiakor, 2003; Danbature et al., 2014; Affo and Akande, 2011 |
| Energy (KJ/100g) | 450 | 363.8 | 320 | 462.6 | 409.7 | | | Osman, 2004; Ezeagu, 2005; Nnam& Obiakor, 2003; Danbature et al., 2014; Affo and Akande, 2011 |
| Calcium (mg/100g) | 200 | 212 | 395 | 410 | 500 | 1.2 | 398 | Muthai et al., 2017; Zah'rau et al., 2014; Osman, 2004; Ezeagu, 2005; Nnam& Obiakor, 2003; Danbature et al., 2014; Affo and Akande, 2011 |
| Magnesium(mg/100g) | 330 | 353 | 352 | 270 | 5287 | | | Muthai et al., 2017; Zah'rau et al., 2014; Osman, 2004; Ezeagu, 2005; Affo and Akande, 2011 |
| Potassium(mg/100g) | 9.1 | 1429 | 910 | 600 | 2500 | 990 | | Muthai et al., 2017; Zah'rau et al., 2014; Osman, 2004; Ezeagu, 2005; Nnam& Obiakor, 2003; Danbature et al., 2014; Affo and Akande, 2011 |
| Sodium(mg/100g) | 190 | 228 | 196 | 283 | 260 | 320 | | Muthai et al., 2017; Zah'rau et al., 2014; Osman, 2004; Ezeagu, 2005; Danbature et al., 2014; Affo and Akande, 2011 |
| Copper(mg/100g) | 2.75 | 2.55 | 2.6 | 2.00 | | | | Muthai et al., 2017; Zah'rau et al., 2014; Osman, 2004; Ezeagu, 2005; Nnam& Obiakor, 2003 |
| Iron(mg/100g) | 6.37 | 11.13 | 18.3 | 6.4 | 6.3 | 13.2 | | Muthai et al., 2017; Zah'rau et al., 2014; Osman, 2004; Ezeagu, 2005; Nnam& Obiakor, 2003; Affo and Akande, 2011 |
| Manganese(mg/100g) | 2.01 | 2.1 | 1.06 | 66 | | | | Muthai et al., 2017; Zah'rau et al., 2014; Ezeagu, 2005; Affo and Akande, 2011 |
| Phosphorus(mg/100g) | 6.0 | 9.24 | 6.14 | 3.263 | 15.1 | | | Muthai et al., 2017; Zah'rau et al., 2014; Ezeagu, 2005; Nnam& Obiakor, 2003; Affo and Akande, 2011 |
| Zinc(mg/100g) | 8.41 | 2.57 | 5.2 | 1.29 | 23 | | | Zah'rau et al., 2014; Ezeagu, 2005; Osman, 2004; Nnam& Obiakor, 2003; Affo and Akande, 2011 |

## 2.7 Baobab Fruit Pulp

### 2.7.1 Production and Consumption of Baobab Fruit Pulp

Various meals in Africa are prepared using the baobab fruit pulp. For instance, West African Communities, mix the pulp powder with water or milk and resulting solution added into cerealbased gruels or sauces and soups (Buchmann et al., 2010). In Nigeria, the pulp is pounded and mixed with water to form a solution which is mixed with milk to form a nutritious drink (Zah'rau et al., 2014). Similarly, in Zimbabwe raw cow milk is mixed with baobab fruit pulp to form a drink locally referred to *mutandabota* or *umlondo* used in infant weaning (Mpofu et al., 2014). In Mali the dried fruit pulp is mixed with millet to prepare millet cream locally known as *dégué* (De Caluwé and VanDamme, 2011). In Sudan, the fruit pulp is consumed either fresh, or used to prepare a traditional drink commonly referred to as *gunguleiz* or *talbadi* juice (Sabina et al., 2020; Gebauer and Luedelin, 2013). Among the Bantu communities of South Africa, baobab fruit pulp is added to fermented maize meal the mixture boiled in order to prepare porridge (Wickens ,2008). Among the Wolofs of Senegal, baobab pulp is mixed with millet and groundnuts to prepare a dish known as *ngalakh* consumed alongside *ndiambdne*, a drink prepared by mixing the pulp with water on special occasions such as Good Friday (Wickens, 2008). In Tanzania, the baobab fruit and fruit of the sausage tree, are incorporated into sugarcane juice to facilitate fermentation to prepare a local brew with 7% ethanol (Wickens, 2008). The pulp could also be dissolved in water and the resulting liquid consumed, fermented to make a local brew, used as a sauce or flavoring or even in baking operations to impart a tart taste (Kabore et al., 2011; De Caluwe et al., 2010). In Kenya, various studies have reported the use of baobab fruit pulp at household level to complement local diets or an alternative food during lean seasons. The fruit pulp is commonly consumed while fresh, where the pulp powder is sucked and the seed spit.

Among the Kamba community particularly in Kitui County, the pulp is used in preparation of *Muswa* a thin, soft kind of *Ugali* that has a sweet and sour taste due to baobab incorporation (Kwamboka, 2020). Along the Kenyan coastal region, the pulp powder is mixed with coconut milk to form a refreshing drink, whose use in juice production has also been reported, the fruit pulp is also added in porridge, gruels, soups, ice creams or frozen into ice lollies (Wanjeri et al., 2020). The most common 'snack' consumed from the fruit pulp along these baobab growing regions in Kenya is '*Mabuyu* sweets' that is made by mixing the baobab fruit pulp embedded on the seed with some artificial coloring, sugar, and spices after which it is consumed like candy, purposely targeted for school going children (Fischer et al., 2020). At an industrial scale the baobab fruit pulp can be used in the manufacture of jams as it contains a high level of pectin (Ndabikunze et al., 2011). The pulp can also be used as a thickener in juices and ice creams due to the high level of mucilage (Sabina et al., 2020; De Caluwe et al., 2010). The fruit pulp also since it is naturally dry has been reported to be easily utilized as an ingredient in various formulations to supplement various food products hence providing a platform to address the various micronutrient deficiencies in these diets (Gabaza et al., 2018).

**Figure 2.4: Baobab Fruit**

Source: Angela Mwangi

### 2.7.2 Nutritional Importance of Baobab Fruit Pulp

Most recent studies have also indicated how the dried baobab fruit pulp can be used as a supplement in a variety of the staple foods such as maize, sorghum and many more (Kwamboka et al., 2020) as the pulp is a good source of both macro elements such as carbohydrates, crude fiber, proteins and lipids and microelements like Vitamin C, calcium, phosphorus, potassium, and Beta carotene (Kinuthia et al., 2018; Aluko et al., 2016). Baobab fruit pulp can be utilized in fortifying foods with fiber while raising the overall nutritional profiles (Braca et al., 2018). In addition, low moisture content of the pulp also gives it excellent keeping qualities (Aluko et al., 2016). The baobab fruit pulp also contains all the essential nutrients required for optimal nutrition as illustrated in **Table 2.4** with levels of some essential nutrients being higher than that present in the widely consumed fruits like mangoes, berries, guavas, and bananas (Muthai et al., 2017). In addition, the pulp contains ten times more Vitamin C than that present in oranges (Buchmann et al., 2010).Baobab fruit pulp is an excellent source of potassium, calcium, and magnesium (Stadlmayr et al., 2020).In addition, baobab pulp from Kenya has been reported by Muthai et al. (2017), to be rich in iron and zinc, making it a suitable candidate for utilization as a dietary supplement in populations facing iron and zinc deficiencies. Baobab is considered a nutraceutical as it contains various bioactive natural components with health promoting properties (Gahane and Kogje, 2013). These bioactive components consist of mainly phenolic compounds, which can inhibit the oxidation activities thereby reducing risk of inflammation related illnesses, cardiovascular dysfunction, cancer, diabetes and many more (Ndiaye et al., 2021).Further, the pulp possesses prebiotic potential capable of enhancing the health of the gastrointestinal tract (Fowoyo et al., 2022).

## Table 2.4: Nutritional composition of Baobab fruit pulp per 100g dry weight according to different authors.

| **Chemical constituent** | | | | | | | | | **References** |
|---|---|---|---|---|---|---|---|---|---|
| Moisture (g/100g) | 9.8 | 8.9-12.1 | 4.7-27.6 | 10.4 | 7.47 | | | | Muthai et al., 2017; Stadylmayr et al., 2020; Stadylmayr et al., 2013; Osman, 2004; Affo and Akande, 2011 |
| Crude fat(g/100g) | 0.4-0.7 | 0.2-1.2 | 0.3 | 0.7-1.03 | | | | | Phytotrade, 2009; Stadylmayr et al., 2013; Osman, 2004; Chabite et al., 2019 |
| Crude protein(g/100g) | 2.2 | 2.04-3.24 | 2.6 | 1.1-3.2 | 3.2 | 3.31-3.76 | 1.23 | | Muthai et al., 2017; Phytotrade, 2009; Zah'rau et al., 2014; Stadylmayr et al., 2013; Osman, 2004; Chabite et al.,2019; Affo and Akande, 2011 |
| Crude Ash(g/100g) | 4.41 | 5.5-6.6 | 5.3 | 3.6-7.5 | 3.7-6.3 | 4.5 | 5.95-6.38 | 4.1 | Muthai et al., 2017; Phytotrade, 2009; Zah'rau et al., 2014. Stadylmayr et al., 2020; Stadylmayr et al., 2013; Osman, 2004; Chabite et al., 2019; Affo and Akande, 2011 |
| Crude Fiber(g/100g) | 8.83 | 4.58-5.39 | 5.7 | 4.4-8.7 | 5.4 | 20.62-24.19 | 4.16 | | Muthai et al., 2017; Phytotrade, 2009; Zah'rau et al., 2014; Stadylmayr et al., 2013; Osman, 2004; Chabite et al., 2019Affo and Akande, 2011 |
| Carbohydrates(g/100g) | 25.3-16.9 | 74.9 | 76.2 | 70.74-77.23 | 82.84 | | | | Phytotrade, 2009; Stadylmayr et al., 2013; Osman, 2004; Chabite et al., 2019; Affo and Akande, 2011 |
| Energy (KJ/100g) | 320.3 | 308.33-312.16 | 336.28 | | | | | | Osman, 2004; Chabite et al., 2019; Affo and Akande, 2011 |
| Calcium (mg/100g) | 270 | 251-370 | 341 | 213-635 | 60-611 | 295 | 250-260 | 555 | Muthai et al., 2017; Phytotrade, 2009; Zah'rau et al. ,2014; Stadylmayr et al., 2020; Stadylmayr et al., 2013; Osman, 2004; Chabite et al., 2019; Affo and Akande, 2011 |
| Magnesium(mg/100g) | 1300 | 126-179 | 2090 | 115-305 | 90-420 | 90 | 1257 | | Muthai et al., 2017; Phytotrade, 2009; Zah'rau et al., 2014; Stadylmayr et al., 2020; Stadylmayr et al., 2013; Osman, 2004; Affo and Akande, 2011 |
| Potassium(mg/100g) | 2120 | 2010-2390 | 621-1874 | 1140-2500 | 1240 | 1948.49-1951.00 | 1890 | | Muthai et al., 2017; Phytotrade, 2009; Stadylmayr et al., 2020; Stadylmayr et al., 2013; Osman, 2004; Chabite et al., 2019; Affo and Akande, 2011 |
| Sodium(mg/100g) | 500 | 546 | 5.1-27.9 | 27.9 | 1292.81-1898.52 | 360 | | | Muthai et al., 2017; Zah'rau et al., 2014; Stadylmayr et al., 2013; Osman, 2004; Chabite et al., 2019; Affo and Akande, 2011 |
| Copper(mg/100g) | 0.45 | 0.53-0.75 | 0.49-1.6 | 1.6 | | | | | Muthai et al., 2017; Phytotrade, 2009; Stadylmayr et al., 2013; Osman, 2004 |
| Iron(mg/100g) | 5.74 | 3.95-9.13 | 1.7 | 0.4-3.0 | 1.5-13.4 | 9.3 | 3.5-6.75 | 17.1 | Muthai et al., 2017; Phytotrade, 2009; Zah'rau et al., 2014; Stadylmayr et al., 2020; Stadylmayr et al., 2013; Osman, 2004; Chabite et al., 2019; Affo and Akande, 2011 |
| Zinc (mg/100g) | 1.04 | 0.42-3.0 | 0.42-2.40 | 1.8 | 31.2 | | | | Zah'rau et al., 2014; Stadylmayr et al., 2020; Stadylmayr et al., 2013; Osman, 2004; Affo and Akande, 2011 |
| Manganese(mg/100g) | 0.272 | 0.65-1.3 | 69 | | | | | | Muthai et al., 2017; Phytotrade, 2009; Affo and Akande, 2011 |
| Vitamin C(mg/100g) | 74-163 | 63-311 | 126-509 | 52.83-62.38 | 124 | | | | Phytotrade, 2009; Stadylmayr et al., 2020; Stadylmayr et al., 2013; Chabite et al., 2019; Affo and Akande, 2011 |

## 2.8 Products processed from baobab

### 2.8.1 Baobab leaf powder

According to Chadare et al. (2009), baobab leaves are sundried under the shade after which they are ground and sieved to make dry leaf powder. The baobab dry leaf powder is then reconstituted with water and boiled to make a sauce that can be consumed with other foods, which is particularly common in Benin. Baobab leaves dried through optimized oven drying methods can be used to develop a ready to use powder with an enhanced shelf life that can be made easily available in the market, while promoting their utilization (Gbaguidi et al., 2020).

### 2.8.2 Baobab seed snacks

The seeds can be roasted and consumed as a snack, because they have a nutty flavor (Sabina et al., 2020). In Kenya, rural populations living along the baobab growing areas according to a study conducted by Wanjeri et al. (2020) roast the seeds for consumption during lean seasons. West African countries are known for a wealth of nutritious foods they consume. For instance, in Benin, sthe seeds are roasted and fermented in various ways to come up with sauces consumed locally in the region. The processes involve either roasting, grinding, and boiling the resulting powder to form a sauce, or fermenting the baobab seeds through adding water and exposing the mixture to the sun for 24 to 72 hours after which the mixture is sieved, and the resulting liquid used in making local sauces (Chadare, 2010). Roasted baobab seeds can also be used as a coffee substitute (Sahil and Yahia 2015).

### 2.8.3 Baobab seed oil

Oil could be extracted from the baobab seeds by first cracking the seed open and oil pressed from the seeds after which the oil meal can be used as feed stuff (Watson, 2014). Baobab seed oil is commonly used in pharmaceutical and cosmetic industries for topical applications since the fatty acids composition in the oil has been established to be beneficial to the skin (Zah'rau et al., 2014).

### 2.8.4 Baobab fruit jam

For the fruit pulp various interventions have been carried out towards processing, whereby the baobab fruit pulp has been utilized in the processing of jam as a substitute of commercial pectin due to its high gelling capacity. It has been reported that, jams produced using commercial pectin and those produced using baobab fruit pulp powder as a pectin substitute, do not have any significant differences in terms of moisture content, total solids and total titratable acidities (Ndabikunze et al., 2011).

### 2.8.5 Baobab Fruit Juice

According to Abdalla et al. (2010) the baobab fruit pulp, due to the combination of health claims (such as prebiotic and anti-oxidation properties, high calcium content, and anti-inflammatory effect) and food technological functions (due to its high pectin and fiber content, baobab fruit pulp gives beverages a thicker consistency and can be also used as filler), is a very interesting candidate for a new generation of functional foods and drinks. The fruit pulp powder can also be processed into baobab juice**.** However, it has been reported that juice produced from the baobab fruit pulp rapidly undergoes fermentation (Adiara et al., 2020).

### 2.8.6 Baobab Fruit wine

Baobab contains fermentable sugars that are useful in the production of wine, wine from baobab is prepared by first pounding the pulp to separate it from the seeds, after which it is soaked for 3 hours, the mixture is then filtered to achieve 7° brix and the solution ameliorated using sucrose to bring the brix to 23°. Pasteurization is then carried out and the mixture cooled to 30°C, fermentation is later done using wine yeast cultures and the product is packaged for sales and distribution. Wines from the baobab fruit have been reported to have a high level of ascorbic acid (Akubor, 2017).

### 2.8.7 *Mabuyu* sweets

In Kenya the most popularly processed baobab product is *mabuyu* sweets popularly sold by women living in the rural baobab growing areas (McMullin et al., 2015). They are produced by covering the pulp powder embedded on the baobab seed with sugar and artificial food grade coloring and to make the *mabuyu* sweets more flavorful, some processors add chilli, cardamom, or other artificial flavors (Jäckering et al., 2019). According to a study carried out in baobab growing areas in Kenya by Jäckering et al. (2019), processing involved separation of the fibers from the pulp embedded on the seed, boiling one litre of water, half a kilogram of sugar added together with some amount of artificial food coloring after which pulp and seed are immersed into this mixture with some addition of baobab fruit pulp to make the sweets soft then the sweets are packaged into small plastic bags ready for sale.

### 2.8.8 Baobab powder

Another form of processing involves, pounding the baobab fruit pulp using a mortar and pestle to separate it from the seeds, after which the powder is packaged and sold (Wanjeri et al., 2020).

Using modern processing technologies studies have shown that baobab can be spray dried to develop instantized baobab powder that can be dissolved easily in water or milk (Abdalla et al., 2010).

## 2.9 Market potential of baobab products

Following the declaration of the baobab fruit as a novel food by the European Union, the fruit has been promoted as a superfood due to its nutritional value (Gebauer et al., 2014). With such increase in demand, the European markets have more than 300 products in the market containing baobab as one of the constituents (Gebauer et al., 2016). In response to the increasing demand, local and export markets are well developed in Western and Southern Sub-Saharan Africa where the income generated from the sale of baobab products is reported to be higher than the subsistence use at household level (Buchmann et al., 2010; Venter and Witkowski, 2013). For instance, in Mali and Benin, marketing of the baobab leaves and fruits is reported to be valuable particularly during lean seasons since small holder farmers can generate some supplementary income (De Caluwe and Van damme, 2011). On the other hand, in Sudan, the highest income generating activity that contributes to more than half of the annual household income of small holder farmers is based on the sale of baobab fruits (Adam, 2013). According to Sanchez et al. (2010), the baobab sector has a great potential of becoming a billion-dollar industry, employing over 25 million households in Africa. In Kenya, the baobab tree has been identified by local communities as a high priority food tree for future domestication (Kehlenbeck et al., 2015), since baobab has a high potential for product development, value addition and high profit margins (Van der Lans et al., 2012; Mwema et al., 2013). The most important marketed product in Kenya from the baobab fruit is the informally processed *mabuyu*, candy prepared from the seeds embedded with the pulp (McMullin and Kehlenbeck, 2015) commonly marketed by women who have reported that producing and selling mabuyu is a profitable business (McMullin and Kehlenbeck, 2015).Commercialization of baobab based products can play an important role in the empowerment and improvement of the rural livelihoods (Venter and Witkowski, 2013; Kehlenbeck et al., 2013), of these women who are the main actors in the sales of these products (Buchmann et al., 2010). Baobab products are therefore capable of providing cash income to rural communities living along the baobab growing zones in Kenya, in addition to supplementing their diets (Kaimba et al., 2020) provided there are proper marketing channels, which will facilitate the movement of baobab products from the point of production to the point of consumption (Bellin, 2016). However, a study by Jackering et al. 2019, established that despite the importance of baobab in the local and international markets, baobab traders in Kenya derive very low income from this venture as a result of poor market channels. The major challenges facing baobab markets in Kenya include poor quality raw materials that hinders new products development, limited flow of information, lack of adequate research and decrease in baobab trees due to active felling of the tree (Jackering et al., 2019). Another study conducted by Kaimba et al. (2020), shows that the biggest percentage of collectors involved in marketing of baobab fruit are mainly the rural markets partly since they are able to collect the fruits freely as illustrated in **Figure 2.5**.

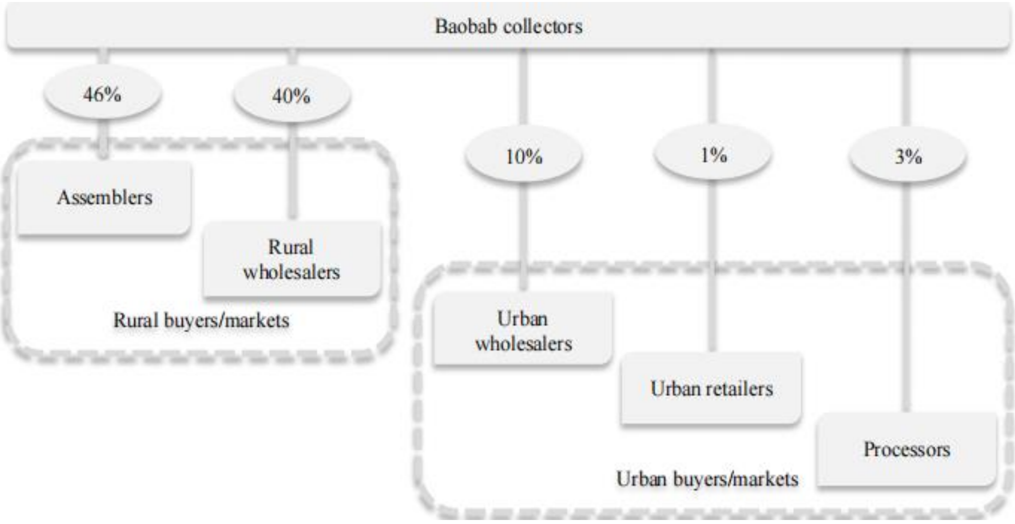

**Figure 2.5: Marketing channel of baobab in Kenya**

**Source:** Kaimba et al., 2020

### 2.10 Role of milk in Human nutrition

Milk and milk products have long been used in human nutrition due to the abundance of essential nutrients present in them (Haug et al., 2007). Consumption of milk and milk products has for long been considered as an important aspect in a healthy and balanced diet (Pereira, 2014). Milk contains all the essential macronutrients that is carbohydrates, lipids, vitamins, and other trace elements all required for proper functioning of the human body (Haug et al.,2007). Moreover, milk consumption has been reported to be a vital aspect for structure and development of skeleton, maintenance of intestinal flora in the gut and promotes calcium absorption for proper bone development and bone mass (Lambrini et al., 2021). Milk is able to deliver approximately 32 g protein/l of high biological value important in the immune function (Pereira, 2014). The fat composition in milk is composed of mainly triacylglycerols which form 98% of fat composition, 2% diacylglycerols, less than 0.5% cholesterol, 0.1% free fatty acids (Pereira, 2014) Fat present in milk is sufficient to supply adequate energy levels and plays a huge part in the flavor and creaminess of milk (Guetouache et al., 2013).

Vitamins present in milk include fat soluble A, D, E and K while thiamine and riboflavin form the water-soluble fraction (Gaucheron, 2011). Milk is an excellent source for minerals such as: Calcium, Phosphorus, Zinc, Selenium and Magnesium (Pereira,2014) as shown in the **Table 2.6** below: However, there are potential risks associated with consumption of milk among certain individuals such as Lactose intolerance and Type I diabetes mellitus (de Oliveira et al., 2023; Wiley, 2020). Lactose intolerance arises as a result of lactose maldigestion and is characterized by gastrointestinal discomfort and diarrhoea (Wiley, 2020). On the other hand, Type I diabetes mellitus is triggered by cow milk proteins that stimulate autoimmune response (de Oleivera, 2023).

**Table 2.6: Nutritional composition of milk per 100g dry weight**

| **Constituent** | **Concentration** |
|---|---|
| Moisture (g/100g) | 88 - 88.2 |
| Fat (g/100g) | 3.58 - 3.6 |
| Protein (g/100g) | 3.2 - 3.4 |
| Lactose (g/100g) | 4.28 - 4.7 |
| Calcium (mg/100g) | 119 – 124 |
| Magnesium (mg/100g) | 11 – 14 |
| Zinc (mg/100g) | 0.4 - 0.6 |
| Phosphorus(mg/100g) | 93 – 101 |
| Potassium (mg/100g) | 151 – 156 |
| Vitamin A (mg/100g) | 22 – 59 |
| Vitamin D (mg/100g) | 0.05 |
| Thiamin (mg/100g) | 0.04 - 0.05 |
| Niacin (mg/100g) | 0.08 - 0.09 |
| Folate (µg/100g) | 0.5 - 0.52 |
| Pyridoxin (mg/100g) | 0.04 |
| Cobalamin (µg /100g) | 0.357 - 0.5 |
| Riboflavin (mg/100g) | 0.16 - 0.17 |

**Source:** Pierra, 2014

### 2.11 Traditional bovine milk fermentation techniques in Kenya

Traditionally in Kenya, milk in particularly pastoral communities such as Maasai, Borana, Kalenjin and Somali are put in traditional containers like gourds and skin bags (Digo et al.,2017), at room temperature to undergo spontaneous fermentation with a primary purpose to extend the shelf life of milk consequently resulting to improved taste and enhanced digestibility (Surono and Husono, 2011). This kind of fermentation is made possible through activity of naturally occurring lactic acid bacteria present in milk, which can break down lactose to lactic acid resulting to reduction in pH and milk coagulation. Therefore, traditionally fermented milk products consist of a broad microbial diversity particularly dominated by yeasts and Lactic acid bacteria (Agyei et al., 2020). Spontaneously fermented milk products have demonstrated therapeutic and probiotic effects (Nduko et al., 2016) Spontaneous milk fermentation is carried out at household level with the fermented milk playing a vital part in the nutrition of vulnerable rural populations such as the elderly, young children, pregnant and infants (Chilton et al., 2015; Nduko et al., 2016).Traditional fermentation of milk products however, has challenges such as low yields, batch inconsistencies, inefficacy (Chiton et al., 2015), the safety of is also not assured due to the possible presence of pathogenic bacteria or chemical toxins (Patel et al., 2013). Further, spontaneously fermented products have been linked to death, oesophageal cancers and biotoxin infections (Nduko et al., 2016).

## 2.12 Spontaneously fermented bovine milk products in Kenya

Various types of traditionally fermented products exist based on the various Kenyan communities involved in their preparations as well as the various methods of preparation such as: smoking/ nonsmoking, boiling/ not boiling milk, and use of back slopping/ non usage all of which results in variations in texture, flavor differences and microbial compositions (Nduko et al., 2016). These include:

### 2.12.1 *Mursik*

*Mursik* is fermented bovine produced among the Kalenjin communities in Kenya whereby the fermentation process takes place in special gourds known as '*sotet*' and after a certain period of time usually a week, the gourd is shaken and the product consumed together with *ugali* (Nduko et al.,2016). The dominant microbiota present in *mursik* are *Lactobacilli* and *Candida* species (Nduko et al., 2016)

### 2.12.2 *Amabere amarunanu*

This product is produced among the Kisii communities involving spontaneous fermentation of bovine milk in special gourds '*ekerandi'*. Back slopping is commonly done whereby already fermented milk is mixed with fresh, boiled, and cooled milk (Nyambane et al.,2014). Predominant microorganisms present in this product are Lactobacillus (45%), Streptococcus (25%), and Leuconostoc (20%), with Streptococcus thermophilus being abundant (Nyambane et al., 2014)

### 2.12.3 *Kule naoto*

*Kule naoto* is the traditional fermented bovine milk product of the Maasai pastoralist community in Kenya. In its production, raw milk is filled into treated gourds made from the hollowed out dried fruit of the plant *Lagenaria siceraria*. Fresh cow blood is first added, and the interior of the gourd rubbed with a burnt stick from *Olea Africana* tree (Onyango et al.,2014). The milk and blood mixture are then fermented for five days at ambient temperatures after which the product is shaken before consumption (Nduko et al., 2016*). Lactobacillus rhamnosus, Lactobacillus plantarum* and *Lactobacillus acidophilus* are the major strains occurring in *Kule naoto* (Nduko et al., 2016).

## 2.13 Cultured Milk

According to Shiby and Mishra (2013), cultured milk is a collective term that is used to refer to milk products fermented using specific selected mesophilic microorganisms capable of growing at a temperature of between 20ºC to 30ºC and can either be homo fermentative Lactic acid bacteria which produces lactic acid only or hetero fermentative which produces lactic acid, carbon IV oxide and diacetyl flavour compounds. When milk is fermented in this manner, the end result is a product with desirable taste, aroma and consistency, further to that the product has reduced potential contamination risks due to secretion of antimicrobial metabolites (Marco et al., 2017) such as bacteriocins, organic acids and hydrogen peroxide all of which are antimicrobial metabolites (Digo et al., 2017). In Kenya therefore, the modern dairy processing industry has applied these modern microbiological processes involving the use of specific mesophilic lactic acid starter cultures under controlled conditions in the production of cultured milk commonly referred to as '*maziwa lala*' (Mokua, 2004). Cultured milk formulations offer an array of health benefits including anti-oxidant, anti-microbial, anti-fungal, anti-inflammatory, anti-diabetic and anti-atherosclerotic activity due to the prevalence of bioactive components secreted by Lactic acid bacteria (Sanlier et al., 2019).

## 2.14 Functional aspects of fermented milk products

Fermented milk products serve as an important tool in alleviating micronutrient deficiencies since they serve as important vehicles for fortification. Fermented milk products can be fortified with various dietary components such as fiber, vitamins, phospholipids, minerals, and other bioactive components (Shiby and Mishra, 2013). Fermented milk products can also be used in probiotic applications since probiotic species such as *Lactobacillus acidophilus*, *Bifidobacterium*, *Streptococcus thermophilus*, and *Lactobacillus casei* can easily be incorporated into the milk (Sanlier et al., 2019). Probiotics can promote the stabilization of the gastrointestinal microecology of human beings through production of secondary metabolites like lactic acid, acetic acid, propionic acid, hydrogen peroxide and bacteriocins all of which are beneficial to the human health (Digo et al., 2016).

**Gaps in Knowledge**

I. Despite baobab (*Adansonia digitata L.*) being approved as novel foods, their nutritive value, having excellent functional properties for various food processing applications, very little has been done in the development, evaluation, and commercialization of functional foods from baobab tree parts as ingredients particularly in the African regions.Development of innovative baobab products will serve to enhance consumption and ultimately result to improved diets that promote health and wellness of vulnerable populations.

II. Inadequate knowledge on modern processing technologies has created overreliance on traditional inferior processing techniques that yield products of low quality, minimum returns and foods associated with groups of people such as children or poor people. Hence high-quality value-added baobab products will not only promote utilization and dietary diversification but also lead to the appreciation of baobab as food for health and wealth and not children or food for the poor.

III. Lack of sensitization of people living along the baobab growing regions on the nutritional importance of the fruit and value addition of the fruit in the development of innovative products both for nutrition and commercialization, has also been witnessed. Much effort is therefore needed in creating awareness on the health benefits of baobab and how well the tree can support vulnerable communities during periods of drought.

IV. Besides the baobab tree parts (*Adansonia digitata L.*) being a store house for the various micro and macronutrients very few studies have been carried out to investigate the bioavailability of these nutrients upon consumption since the leaves seeds and the pulp possess phytochemicals that can serve as antinutritional factors.

# CHAPTER THREE: PRODUCTION, PROCESSING, MARKETING AND NUTRITIONAL QUALITY OF BAOBAB AND BAOBAB-BASED PRODUCTS IN MAKUENI COUNTY KENYA

## 3.0 Abstract

All parts of the baobab tree have been considered vital in addressing various nutritional needs and augmenting household incomes thus improving living standards of rural populations. However, the roles of the baobab tree in terms of nutrition and income generation has remained unexploited in Makueni County. This study therefore aimed at assessing the status of production, consumption, processing, and marketing of baobab and baobab-based products as well as the nutritional quality of the baobab tree products consumed within the area. Data on the modes of utilization and nutritional quality of baobab products seves to encourage communities living along the baobabgrowing regions to appreciate baobab products as part of their diets. Despite the fruit pulp gaining mass interest in developed countries where it is being promoted for use as a natural ingredient in various foods, limited utilization, processing and marketing exists in developing countries like Kenya. This is largely attributed to the fruit being regarded to as" monkey food" and " food for children" while the leaves were considered to be livestock fodder. Due to these reasons, farmers and communities cut a low value to the tree and do not appreciate it as a source of food and income. To understand the status of utilization of baobab and baobab products in Makueni County, a cross sectional design was used to carry out the study and purposive sampling done to identify 250 study cohorts. Five focus group discussions and ten key informant interviews were also conducted. Data was expressed in terms of frequencies and percentages and cross tabulations to indicate relationships between various study sites. Baobab products were also analyzed for their proximate, micronutrient and phytochemical composition using standard methods. The findings of the study indicated that the fruit pulp was abundantly consumed by 72% of the respondents while all the other parts were consumed to a limited extent. Pulp/seed sweets (*mabuyu*) were largely known and vended in the study area by 47% of the respondents with most of the processing activities being carried out by women. Marketing and processing activities were quite limited due to financial constraints among majority of the respondents (41%) consequently deriving minimal profits of less than KES 5000 in the sale of inferior processed products. However, multiple uses of baobab at household level were reported particularly during lean seasons. The study also established that baobab fruit pulp in Makueni County contains significant levels of fiber (8.63 ± 0.18), while the kernels recorded the highest amount of fat (25.54±0.35) and protein (18.79 ± 0.06) at $p \leq 0.05$. The leaves on the other hand recorded the highest amount of calcium (2061.77±4.69) and Iron (10.47±0.07) while kernels recorded the highest amount of zinc (7.67±0.01) at $p \leq 0.05$. In addition, the baobab fruit pulp displayed the highest antioxidant activity compared to the leaves and the kernels. Considering the nutritional importance of baobab products, more efforts are needed on creating awareness to rural communities on utilization of baobab products in their dietary diversification. Training on processing of high value added baobab products, promotion of baobab formulated products, exploring market opportunities for value added products, strengthening baobab value chains and improving postharvest handling techniques is necessary for growth and expansion of baobab trade.

**Key Words**: baobab tree, utilization, processing, superfood, food security, supplement

### 3.1 Introduction

Non timber forest products play a significant role in fulfilling several requirements of rural livelihoods, ultimately resulting in reduced vulnerability during lean seasons (Meinhold et al., 2022; Shackleton et al., 2011). These forest products are often vital sources of nutrition and capable of improving dietary diversity in vulnerable poor households (Meinhold and Darr, 2022). Various marginalized communities living in dryer parts of Africa rely on such products as alternative sources of food, during lean seasons often characterized by crop failures and livestock losses (Wanjeri et al., 2020). The baobab tree (*Adansonia digitata L.*), endemic to the semi-arid regions of Africa is often depended upon to supplement local diets, nutrition, and a buffer during such times of scarcity (Muriungi et al., 2021; Venter and Witkowski, 2013). Besides the baobab tree (*Adansonia digitata L.*) being utilized as a source of nutrition, the tree has also been long revered for its multiple applications and traditionally considered essential as a source of food, fodder, medicine, shelter, and commercial handicrafts (Buchmann et al., 2010, Gebauer et al., 2016). The nutritional profile of parts of the baobab tree in the supply of essential nutrients is reportedly better than staple food crops (Stadlmayr et al., 2020). For instance, baobab leaves and seeds contain a protein content higher than that occurring in commonly consumed cereals such as rice, barley, wheat and sorghum (Habte et al., 2021) and can effectively be used to supplement foods that have insufficient quantities in protein (Danbature et al., 2014). On the other hand, the baobab fruit pulp contains essential nutrients required for optimal nutrition as it possesses high amounts of dietary fiber and micronutrients such as Calcium, Iron and Zinc (Muthai et al., 2017). Further, baobab fruit pulp displays a high antioxidant activity due outstanding amounts of bioactive components such as Vitamin C, phenolic compounds and epicatechins (Habte and Krawinkel, 2017). When consumed, baobab fruit pulp can provide 54-100% of the recommended dietary intake of Vitamin C (Sabina et al., 2020) while consumption of dry or fresh baobab leaves contributes to high calcium and protein intake (Wanjeri et al., 2020). This is a clear indication that baobab products can boost the nutrient uptake and prevent nutritional deficiencies (Momanyi et al., 2019) in rural communities where malnutrition is prevalent. The nutritional value of baobab products has resulted to appreciation of the baobab tree in international markets thereby putting pressure on baobab pulp exportation to European Union and United States (USA) markets (Fischer et al., 2020). Rapid development of the baobab fruit pulp market has been triggered by the declaration of the fruit pulp as a novel food, by the European Commission (Meinhold et al., 2022), consequently resulting to its promotion as a superfood and its application as a natural ingredient in over 300 formulations (Gebauer et al., 2014). In West African countries the tree has been well appreciated, whereby the fruit pulp is incorporated traditionally into diverse cereal gruels or consumed in its fresh state as a snack (Buchmann et al., 2010). Despite the baobab tree gaining mass interest in other countries, there is limited utilization of baobab products in countries such as Kenya. This is largely attributed to increased attention towards the production of staple foods with minimum efforts being directed towards high ecological tolerance indigenous foods (Mc Mullin and Kehlenbeck, 2015) resulting in limited production of innovative high value nutritious products from baobab. Baobab products are particularly useful during lean seasons in the rural poor communities where they reportedly act as hunger survival strategies (Darr et al., 2021; Legwaila et al.,2011). However, the tree products such as the fruit pulp are regarded as poor man's food and food for kids (Stadlmayr et al., 2020). This has resulted to minimum formal baobab processing of baobab products in Kenya, with most of the existing baobab products being informally processed and sold on a limited scale (Kaimba et al., 2020; Muriungi et al., 2021). The product largely processed and vended is pulp/seed sweets (*mabuyu*), a candy prepared from the seeds embedded in the pulp (McMullin and Kehlenbeck, 2015) often perceived as food for kids (Kinuthia, 2018). Scarcity in research and innovation on superior processing techniques has largely resulted to a gap in development and commercialization of substantial high quality baobab products for consumption by the general population (Omotayo and Aremu, 2020). Considering minimal employment in the rural areas, commercialization activities of baobab fruit is a worthwhile venture in ensuring the improvement of rural livelihoods

(Meinhold et al., 2022). For instance, some parts of the baobab tree (*Adansonia digitata L.*) such as the bark and fruit shells can offer an array of economic benefits as they can be utilized as raw materials for many useful items (Kamatou et al., 2011). The bark of the tree possesses robust fibers that have been successfully exploited in the manufacture of ropes, baskets, and clothing (Chadare, 2010). Such commercial value offers an opportunity for income diversification which contributes to household sustenance since in countries like Sudan, baobab trading activities generates more than half of the annual income of small holder farmers (Adam et al., 2013). However limited knowledge in marketing of baobab products in Kenya due to weak entrepreneurial spirits among the rural communities has impeded successful realization of the full potential of the baobab sector in Kenya (Kaimba et al., 2020). This could be attributed to, inferior processing techniques resulting in poor quality products and socio-cultural factors which contribute to negative consumer attitudes (Jäckering et al., 2019). Whereas well-developed baobab products can foster economic prosperity while promoting better nutrition among the rural poor. Hence, there is a need to determine the contribution of baobab products to the diet and in the overall household income towards poverty alleviation (Wanjeri et al., 2020). This study was therefore conducted among different rural communities in Makueni County, Kenya to assess the status of production, consumption, processing, and marketing of the baobab fruit pulp.

## 3.2 Materials and methods

### 3.2.1 Study design

The study involved a cross-sectional survey of randomly selected small holder farmers, traders, Micro Small Medium Enterprises (MSMEs) and households actively involved utilization of the baobab fruit to assess the status of production, consumption, processing, and marketing of the baobab fruit. The Open Data Kit (ODK) mobile application was used in administering Semi structured questionnaire to the respondents. An experimental design was used to determine the nutritional quality of the baobab tree products consumed within the study area.

### 3.2.2 Study Area

The study was conducted in Makueni County located in the South-eastern part of Kenya as shown in **Figure 3.1**. The study site was selected due to the vast dominance of baobab trees with the study being carried out in October 2020 during which a lot of baobab fruit had been harvested for sale or processing purposes. The county lies between a latitude of 1° 35’ and 32° 0’ South, and longitude of 37° 10’ and 38° 30’ East (CGM, 2018). Makueni County covers an area of 8008.7 sq. km (CGM, 2018). According to the KNBS (2019) census, the County has a population of 987,653 people, male population of 489,691 and female population of 497,942. The County is largely aid and semi-arid with the lower regions receiving rainfall ranging from 250 mm to 400 mm while high regions receive 800 mm to 900 mm (CGM, 2018). Most residents rely on rain fed farming (Gevera et al., 2020). The County is characterized by a rapidly growing population, water scarcity, falling food production and low resilience to climatic changes and with all these factors combined result to increased food insecurity, environmental degradation, and high poverty levels (Gevera et al., 2020). The county is divided into six sub-counties which are further subdivided into 30 wards and 60 sub-wards (CGM, 2018). Two sub-counties that is Kibwezi East and Kibwezi West were purposively selected from which four wards were randomly selected as study sites. Authority to conduct the survey was obtained from the respective sub-county Agricultural Officers and Head of Wards. The enumerators who participated in data collection process were selected by sub-county agricultural officers.

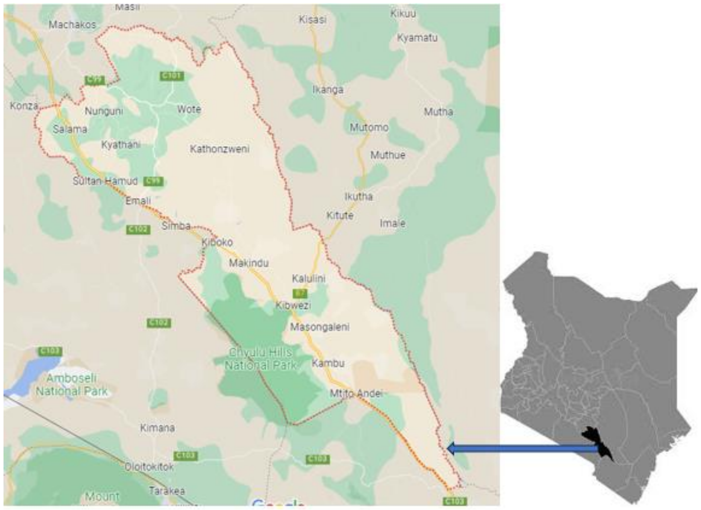

**Figure 3.1: Map of Kenya showing the location of Makueni County**

**Source**: Google maps

### 3.2.3 Sampling and Sample Size

Data was collected from two sub-counties namely Kibwezi East and Kibwezi West. From the two sub-counties respondents further selected from four wards namely Makindu, Mtito Andei, Kambu and Ivingoni/Nzambani. These sub-counties were purposively selected as they represent baobab consumption and processing in Kenya, hence a variety of processed products is known to be processed and sold in these areas. A sample size of 250 respondents were involved in the study to which the semi structured questionnaire was administered. The sample size was calculated using the method described by Anderson et al. (2016).

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

Where $n$ is the sample size, $p$ is the proportion of the population involved in the utilization of the baobab fruit, $Z$ is the confidence interval and $E$ the marginal error.

Since the proportion of the population involved in the utilization of the baobab fruit was unknown in the study site, the values were then set as $p$= 0.5, $Z$=1.96 and $E$= 0.062.

### 3.2.4 Data Collection

A validated tool was used for surveys, key informant interviews (**Annex 2**) and focus group discussions (**Annex 1**). A semi-structured questionnaire (**Annex 3**) was developed by the researchers and loaded in the Open Data Kit (ODK) mobile application to gather information.

#### 3.2.4.1 Household survey

Face to face interviews in 250 households was used to gather information on the sociodemographic and socioeconomic characteristics of the study population as well as the production, consumption patterns, processing, and marketing activities. The questionnaire was written in English, but questions were interpreted into the local dialects of the respondents for ease of communication. Written consents of the respondents were sought once the study objective was fully explained to them before their participation in the study. During the survey geographical co-ordinates of the households visited were also recorded. The semi- structured questionnaire was validated by pretesting with ten small holder farmers that were not included in the actual study. The necessary adjustments were made and additional questions that arose during the Focus Group Discussion included in the tool. The questionnaires were administered with the help of field enumerators who were first trained on the operation of the Open Data Kit application, administration of the questionnaire as well as data collection ethics, with each question being explained to the enumerators to ensure that they familiarized themselves with the survey tool.

#### 3.3.4.2 Focus group discussions

Five focus group discussions were used to collect information in the study, with the intention to bring together small holder farmers, traders, and processors to understand various ways which the parts of the tree are included in the local delicacies, perceptions around the baobab tree and various products processed from the baobab. This is because focus group discussions play a vital role in eliciting qualitative information from a group of people with similar experiences (Kidasi et al., 2021; Heary and Hennesy, 2002). Five focus group discussions were conducted, and each focus group discussion consisted of 11 to 15 participants. The areas were chosen since they were easily accessible by farmers and were part of the baobab processing sites for some women group associations. Key questions were used to guide the focus group discussion, with the facilitator ensuring even participation from all members. Neutrality was maintained while the diverse opinions that were expressed and agreed by all members of the focus group discussions noted down.

#### 3.2.4.3 Key Informant interviews

Ten face to face key informant interviews were conducted using formulated key guide questions. The interviews consisted of sub-county agricultural officers, women group leaders in small scale baobab processing facilities, middlemen involved in the sale of baobab fruits and one large scale baobab fruit processor located in Kibwezi. The key informant interviews were conducted in order to provide in depth qualitative information from community experts who had knowledge and understanding of the baobab tree, while providing insights on the nature of the problems experienced in processing and other utilization activities.

## 3.3 Nutritional quality of baobab tree parts consumed within Makueni County

### 3.3.1 Proximate composition

#### 3.3.1.1 Determination of moisture content

Moisture content determination was done based on AOAC 950.46 (AOAC, 2005). Five ml of the milk sample was weighed in a clean and dry moisture dish after which the weight of the sample and the dish was taken. The sample was transferred in a moisture oven and drying carried out for 3 hours at 105 °C. The samples were removed and cooled in a desiccator and weight taken.

#### 3.3.1.2 Determination of crude protein

Crude protein level was determined according to AOAC (2005) 992.15 methodology. In a Kjedahl flask folded with a nitrogen free filter paper, 0.5 ml of the sample was measured and transferred in it. A catalyst tablet and sulphuric acid was carefully added to digest the sample, and this was carried out in a fume chamber. A few drops of phenolphthalein indicator were added to the mixture and the Kjedahl flask was connected to a distillation unit. Back titration using 0.1N NaOH was done and conversion to protein done by multiplication with 6.25 conversion factor.

#### 3.3.1.3 Determination of crude fiber

Crude fiber was determined according to AOAC (2005) 978.10 methodology. 10 ml of the milk samples was added to 200ml of 0.225N Sulphuric acid and was subjected to boiling for 30 minutes. The contents in the flask after boiling was filtered using glass wool and later washed with hot water to remove the acid. 200ml of 0.313 NaOH was preheated, and the contents of digestion transferred in the preheated NaOH and boiling of the mixture was done for 30 minutes.

The contents were filtered, dried, and weighed after boiling. The resultant residue was subjected to a temperature of 540 ℃ in a muffle furnace. % Crude fiber will be expressed as: (Weight of Crude fiber/ Weight of sample × 100)

### 3.3.1.4 Determination of crude fat

Crude fat was determined through the Soxhlet method according to AOAC, (2005) 954.02 method. 5ml of sample was accurately measured and transferred in a thimble containing cotton wool, after which the sample was transferred to a solvent extractor for extraction of crude fat in a tared flask using petroleum ether of 40-60 ℃ boiling point. The fat was then evaporated in a rotary evaporator and the resultant residue dried in an air oven at 105 ℃. Drying was done for 1 hour after which the weight was taken, and the crude fat expressed as a percentage of sample versus dry matter content.

### 3.3.1.5 Determination of ash content

AOAC method 942.05 (AOAC, 2005) was used in the determination of the ash content of the milk samples. 5ml of the samples were first be charred in a fume chamber until smoking ceases. Charred samples were then transferred in a muffle furnace and heated to 525 $^{o}$ c for 6 hours. The samples were removed from the furnace allowed to cool in a desiccator. The percentage ash content was determined by dividing the weight of the ash obtained and weight of the sample.

### 3.3.1.6 Determination of Carbohydrates and Total Energy

Carbohydrates was first determined by:

Carbohydrates = (100% - [% protein + % fiber + % moisture + % fat + % ash]).

The total energy was then calculated as:

Energy = [(4 kcal/g (protein)+ 9 kcal/g (fat) + 4kcal/g (carbohydrates)] AOAC, 2005).

### 3.3.2 Micronutrient composition of the baobab based cultured milk.

Analyses of Calcium, Iron and Zinc was determined using Atomic Absorption Spectrophotometry following the methods described by the AOAC (2010). Vitamin C was determined according to AOAC method 967.21 (AOAC, 2006).

### 3.3.3 DPPH radical scavenging activity

DPPH radical scavenging activity of the baobab extracts will be determined according to the method described by Wintola and Afolayan (2011) with some modifications. One milliliter (1 ml) of 0.135 M DPPH in methanol will be prepared and mixed with 1.0 ml of various concentrations (0.2 – 1.0 mg/ml) of the baobab extracts, BHT will be used as the standards. The reaction mixture was vortexed thoroughly and left in the dark at room temperature for 30 min. The absorbance of the mixture will be measured using a UV/VIS spectrophotometer at 517 nm. The ability of the plant extract to scavenge DPPH radical will be calculated by the equation: DPPH radical scavenging activity = {(Abs control – Abs sample)}/ (Abs control} × 100 where Abs control will be the absorbance of DPPH radical + methanol; Abs sample will be the absorbance of DPPH radical + sample extract or standards (BHT).

### 3.3.4 Quantitative phytochemical analysis

#### 3.3.4.1 Determination of total phenols content

Total phenol content was analysed according to the Folin–Ciocalteu method whereby about 1.5 ml of Folin–Ciocalteu reagent was added to 300 µl of extract in a test tube, followed by 1.2 ml of Na

CO solution (7.5% w/v). The mixture was then allowed to stand for 30 minutes at 28 C before the absorbance was measured at 765 nm against a blank (Chan et al., 2007).

#### 3.3.4.2 Determination of total flavonoids content

Total flavonoid content was determined using the method reported by Kale et al. (2010), 0.5 ml of the extract was dispensed into test tube, followed by 1.5 ml of methanol, 0.1 ml of aluminium chloride (10%), 0.1 ml of 1 M potassium acetate and 2.8 ml of distilled water. The mixture was allowed to stand at 28 C for 30 minutes, before absorbance was read at 514 nm.

#### 3.3.4.3 Determination of total saponins content

Total saponin was determined following the method described by Makkar et al. (2007). 0.25 ml of the extract was dispensed into a test tube with 0.25 ml vanillin reagent after which 2.5 ml of 72% aqueous $H_2 SO_4$ were added to it. The reaction mixture in the tube was heated in a water bath at 60 C for 10 minutes. Then the tubes were cooled in ice for 4 minutes and allowed to cool to room temperature. The absorbance was then recorded at 544 nm using a UV/VIS spectrophotometer.

### 3.4 Data Analysis

Descriptive statistics for mean, frequency and percentages were used to analyze data for consumption and processing of the baobab fruit while cross tabulations were used to determine the relationship between the different study sites and demographic, socioeconomic characteristics, and the marketing aspect of the baobab fruit and products. Data was analysed using the Statistical Package of Social Sciences (SPSS) version IBM Corp. (2016). Data on the nutritional, phytochemical and antioxidant characteristics of baobab tree products was subjected to analysis of variance (ANOVA) using STATA version 12 and means separated using Bonferroni’s method ($p<0.05$) to identify any significant differences between characteristics.

## 3.5 Results

### 3.5.1 Socio-demographic characteristics of households utilizing baobab products

In the study, 58.3% of the respondents were females while 41.7% were males and only a few respondents (9.1%) reported to have completed tertiary education while the remaining (4.8%) were illiterate. 77.8% of the respondents reported to be married as shown in **Table 3.1**

**Table 3.1: Socio-demographic characteristics of study population in various study sites**

| **Variables** | | **Ivingoni Nzambani** | **Kambu** | **Makindu** | **Mtito Andei** | **Combined (Pooled)** |
|---|---|---|---|---|---|---|
| | | | **Percentage (%)** | | | |
| **Gender** | Female | 43.5 | 61.9 | 56.9 | 44.4 | 58.3 |
| | Male | 56.5 | 38.1 | 43.1 | 55.6 | 41.7 |
| **Marital status** | Divorced | 0.0 | 1.3 | 1.5 | 0.0 | 1.2 |
| | Married | 87.0 | 78.7 | 70.8 | 88.9 | 77.8 |
| | Separated | 0.0 | 1.3 | 0.0 | 0.0 | 0.8 |
| | Single | 8.7 | 8.4 | 24.6 | 0.0 | 12.3 |
| | Widowed | 4.3 | 10.3 | 3.1 | 11.1 | 7.9 |
| **Level of education** | No education | 4.3 | 3.9 | 7.7 | 0.0 | 4.8 |
| | Primary | 39.1 | 44.5 | 23.1 | 22.2 | 37.7 |
| | Secondary | 56.5 | 47.1 | 47.7 | 44.4 | 48.0 |
| | Tertiary | 0.0 | 3.9 | 21.5 | 33.3 | 9.1 |

*N = 252
P values = 0.325, 0.123, 0.004 respectively

Regarding age of respondents, only 4.8% of the respondents were aged 18-34 years while the majority (48%) were 45 years and above (**Figure 3.2**).

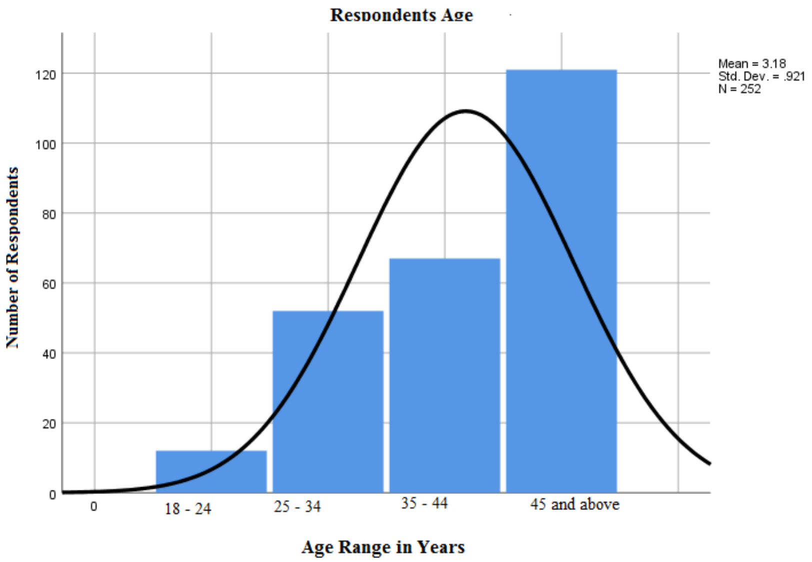

**Figure 3.2: Age of the respondents in Makueni County**

### 3.5.2 Socio-economic characteristics of households in the study area

The main income generating activity reported by 29% of the households was crop farming with small holder farmers largely depending on rain-fed agriculture. As a supplement to monthly incomes, at least 13% of the respondents were involved in income generation from baobab.

However, majority of these reported to derive low income from sale of the fruit and other products. 11% of the interviewed households depended on wages from piece works while the rest were involved in either small business, mixed farming, livestock keeping, bee keeping and salaried employment as indicated in **Figure 3.3**

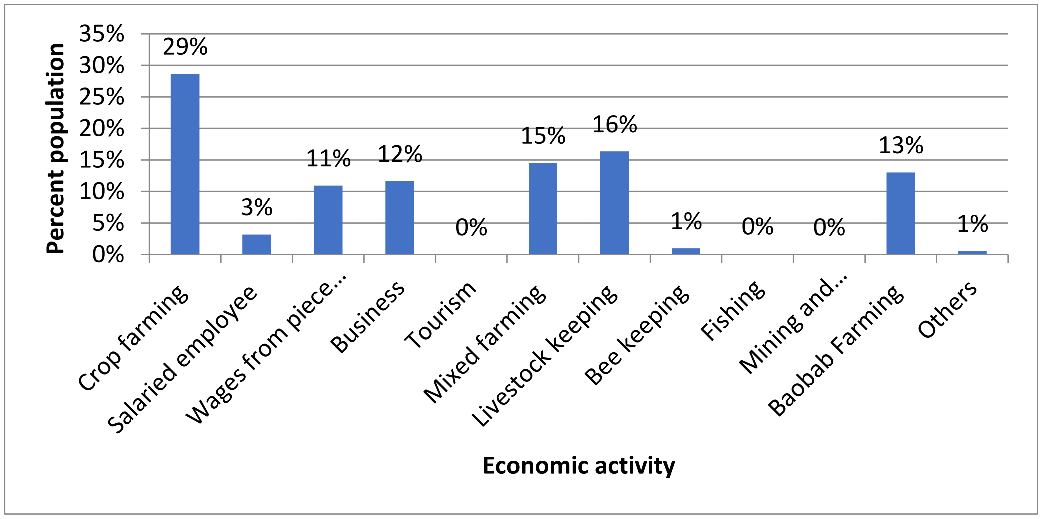

Figure 3.3: Main economic activities in Makueni County

The study area was characterized by rising levels of poverty with 81.7% of the respondents earning a monthly income of less than KES 20000 while 15.9% reported to earn a monthly income of KES 20000 to KES 30000 and 2.4% of the respondents reported to earn an income of more than KES 3000 as shown in **Figure 3.4**.

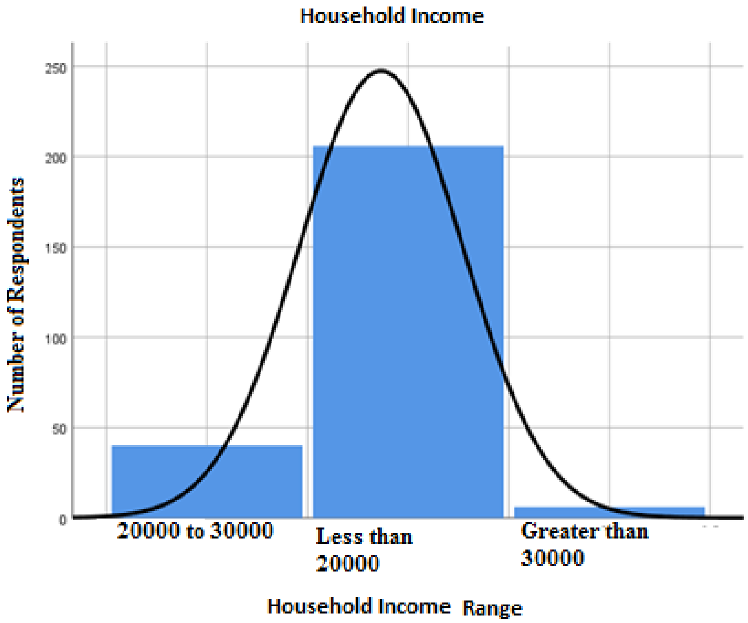

Figure 3.4: Average household incomesin KES of respondents in Makueni County

### 3.5.3 Production and utilization of baobab products

#### 3.5.3.1 Production of Baobab products

All the respondents in the study area reported to know the baobab tree with and 84.1% of respondents growing at least one tree in their farms. On average each household had at least 1.02 ± 0.166 baobab tree growing in their farm. These households reported that the baobab trees existed in their farms naturally and had not been cultivated. However negative effect on crop farming in the presence of baobab trees was reported, which claimed that the roots of the tree suck all the water, allowing no food crop to grow around it. Majority of the respondents reported to own baobab trees, however respondents that claimed no ownership reportedly accessed the baobab trees from either surrounding neighbourhood or community lands as shown in **Figure 3.5**.

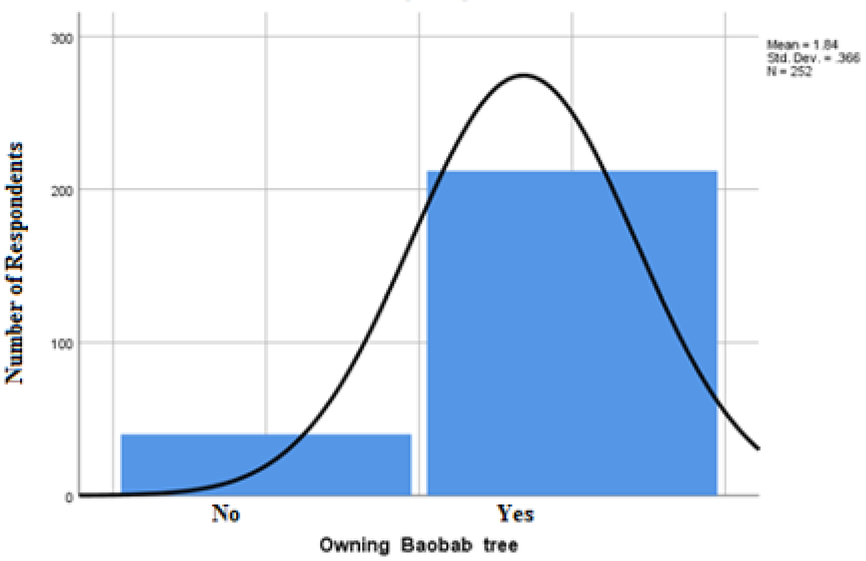

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**Figure 3.5: Ownership of baobab trees among respondents in Makueni County**

### 3.5.3.2 Consumption of Baobab plant products

Majority of the respondents (98.4%) reportedly use of the baobab tree parts in one way or another in their local diets. Baobab fruit pulp was the most common consumed part in the study area (**Figure 3.6**) while consumption of all other parts was to a limited extent.

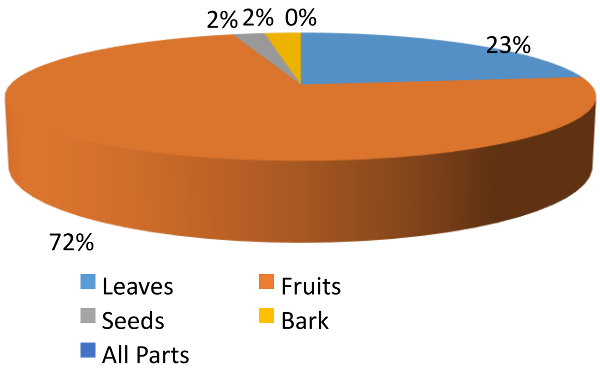


**Figure 3.6: Consumption of baobab tree parts in the study area**

#### 3.5.3.2.1 Consumption of baobab fruit pulp

For the baobab fruit pulp, 87.3% of the respondents reported the consumption of the fruit pulp by all family members, 11.1% reported consumption of the fruit pulp by only children (5-12 years) while 1.6% reported consumption by only adults. The frequency of consumption of the baobab fruit pulp is as indicated in **Figure 3.7.**

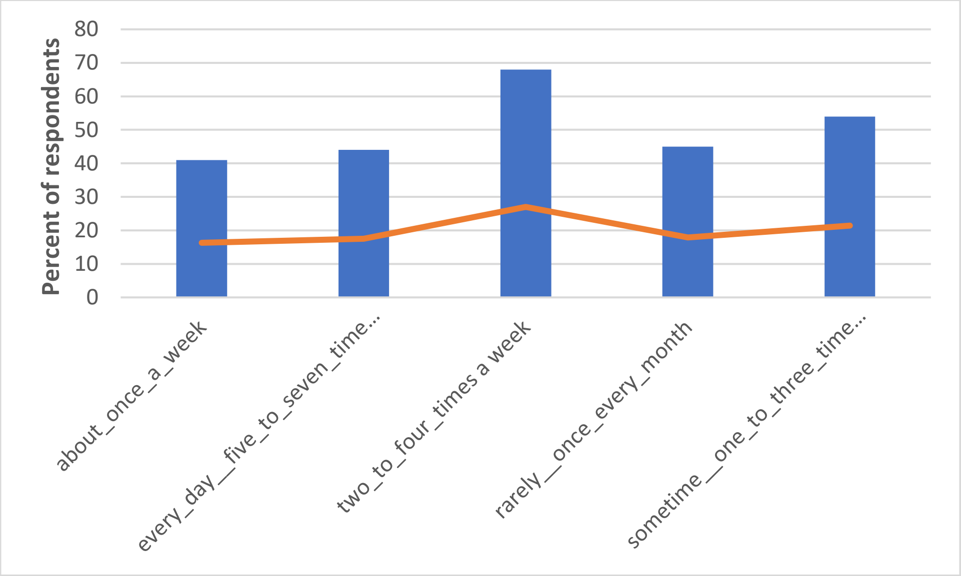


**Figure 3.7: Frequency of consumption of baobab fruit pulp in Makueni County**

The study revealed that the baobab fruit pulp is the most consumed part in Makueni County since majority of the study population reported consumption at least two to four times a week. The most common mode of consumption of the baobab fruit pulp reported respondents in Makueni County involved cracking the outer shell of the baobab fruit and sucking the pulp like candy. Another mode of utilization reported in focus group discussions involved the incorporation of the fruit pulp into porridge to impart a sweet and sour flavor. The fruit pulp embedded on the seed was reportedly soaked in water to separate the pulp from the seed after which the fruit pulp emulsion is added into sorghum porridge as part of cultural food. The baobab fruit pulp was also reported to be useful in hastening the spontaneous fermentation of milk, to prepare a special type of fermented milk (*maziwa mala*) also used as an accompaniment of hard gruel (*ugali*). In addition to that, some households reportedly add the dry fruit pulp into the milk to give it a sour flavor for refreshment.

In addition, a few respondents reported lack of consumption of the baobab fruit pulp following several perceptions that result to aversion from consumption. Claims reported were that: the fruit is meant to be consumed by only children, others termed the fruit as ‘monkey food’, ‘poor men food’ while others reported stringent taste as indicated in **Figure 3.8**.

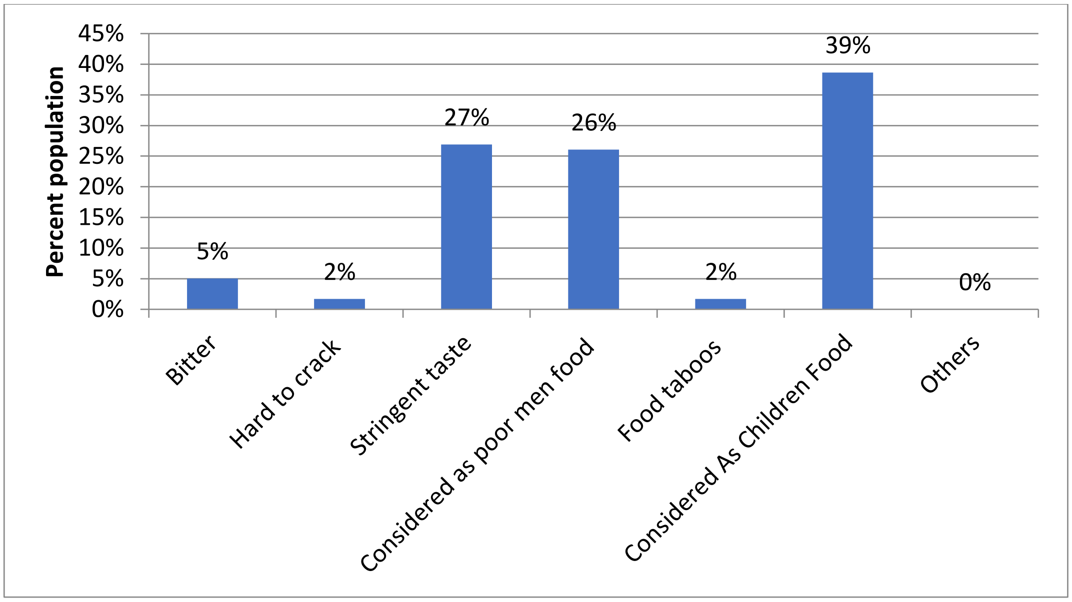


**Figure 3.8: Several reasons for lack of consumption of baobab fruit in Makueni County**

### 3.5.3.2.2 Consumption of baobab leaves

Consumption of the leaves was quite unknown to most of the respondents with 96% considering them as livestock fodder . In this study only 2% of the respondents reported the use of the baobab leaves as substitutes for regularly consumed vegetables.These households embraced the cultivation of young baobab seedling nurseries with the intention of harvesting the young leaves after four weeks for consumption as they were believed to be nutritious. Majority of the respondents in the area (82%) lacked knowledge on the consumption of baobab leaves and considered them as animal feed stuff whereas 18% reported their lack of consumption being attributed to the mucilaginous nature of the leaves upon cooking.

#### 3.5.3.2.3 Consumption of baobab seeds

Baobab seeds consumption was also reported, with 61% of respondents consuming the nutty flavored kernels after cracking the hard outer shell. 21% of the respondents roasted the seeds and ground it for use as a coffee substitute, 3% reportedly grind the seeds after sun-drying for use in thickening of soups, 6% were involved in trading of the seeds whereby they sold the seeds to urban processors involved in cosmetic oil extraction, 3% planted the seeds to yield seedlings whose young leaves were reported to be utilized as vegetables and 6% reported to boil the seeds and consume them during hard times of food scarcity as indicated in **Figure 3.9**.

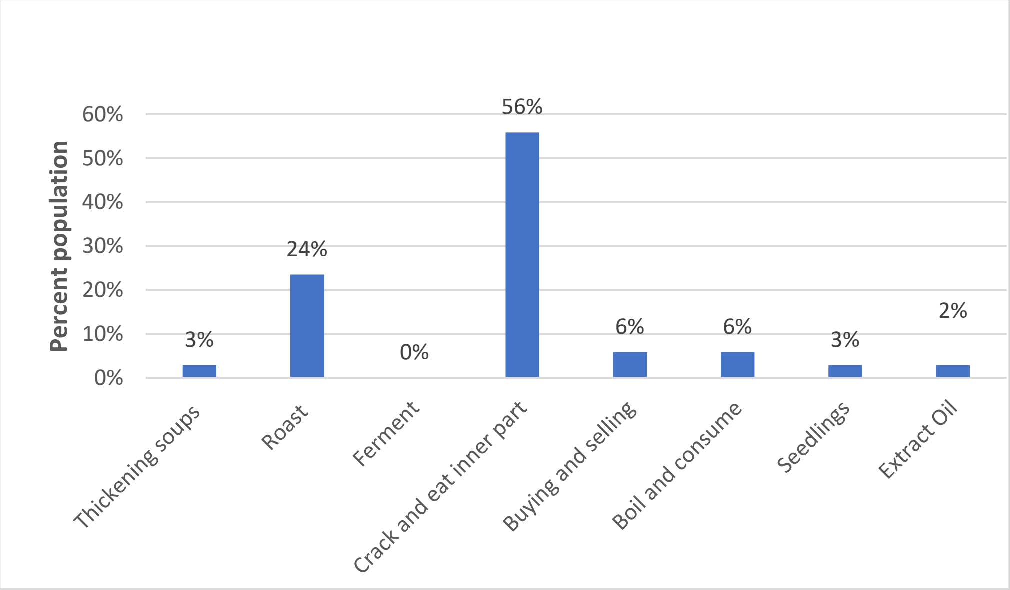


**Figure 3.9 Modes of consumption of baobab seeds in Makueni County**

In Focus group discussions, the seeds were described to be useful during severe drought. During these lean times they are pounded together with the pulp covering them to separate the inner part from the kernels and the rest of the mixture blended with maize meal, to prepare a paste that is believed to have a high level of satisfaction. However, not all respondents acknowledged consumption of baobab seeds, some reported that they were not edible.

#### 3.5.3.3 Non-food uses of parts of the baobab tree

Despite the baobab tree parts being used as food, other non-food uses were also reported: 15% reported to use the tree parts for medicinal purposes. The fibers of the inner bark were reported useful in weaving baskets and ropes in 28% of the respondents who utilized the baobab tree for commercial purposes. The outer shells of the fruits on the other hand were reported useful in the manufacture of calabashes and decorative carvings. 4% reported the use of the baobab tree for cultural and religious purposes since the tree is used for conducting various traditional rituals or used as an area of worship as shown in **Figure 3.10**.

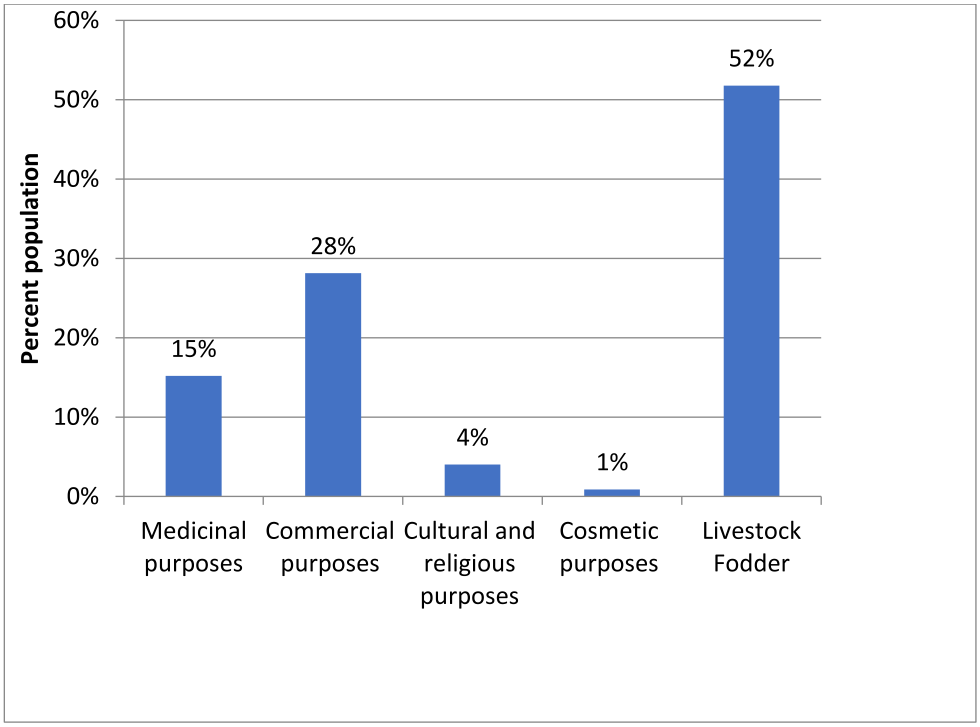


**Figure 3.10: Non-food uses of baobab tree parts**

### 3.5.4 Processing of Baobab products in Kenya

In the current study, only 28.2% of the respondents were involved in processing products from baobab while 71.8% were not involved in any form of processing. 15% of the respondents reportedly extracted cooking oil from the baobab seeds. 31% roasted the seeds with the intention of grinding them for use as a coffee substitute, 23% roasted the seeds to consume as a snack, 8% extracted cosmetic oil from the seed and 23% were involved in drying the seeds and selling them to urban processors as illustrated in **Figure 3.11**.

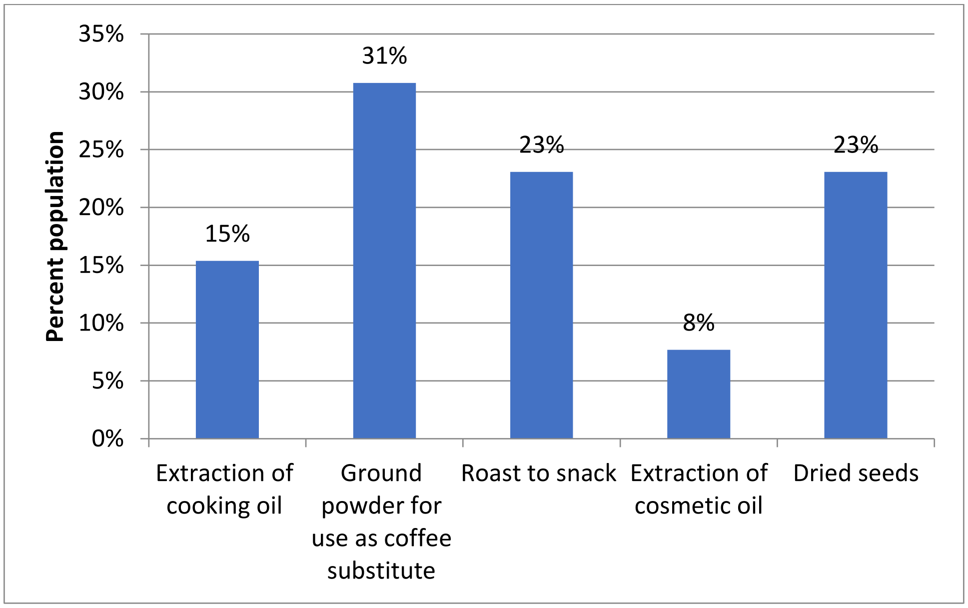


**Figure 3.11: Products derived from baobab seeds in Makueni County, Kenya**

The baobab fruit pulp was the most processed part in the study area. Baobab fruit pulp was reportedly useful in the manufacture of local brews, baobab jam, baobab juice, pulp/seed sweet (*mabuyu)* and baobab fruit powder (**Figure 3.12**).

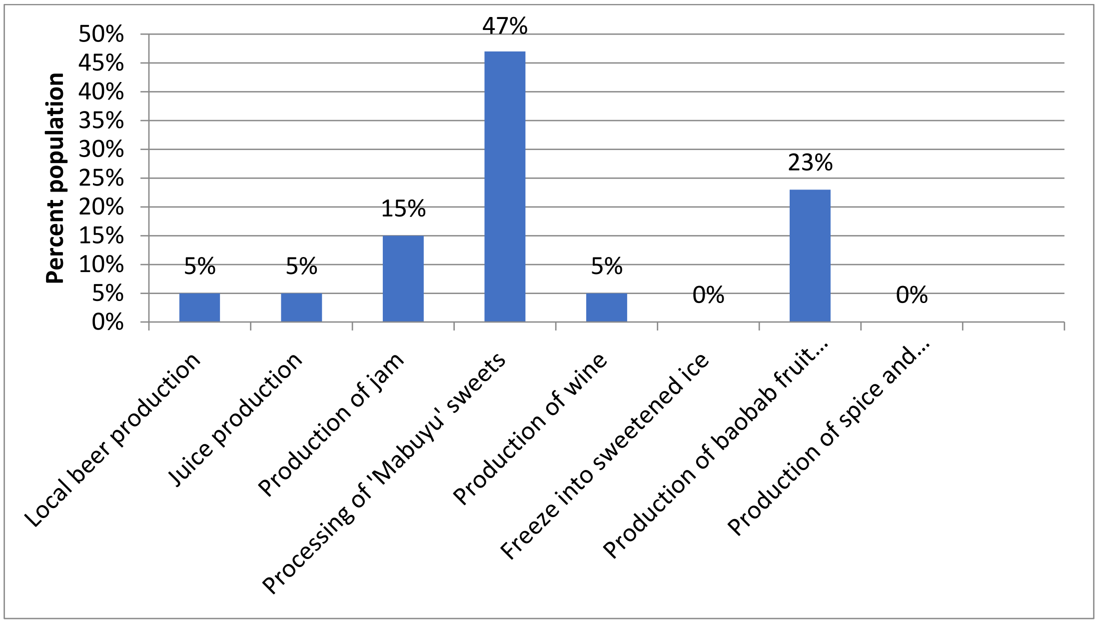


**Figure 3.12: Modes of processing of baobab fruit pulp in Makueni county, Kenya**

On an annual basis it was established that pulp/seed (*mabuyu)* sweets were the most common processed and marketed product recording the highest volume of production (8875 KGS) annually as illustrated in **Figure 3.13**, followed by baobab fruit powder (3598 KGS) and the least processed product reported was baobab seed oil.

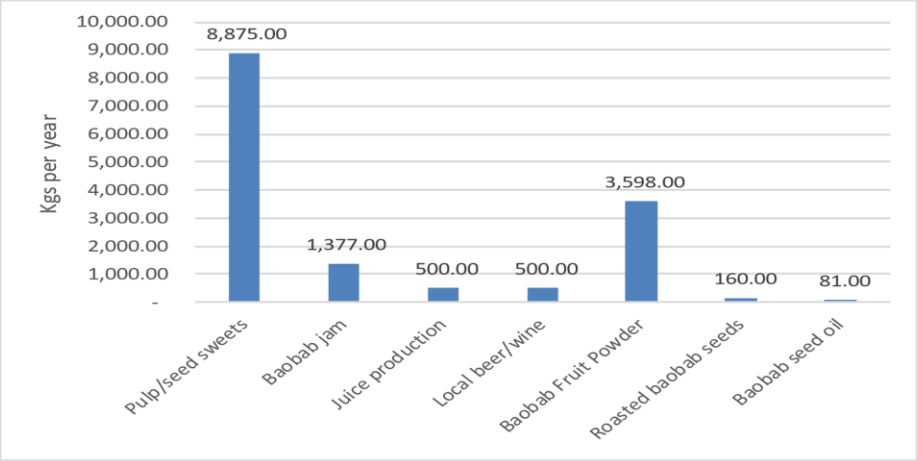


**Figure 3.13 Annual volume of production in KGS of baobab products in Makueni County**

### 3.5.6 Marketing potential of the Baobab fruit

Income generation from the baobab processed products in various study sites within Makueni County is as indicated in **Figure 3.14**.

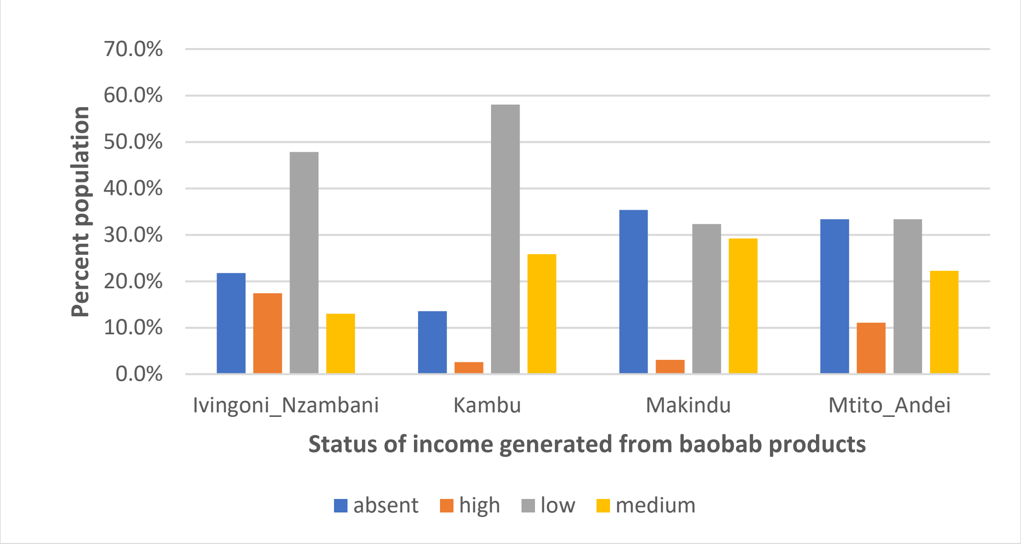


**Figure 3.14: Income generation from the Baobab products in Makueni County**

In the current study, pulp/seed (*mabuyu*)sweets were the most sold product in packages that cost KES 20. The study area consisted of organized community women groups who besides the sale of pulp/seed (*mabuyu*) sweets were also involved in the sale of baobab jam sold at KES 400 per 50g and baobab fruit powder sold at KES 1000 per 1kg. In the current survey, 29.8% of the respondents reported involvement in marketing baobab products. Majority of the respondents reported to have been involved in the sale of the baobab processed product for less than five years with an aim of generating supplementary income. 13.1% of the respondents reportedly derived their main sources of income from baobab products. From this venture, 52% of the respondents earned profit less than KES 5000, 39% reportedly earned between KES 5000-10000 while only 5% of the respondents earned more than KES 10000. as illustrated in **Table 3.2**.

## Table 3.2: Sales and marketing of baobab processed products

| Characteristic | Response | Ivingoni Nzambani | Kambu | Makindu | Mtito andei | Pooled |
|---|---|---|---|---|---|---|
| | | | Percent (%) | | | |
| Involvement in processed baobab products marketing | No | 73.9 | 83.9 | 35.4 | 77.8 | 70.2 |
| | Yes | 26.1 | 16.1 | 64.6 | 22.2 | 29.8 |
| Frequency of sale of baobab products | 2-3 times a week | 8.7 | 13.5 | 12.3 | 11.1 | 12.7 |
| | Everyday | 39.1 | 12.3 | 36.9 | 11.1 | 21.0 |
| | Not involved | 26.1 | 34.2 | 35.4 | 44.4 | 34.1 |
| | Once a week | 26.1 | 40.0 | 15.4 | 33.3 | 32.1 |
| Period involved in income generation | >20yrs | 0.0 | 6.5 | 0.0 | 0.0 | 4.0 |
| | <5_yrs | 47.8 | 24.5 | 53.8 | 33.3 | 34.5 |
| | 10-20yrs | 8.7 | 6.5 | | 11.1 | 5.2 |
| | 5-9yrs | 17.4 | 27.7 | 10.8 | | 21.4 |
| | Not involved | 26.1 | 34.8 | 35.4 | 55.6 | 34.9 |
| Main reason for engaging in sale of baobab products | Generate major source of income | 47.8 | 12.9 | 3.1 | 0.0 | 13.1 |
| | Generate supplementary income | 26.1 | 52.3 | 61.5 | 55.6 | 52.4 |
| | Not involved | 26.1 | 34.8 | 35.4 | 44.4 | 34.5 |
| Demand of baobab products | Decreasing | 4.3 | 2.6 | 1.5 | 0.0 | 2.4 |
| | Fluctuating | 13.0 | 20.6 | 27.7 | 22.2 | 21.8 |
| | Not changed | 4.3 | 8.4 | 27.7 | 22.2 | 13.5 |
| | Increasing | 56.5 | 34.8 | 7.7 | 11.1 | 29.0 |
| | Not involved | 21.7 | 33.5 | 35.4 | 44.4 | 33.3 |
| Ability to meet demand | No | 52.2 | 85.8 | 89.2 | 88.9 | 83.7 |
| | Yes | 47.8 | 14.2 | 10.8 | 11.1 | 16.3 |
| Profits | 5000__10000kshs | 34.8 | 38.1 | 16.9 | 33.3 | 32.1 |
| | <5000kshs | 39.1 | 23.9 | 47.7 | 22.2 | 31.3 |
| | >10000kshs | 4.3 | 3.2 | 0.0 | 0.0 | 2.4 |
| | Not involved | 21.7 | 34.8 | 35.4 | 44.4 | 34.1 |

*N = 252
P value = 0.004

Various sale avenues of baobab processed products was also reported as illustrated in **Figure 3.15**. The importance of the sales of baobab products in the contribution of the overall household income was reported to be less than twenty percent in 58% of the respondents, between forty to fifty-nine percent in 28%, between sixty to seventy-nine percent in 10% and more than eighty percent in 4% of the respondents.

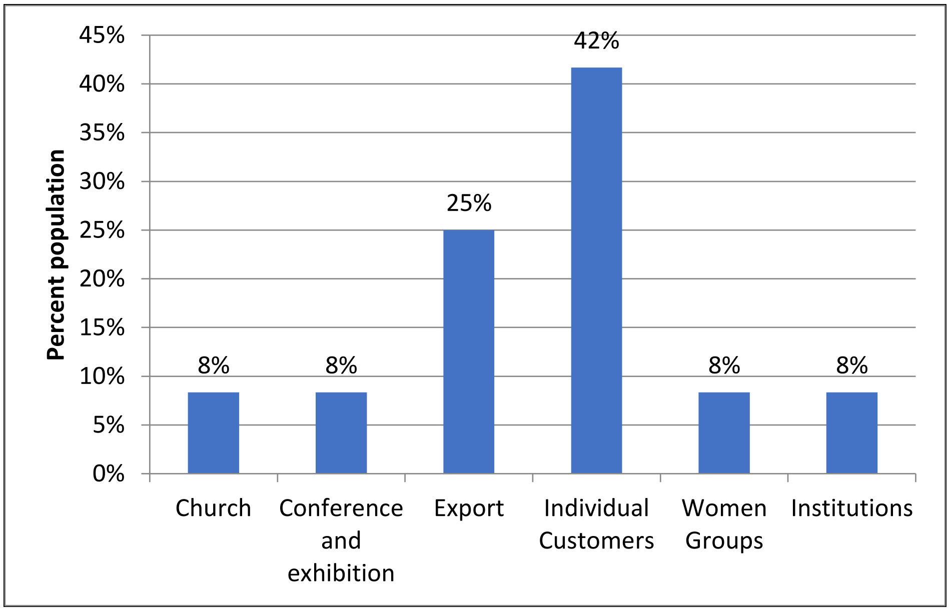


**Figure 3.15: Various sale avenues of baobab products in Makueni County**

### 3.5.7 Challenges faced by Baobab processors in Makueni County

Rural marketers of baobab products face several challenges with majority of the small holders encountering financial constraints (41%) in running their SME's while deriving meagre profits from sale of their products. 25% of the respondents reported few customers, 12% reported limited market space while 23% reported minimum returns. Minimum substantial capital developments acquired from the sale of baobab products was reported whereby 70% utilized profits in expansion of businesses, 2% built houses while 28% bought livestock.

### 3.5.8 Nutritional quality of baobab products consumed in Makueni County

#### 3.5.8.1 Proximate and energy of baobab leaves, pulp, and kernel

The predominant proximate component in baobab leaves and pulp was carbohydrate followed by moisture while crude fat was the least component while in the kernel the predominant proximate component was crude fat followed by carbohydrates while crude fiber was the least. Moisture content differed significantly among the baobab products with the pulp having the least content (11.13±0.43 %). The baobab leaves had the highest crude ash content (12.15±0.002 %) compared to leaves and pulp. Regarding crude fiber baobab pulp recorded the highest amounts of 8.63±0.18% compared to leaves and kernels. Baobab kernel recorded the highest amounts of crude protein (18.79±0.06%) and crude fat (25.54±0.35%) compared to leaves and the pulp. Similarly, baobab kernel provided the highest energy followed by pulp while the leaves had the least energy levels as shown in **Table 3.3**.

**Table 3.3: Proximate and energy of baobab leaves, pulp, and kernel on a dry weight basis**

| Baobab products | Moisture (%) | Crude ash (%) | Crude fiber (%) | Crude protein (%) | Crude fat (%) | Carbohydrates (%) | Energy (Kcal/100g) |
|---|---|---|---|---|---|---|---|
| Leaves | $14.58 \pm 0.28^{b}$ | $12.15 \pm 0.002^{c}$ | $1.99 \pm 0.32^{a}$ | $7.77 \pm 0.17^{b}$ | $0.67 \pm 0.05^{a}$ | $62.85 \pm 0.48^{b}$ | $288.50 \pm 2.17^{a}$ |
| Pulp | $11.13 \pm 0.43^{a}$ | $4.63 \pm 0.38^{a}$ | $8.63 \pm 0.18^{c}$ | $2.84 \pm 0.11^{a}$ | $0.66 \pm 0.05^{a}$ | $72.11 \pm 0.79^{c}$ | $305.73 \pm 3.20^{b}$ |
| Kernel | $18.04 \pm 0.44^{c}$ | $7.17 \pm 0.11^{b}$ | $5.85 \pm 0.13^{b}$ | $18.79 \pm 0.06^{c}$ | $25.54 \pm 0.35^{b}$ | $24.62 \pm 0.71^{a}$ | $403.47 \pm 0.08^{c}$ |
| P value | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

*Values are means ± SD. Means with different superscript letters along the columns are significantly different at $p<0.05$.

#### 3.5.8.2 Micronutrient composition of baobab leaves, pulp, and kernels

The baobab pulp had a vitamin C content of 195.06 mg/100g while calcium levels among the baobab products differed significantly with the leaves having the highest amounts followed by the pulp while the kernel had the least amounts. There was a significant difference in the iron content of the baobab products with the leaves having the highest amounts and the kernel the least amount. The baobab kernel had the highest zinc content followed by the leaves while the pulp had the least content as shown in **Table 3.4**.

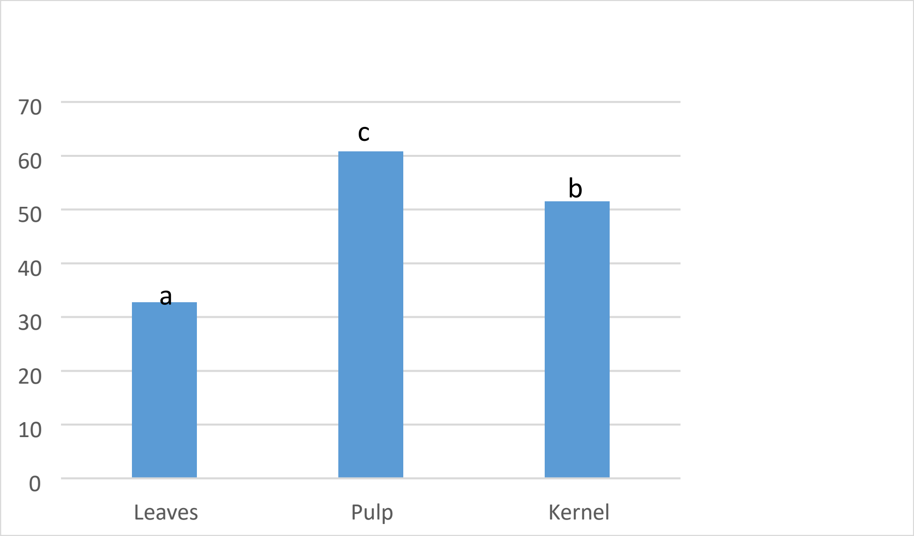
**Table 3.4: Micronutrient composition of baobab leaves, pulp, and kernel on a dry weight basis**

| Baobab products | Calcium (mg/100g) | Iron (mg/100g) | Zinc (mg/100g) |
|---|---|---|---|
| Leaves | $2061.77 \pm 4.69^c$ | $10.47 \pm 0.07^c$ | $4.55 \pm 0.09^b$ |
| Pulp | $302.83 \pm 1.78^b$ | $9.29 \pm 0.27^b$ | $2.32 \pm 0.16^a$ |
| Kernel | $28.44 \pm 0.22^a$ | $6.41 \pm 0.35^a$ | $7.67 \pm 0.01^c$ |
| P value | <0.0001 | <0.0001 | <0.0001 |

Values are means ± SD. Means with different superscript letters along the columns are significantly different at p<0.05. Vitamin C content of the baobab fruit pulp was 195.06±0.70mg/100g

### 3.5.8.3 Antioxidant activity and phytochemical content of baobab pulp, leaves, and kernels

The baobab pulp had a significantly high level of antioxidant activity followed by the kernel while the leaves had the least antioxidant activity (**Figure 3.16**).



Leaves-SD ± 0.25; Pulp-SD± 0.16; Kernels-SD ± 0.36; p value <0.0001

**Figure 3.18: DPPH radical scavenging activity in baobab leaves, pulp, and kernel**

There was a significant difference in the flavonoid content among the baobab products (p<0.0001). The baobab pulp had the highest amounts of flavonoids followed by leaves while the kernel had the least amounts. The phenol content significantly differed among the baobab products with the kernel and the pulp having the highest amounts while the leaves had the least amounts (p=0.0001).

There was a significant difference in the saponin content among the baobab products ($p<0.0001$). The baobab kernel had the highest saponin content followed by the pulp while the leaves had the least saponin content as illustrated in **Table 3.5**.

**Table 3.5 Phytochemical content of baobab leaves, pulp, and kernels**

| Baobab plant products | Flavonoid (mg EQ/g) * | Phenols (mg EAG/g) * | Saponins (%) * |
|---|---|---|---|
| Leaves | $0.025 \pm 0.001^b$ | $0.008 \pm 0.0002^b$ | $1.39 \pm 0.11^a$ |
| Pulp | $0.16 \pm 0.001^c$ | $0.032 \pm 0.001^a$ | $2.28 \pm 0.02^b$ |
| Kernel | $0.017 \pm 0.001^a$ | $0.030 \pm 0.005^a$ | $5.62 \pm 0.19^c$ |
| P value | <0.0001 | 0.0001 | <0.0001 |

*Values are means ± SD. Means with different superscript letters along the columns are significantly different at $p<0.05$.

## 3.6 Discussion

### 3.6.1 Sociodemographic characteristics

Majority of the population included females hence giving a clear indication that females in the area form most of the people involved in the processing and sale of baobab products (McMullin and Kehlenbeck, 2015). This study revealed that most of the baobab sale and processing activities at household level and processing is normally carried by women (McMullin and Kehlenbeck, 2015). Following the small percent of youth who participated in the study, declining interest in engagement in traditional subsistence activities was noted. Young people therefore give up these activities in search for other income generating activities and greater autonomy (FAO, 2017). Furthermore, socio culturally baobab is perceived as ‘food for children’, ‘poor men food’ or ‘Monkey food’ thereby lowering the value of the baobab tree (Stadlmayr et al., 2020) and ignoring the fact that the tree could play a role in improving livelihoods.

### 3.6.2 Socioeconomic characteristics

Most small holder farmers depending on rain fed agriculture as their main economic activity is an indication of high susceptibility to threatening environmental factors such as harsh climatic impacts, crop failure and low agricultural productivity (Kiprotich et al., 2019). Therefore, this and another study by Fischer et al. (2020) shows the great potential in baobab as an important part of the rural livelihoods diet during emergencies to help overcome food insecurity. Low-income generation from the baobab fruit was particularly evident among small holder farmers who sold the whole fruits at farm gate to middlemen who would later sell the fruits to processors. The weak bargaining position of the small holder farmers cause them to accept low prices (Jäckering et al., 2019) since the maximum price reported for a kilogram of baobab fruits was 10KES. The respondents who reported high income generation from the baobab fruit were medium to large scale processors or middlemen (those involved in the sale of the baobab fruits to urban or largescale processors). These findings agree with a study conducted by Kaimba et al. (2020) and Jäckering et al. (2019) which indicated that processors are the value chain actors that receive the highest profits from the sale of baobab based processed products. This therefore shows that efforts towards active value addition and commercialization of baobab and baobab products respectively could help in the empowerment and improvement of livelihoods in especially rural settings (Venter and Witkowski, 2013).

### 3.6.3 Production and consumption of baobab products

Various negative perceptions revolve around the baobab tree causing some households to completely eradicate the tree from their premises. This is a finding similar to a study conducted by Wanjeri et al. (2020) in Kitui County which claimed that the roots of the tree suck all the water around it and hence nothing is able to grow around it. In the same study in Kilifi County the tree was reported to harbor evil spirits and was not allowed to thrive in homesteads. Another study by Fischer et al. (2020) conducted in Voi and Taita Taveta Counties of Kenya, had respondents report the negative effects of the baobab tree on growth of maize due to shading, nutrient uptake and high water use forming part of the reason why farmers cut a low value to the tree.

However, in Makueni county the tree was easily accessible facilitating consumption among the rural poor and encouraging business ventures into various baobab products (Vinceti et al., 2013). Notwithstanding indigenous foods are often considered inferior, they can be exploited in the production of premium specialty products vended in urban markets therefore improving income generation among these vulnerable populations (Darr et al., 2020). This study corroborates with findings of Wanjeri et al. (2020) who established that households in Kilifi and Kitui Counties often consume baobab fruit pulp in its fresh state. Correspondingly in the same study, the fruit pulp is directly included in porridge. On the other hand, Bantu communities in South Africa reportedly boil the fruit pulp with partly fermented maize to come up with an acid porridge (Wickens, 2008).

Comparably in Nigeria, the pulp emulsion (mixture of baobab and water) is added to milk to form a refreshing drink among the Hausa and Fulani communities (Zahra’u et al., 2014). With all these multiple uses of the baobab fruit pulp, during lean seasons it is quite evident that the pulp comes in handy in the provision of nutrients when the rural poor cannot afford the acquisition of fruits from markets/farms or during pre-harvest periods of the rural staples (Wanjeri et al., 2020). Furthermore, such traditional knowledge should be taken into consideration in future efforts directed towards the development and promotion of indigenous nutritious foods (Vinceti et al., 2013). This will also aid in overcoming the negative perceptions revolving around the baobab fruit.

This study and another conducted by Wanjeri et al. (2020) reveals that there is a need for sensitization of communities living along the baobab growing regions on the utilization of baobab leaves as an alternative source of food during periods of food scarcity as well as their engagement in value addition activities of the baobab leaves as part of income generation. Notwithstanding the highly mucilaginous nature of the baobab leaves, they are preferred in the preparation of West African delicacies because the leaves impart a desirable slimy like consistency to the local soups and stews (Zah'rau et al., 2014). The kind of utilization of baobab seeds revealed in the study was an indicator of a coping mechanism among the rural poor when calamities strike or during food shortages (Wanjeri et al., 2020; Fanzo et al., 2013).

The bark, roots, leaves, and seeds have been appreciated for their traditional medicinal value. The leaves and the fruit pulp have been successfully utilized in ethnomedicinal purposes in the treatment of fevers and dysentery (Zahra'u et al., 2014). Powdered leaves on the other hand, are considered useful in the treatment of fatigue, guinea worm infestation and internal pains while the baobab seed oil has been utilized in the treatment of gum diseases (Zah'rau et al., 2014). The fibers of the inner bark of the baobab tree are quite robust (Zah'rau et al., 2014) consequently useful in basket and rope weaving.

### 3.6.4 Processing baobab products

With regards to processing of baobab products, there is a clear indication of how underutilized the baobab tree is in Kenya. Products processed from the baobab leaves were not available in the study area yet in other countries like Mali and Benin the fresh leaves are sundried and ground into leaf powder for sale (Sidibe and Williams, 2002). Extraction of cooking oil from the baobab seeds was however reported. Baobab seed oil contains a high fatty acid composition with a low degree of unsaturation making it a promising source of vegetable oils (Abubakar et al., 2015). Baobab fruit pulp was the prevalent raw material in majority of processed products. The most actively commercialized products included pulp/seed sweets and baobab jam. The pulp/seed sweets were produced by covering the pulp powder embedded on the baobab seed with sugar and artificial food grade coloring (Jäckering et al., 2019). All these products were being processed by women group associations, confirming the findings of a study conducted by Jäckering et al. (2019) on the main value chain actors being predominantly women. Other additional baobab processed products from the fruit reported in Key Informant Interviews included baobab toffees and biscuits enriched with baobab fruit pulp.

Processing of pulp/seed (*mabuyu*) sweets was reported to be done by first cracking the outer shell of the fruit with a hammer or stone, separating the fibers from the pulp covering the seed after which artificial coloring and sugar is boiled in water to form a thick paste in which the seed containing the pulp is added. A small amount of the pulp powder is added, allowed to cool and packaged in polythene bags or plastic containers. The current findings on the processing of mabuyu sweets agree with a similar study by Jäckering et al. (2019). Baobab jam on the other hand involved soaking of the fruit pulp for approximately one hour in water to form a thick paste and sieving to separate the fibers. Afterwards, sugar in the ratio of three quarters the amount of baobab fruit pulp is dissolved in approximately one liter of warm water. The mixture is then put over heat while stirring to prevent caramelization and a golden-brown color change serves as an indication of achievement of the correct brix. The high level of pectin in baobab imparts a high gelling capacity in jam and has been utilized as a substitute for commercial pectin (Ndabikunze at al., 2011) forming part of the reason why it is possible to produce jam using the baobab fruit.

Toffees processed using baobab fruit pulp were also reported, in this case sugar, gum arabica and baobab fruit pulp were brought to boiling until a thick hard paste is formed after which it was spread on aluminum foil, wrapped, and allowed to cool for the toffees to take shape. All these baobab fruit products were processed informally on a small-scale basis using informal equipment such as sufurias, cooking sticks, energy generated from firewood and measurement estimation using cups and spoons. The least processed product was baobab seed oil due to the lack of proper facilities for carrying out subsequent extraction processes.

### 3.6.5 Marketing of baobab products

Marketing of baobab-based products is considered to provide an opportune buffer during times of scarcity (Mwema et al., 2013) and serve to alleviate poverty (Venter and Witkowski, 2013). Further to that, since constant drought in the arid and semi-arid lands leads to livestock losses and crop failures, households have delved in alternative sources of food and income (Mwema et al., 2013) such as the sale of non-timber forest foods like the baobab fruit. However, the baobab fruit pulp market in Kenya is still at an infancy stage (Meinhold and Darr, 2020) with most of the baobab products occupying a small market share and being traded by a small number of actors compared to tropical fruits (Kiprotich et al., 2019). The successful commercialization of underutilized indigenous fruits is impeded by the lack of financial resources and lack of entrepreneurial capabilities by the rural processors (Meinhold and Darr, 2019) resulting to minimum returns.

Further to that, the lack of interest and acceptance of indigenous fruits plays a big part in derailing the successful innovation and commercialization of indigenous based products (Bvenura and Sivakunar, 2017). This explains why majority of the respondents reported no increase in demand of baobab fruit products with most of the products being sold to individual customers than retailers.

The demand of particularly mabuyu sweets is high during school events such as sports or during county events such as agricultural shows as earlier stated by the respondents. In a study conducted by Jäckering et al. (2019) the demand of mabuyu sweets is reportedly high during festive seasons such as Ramadan. In the same study rural processors were involved in transportation of mabuyu sweets to urban centers like Nairobi (Eastleigh) and Mombasa (Kongowea market) with consumption being largely appreciated by the Muslim population. Some respondents reported an increase in demand of baobab fruit products, particularly the fruit powder as it was considered by most of their clients important in boosting immunity following the rising COVID-19 cases. This is attributed to the substantial Vitamin C levels in the baobab fruit pulp. Vitamin C is an essential micronutrient that contributes to the immune defense and its supplementation can prevent and treat various respiratory and systemic infections (Carr and Maggini, 2017).

### 3.6.6 Challenges faced in baobab processing

Limited knowledge on the potential health benefits of the baobab fruit due to inadequate research, thwarts baobab commercialization activities in East African countries such as Kenya (Gebauer et al., 2016). Furthermore, baobab fruit pulp is regarded as a snack or poor man food and not an essential part of the diet (Jäckering et al., 2019) thereby impeding its success in the market. Owing to the fact that local value chains provide low incomes to traders compared to global value chains (Mwema et al., 2013; Shackelton et al., 2007), this forms part of the reason why minimum capital developments are derived from the sale of baobab products. Regulatory frameworks in Sub Saharan Africa do not actively promote development of small enterprises since laws are bureaucratically or weakly enforced (Meinhold and Darr, 2020; Rogerson, 2001). In addition, small processors face various challenges in their small-scale manufacture of products such as: lack of proper processing facilities, lack of proper equipment which has consequently derailed the certification of their products and lack of proper training on processing of diverse baobab products that would enable them to earn more income. The lack of financial muscle to facilitate all these activities results in limited value addition and low economic impact (Meinhold and Darr, 2019).

### 3.6.7 Nutritional value of parts of the baobab tree

Regarding the nutritional content of these parts of the baobab tree sampled in the study area, baobab fruit, kernels and leaves provide essential nutrients which complement their nutrient-poor staple-crop based diet (Buchmann et al., 2010). Generally, baobab leaves contain appreciable amounts of essential nutrients vital for good health and body cell maintenance (Arowora et al.,2019). Macronutrient content of four weeks old baobab leaves harvested in the study area seed bed nurseries, was slightly higher than that reported by Abioye et al. (2015) of 1.16% crude fat, 12.28% crude protein, 8.01% crude ash, 8.0% crude fiber and 52.23% carbohydrates. The degree of maturity as well as processes such as drying influences the overall proximate composition of fresh leaves (Abioye et al., 2015; Ogbaga et al.,2017). Baobab leaves are an excellent source of minerals such as calcium, potassium, manganese, molybdemum, phosphorus, zinc, and iron (Zahrau et al., 2014). The calcium content values reported in this study were slightly lower than those reported in 8 weeks old leaves harvested in Kenya by Hyacinthe et al. (2015) but was within the range reported for baobab leaves from other provenances (1771-2478 mg/100g) around Sub-saharan Africa. Iron and zinc levels from the same study were lower (11.6 and 6.58 mg/1g respectively). This can be due to the fact that, the degree of maturity affects the mineral content of young baobab leaves, as well as the environmental, geological and climatic conditions of the regions of growth (Hyacinthe et al., 2015). In African communities where the leaves are often consumed as a staple food, they offer a significant calcium and iron source (De Caluwe et al., 2010). According to Habte and Krawinkel (2017), 30g of the leaves is sufficient to meet the daily requirement of Calcium and Iron consequently reducing these deficiencies in East Africa. Baobab fruit is capable of meeting the recommended daily intake (RDI) for energy, carbohydrate and protein for children and pregnant women (Chadare et al., 2009). Proximate content of the fruit pulp in the study was within the range reported by Stadylmyr et al. (2013) of 0.2-1.2% crude fat, 1.1-3.2% crude protein, 3.7-6.3 crude ash, 4.4-8.7% crude fiber and 70.74-77.23% carbohydrates. The levels of calcium and zinc in the fruit pulp agree with those reported by Stadylmyr et al. (2020) while iron levels are similar to those reported by Osman, (2004) but lower than that reported by Chadare et al. (2009) and Stadylmyr et al. (2020). Iron content in the pulp is considered to be moderate and on average comparable to the level occurring in beef (4mg/100) (Habte and Krawinkel, 2017). Moreover, the fruit pulp can serve as a calcium supplement (Zahrau et al., 2014) particularly for pregnant women, lactating mothers, children, and elderly (Osman, 2004). Consumption of 60 g and 100 g would cover 42.1% and 70.1% of the RDI for calcium in children and pregnant women (Chadare et al., 2008). Zinc levels in this study agree with those reported by Stadylmyr et al. (2020) ranging from 0.66-3.02 mg/100g. Further to that, baobab fruit pulp has been reported to be an excellent source of Vitamin C with an ascorbic acid content ten times more than that present in oranges (De Caluwe et al., 2010). Part of the reason for this occurrence is that the baobab fruit s naturally dry with a moisture content of up to 10%, compared to juicy oranges with high moisture content levels (Stadylmyr et al., 2020). Vitamin C content from baobab fruit pulp sampled from Kibwezi and Mtito Andei ranges from 107- 311 mg/100g and 66-255 mg/110g (Stadylmyr et al., 2020). Vitamin C content established in this study was within the reported range.

Baobab kernels are cream in color and are obtained after deshelling the seed (Chadare et al., 2009). Compared to the baobab fruit pulp, the kernels possess a relatively higher amount of protein and energy, thereby qualifying them as suitable candidates in infant foods formulation. The proximate content of kernels reported in this study are within ranges reported by Chadare et al. (2009) for 22.1-48.1% carbohydrates, 14-32.1% crude protein, and crude ash of 5-7.9%. However, the crude fat values reported in this study (27.8-34.1%) were slightly lower than what was established in the current experiment. Variations in the various proximate components from literature may be due to differences in climate, soil, and weather conditions (Magaia et al., 2013). Kernels constitute a high degree mono and polyunsaturated fatty acid (linoleic and oleic acids) thereby increasing their suitability in the extraction of oil for human consumption (Kinuthia, 2018; Osman 2004). Levels of iron in the baobab kernels was similar to that reported by Osman (2004) whereas levels of zinc and calcium were comparable to those reported by Lockett et al., (2000).

### 3.6.8 Phytochemicals and Antioxidant activity of Baobab tree products

Baobab plant products (leaves, kernels, and pulp) sampled from the study area showed varying levels of phytochemicals. Phytochemicals have the ability of exhibiting free radical scavenging and antioxidant activity (Arowora et al., 2018). This is a beneficial aspect since these phytochemicals have chemical structures capable of combating oxidative stress thus inhibiting diseases such as cancer, atherosclerosis, hypertension amongst others (Habte and Krawinkel,2017). The findings on the flavonoids and phenol content of baobab products were similar to a study conducted by Eltahir and Eltahed (2019). Similarly, the study also established that the fruit pulp possesses a higher antioxidant activity compared to the leaves.

## 3.7 Conclusion

Consumption of the baobab fruit pulp was well appreciated in the area with multiple uses being reported particularly during the recurrent drought seasons. Following the immense nutritional benefits that can be derived from the baobab products during lean seasons, more emphasis on utilization of these products should be laid. Established nutritional properties are a clear indication that baobab products can capably complement rural diets. To increase utilization of baobab product, research-based organizations should disseminate information on the nutritional profile of baobab products and sensitize vulnerable communities on their consumption to increase nutrient uptake. This will ultimately lead to the assimilation of scarcely consumed baobab products (leaves and kernels) into their daily diets. Further, value addition of baobab products greatly contributes to better appreciation of the baobab tree besides providing a means of income generation. Finally, to ensure sustainability of baobab trade markets, domestication of the baobab tree should be promoted, and an enabling environment created to ensure production of high-quality baobab products.

# CHAPTER FOUR: ENHANCING NUTRITIONAL VALUE AND SAFETY OF BOVINE MILK THROUGH BAOBAB FRUIT PULP SUPPLEMENTATION.

## 4.0 Abstract

Incorporation of the baobab fruit in various innovative formulations remains limited, despite the pulp being abundant in various nutrients and bioactive components. When milk is supplemented with baobab fruit pulp before fermentation, baobab fruit pulp has proven to increase the overall nutritional value of milk. The objective of this study was therefore to enhance utilization through the development of baobab supplemented cultured milk product after which physicochemical, micronutrient, and microbial characteristics were studied. Baobab pulp and milk were blended into five different formulations (10:990), (15:985), (20:980), (25:975), (30:970). One batch was subjected to spontaneous fermentation while two batches were fermented using a mesophilic culture concentration of 0.001% and 0.0005%. The experimental design involved in the formulation was a random complete block design while in all analyzed parameters, significant difference between means were determined using Bonferroni test at $p<0.05$. Crude protein in the formulations ranged from 2.14± 0.07 g/100g and 4.8± 0.07g/100g. The fat content in the samples ranged from 1.01±0.02 g/100g and 2.69±0.02g/100g. Carbohydrates ranged from 5.31±0.27 g/100g and 7.58±0.27g/100g. A significant increase in the calcium content between 30.87±0.03mg/100g and 36.25±0.03mg/100g with increase in baobab pulp concentration was witnessed. Zinc content was significantly different between formulations and ranged between 0.74±0.01mg/100g and 1.08±0.01mg/100g. Iron content in the developed products ranged between 0.64±0.02mg/100g and 1.34±0.02mg/100g while vitamin C content ranged between 10.09±0.10mg/100g and 4.43±0.10mg/100g. The formulations were free from pathogenic bacteria hence safe for human consumption. It was also established that *Leuconostoc mesentoroides* was responsible for fermentation of the cultured formulations. It can be concluded that cultured milk supplemented with baobab fruit pulp can serve as a vehicle in the delivery of all essential nutrients among vulnerable communities.

**Key words:** baobab pulp, LAB, fermentation, spontaneous, culture

## 4.1 Introduction

Baobab fruit pulp has been reported to supplement food products such as cereals, snack bars, bread, and cookies due to significant levels of calcium, zinc, and potassium (Aluko et al., 2016). Addition of baobab in various formulations provides an opportunity to address the various micronutrient deficiencies in diets. In 2008, the Commission of the European Union approved the utilization of the baobab fruit as a novel food ingredient (Stadylmyr et al. 2020; Vassilou, 2008). Since then, the fruit pulp has been marketed as a superfood and constantly been used in the formulation of various products in Europe and USA (Chadare, 2009). Taking into account the immense nutritional benefits packed within the baobab fruit pulp, a transition has been witnessed from traditional utilization to higher retail segment (Darr et al., 2020). This provides a vital incentive in the realization of baobab fruit pulp’s economic value which can be achieved through its utilization as a food ingredient in various formulations (Gebauer et al., 2014). To enhance utilization of the baobab fruit pulp through its incorporation in foods, this study aimed at developing a mesophilic cultured bovine milk product commonly known as *maziwa lala* (in Kenya) enriched with baobab fruit pulp and determining the physicochemical, micronutrient and microbial characteristics of the developed product. When the baobab fruit pulp is added into foods, it is capable of combating zinc and iron deficiencies (Muthai et al., 2017). Additionally, the fruit pulp is a good source of vitamin C even after storage over long periods of time (Stadylmyr et al., 2020). Vitamin C is a powerful antioxidant and extremely important in human nutrition (Kabore et al.,2011). According to FAO, (2020) the amount of vitamin C present in the baobab fruit pulp is three times more than that occurring in oranges. Therefore, there is a need to increase the utilization of the baobab fruit pulp through its incorporation in foods to boost nutritional value. The utilization of the baobab fruit pulp in food fermentation is a prevalent practice in Africa due to abundance of organic acids: citric and tartaric acids (Donkor et al., 2014; Sabina et al., 2020).

Fermentation processes yields food products containing both nutritional and therapeutic properties (Shiby and Mishra,2013). *Maziwa lala* is a spontaneously fermented milk product widely consumed by various communities in Kenya. The shelf life and safety of *maziwa lala* can further be improved by using mesophilic starter cultures during fermentation, mainly comprising of the *Lactococcus* and *Leuconostoc* genera (Shah and Champagne, 2015). During production of cultured *maziwa lala*, milk is pasteurized to a temperature of 80 ℃ for 30 minutes, after which the milk is cooled to 30 ℃ and inoculation done, incubation of the milk is done until the pH of milk drops to 4.8 (Muelas et al., 2022). Fermented milk of this nature is capable of promoting the health of consumers in ways not directly attributable to fresh milk (Marco et al., 2017). Additionally, lactic Acid Bacteria used in the fermentation of cultured dairy products are also responsible for producing key flavor compounds (Chen et al.,2017). In addition, lactic acid bacteria are also responsible for coagulating milk through lactose hydrolysis and work synergistically to bring about desirable characteristics in cultured dairy products (Wairimu et al., 2022). Through acid production these bacteria create an unfavorable environment for pathogenic and spoilage bacteria thereby increasing safety and prolonging shelf life of milk (Sanlier et al.,2019).

Further, cultured dairy products are capable of confering certain health benefits such as anti-fungal anti-microbial, anti-atherosclerotic, antidiabetic and anti-inflammatory activity besides boosted immunity (Sanelier et al., 2019). This may be attributed to bioactive components produced during the fermentation process (Sanelier et al., 2019). These bioactive components secreted by lactic acid cultures and other functional properties associated with the baobab fruit pulp (antioxidant, anti-inflammatory, antidiabetic etc.) qualifies the product under study to be termed as a functional food. A functional food is a food that can offer health benefits beyond basic nutritional value (Lee and Foo,2014). This product will come in handy in combating iron and zinc deficiencies prevalent in communities living in abject poverty who cannot afford mineral supplements and fortified foods and fruits (Kinuthia et al., 2018). With the rising demand for natural and nutritious food, the study findings can further contribute to value addition of the highly underutilized baobab fruit pulp while creating positive impact on the human nutrition by addressing various micronutrient deficiencies among the rural poor. Further, commercialization such kind of a product can greatly contribute to the income status of the households consequently boosting the food security status (Darr et al., 2020).

## 4.2 Materials and Methods

### 4.2.1 Experimental Design

The study involved a laboratory experimental design whereas during sample preparation, a Completely Randomized Design was used. Varying baobab fruit pulp and culture concentration were randomly assigned to fifteen treatments.

### 4.2.2 Sample preparation

Extraction of the baobab fruit powder was done according to the method of Kinuthia (2018). The fruits were cracked using a hammer in order to separate the seed embedded in the pulp from the fruit shell. The pulp/seeds were subjected to sieving to remove fibers. Crushing of the pulp was carefully done using a mortar and pestle to obtain a fine pulp powder separately from the seeds. The pulp powder was then stored in airtight zip loc bags for further processing. On the other hand, raw milk was subjected to various platform quality tests such as: density tests, butter fat, resuzurin test, alcohol test and pH test. This was done to ascertain the freshness of milk and ensure that it was of good quality before processing.

### 4.2.3 Formulation of mesophilic cultured milk supplemented with baobab fruit pulp

The baobab fruit pulp was blended with milk at different concentrations as indicated in **Table 4.1.**

**Table 4.1: Formulation of baobab pulp supplemented cultured milk**

| Formulation | Ingredient proportions Percent (%) | | | Description |
|---|---|---|---|---|
| | Milk | Baobab pulp | Culture | |
| A | 100 | 0 | 0.001 | No baobab enrichment |
| $B_1$ | 99 | 1 | 0.001 | Standard culture concentration Ten grams baobab |
| $B_2$ | 99 | 1 | 0.0005 | Half the standard culture concentration Ten grams baobab |
| $C_1$ | 98.5 | 1.5 | 0.001 | Standard culture concentration Fifteen grams baobab |
| $C_2$ | 98.5 | 1.5 | 0.0005 | Half the standard culture concentration Fifteen grams baobab |
| $D_1$ | 98 | 2 | 0.001 | Standard culture concentration Twenty grams baobab |
| $D_2$ | 98 | 2 | 0.0005 | Half the standard culture concentration Twenty grams baobab |
| $E_1$ | 97.5 | 2.5 | 0.001 | Standard culture concentration Twenty-five grams baobab |
| $E_2$ | 97.5 | 2.5 | 0.0005 | Half the standard culture concentration Twenty-five grams baobab |
| $F_1$ | 97 | 3 | 0.001 | Standard culture concentration Thirty grams baobab |
| $F_2$ | 97 | 3 | 0.0005 | Half the standard culture concentration Thirty grams baobab |

The product was produced according to the method of Aluko, 2017 with slight modifications. The temperature of the milk was slightly raised to 30 ℃ after which a small portion of the milk was blended with the required amount of fruit pulp. The mixture was transferred back to the larger volume of milk and temperature raised to 85 ℃ to achieve pasteurization. The milk was rapidly cooled to 25 ℃ and mesophilic starter culture added to aid in fermentation. Incubation was carried out at ambient temperature for 16 to 18 hours after which the curd was broken, and the product cooled to 4 ℃ to stop further fermentation. The product was held at 4 ℃ until further analysis

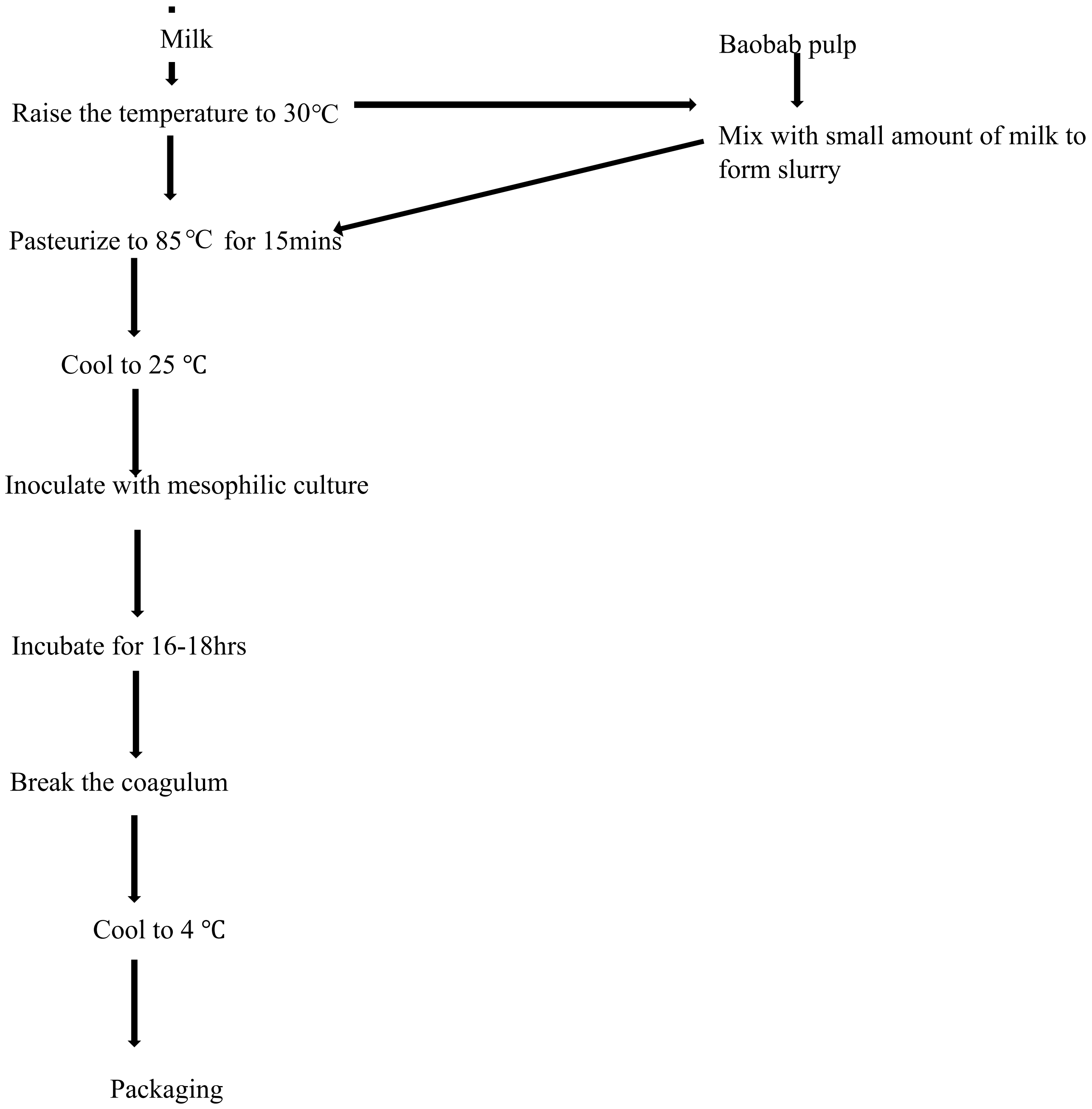


**Figure 4.1: Flow chart for production of baobab supplemented cultured milk**

### 4.2.4 Physicochemical characteristics of the baobab-based cultured milk.

#### 4.2.4.1 Total Titratable acidity

Titratable acidity of samples was determined using 0.1M NaOH to the end point of pH 8.1. 50ml of 0.1 M NaOH was then filled in a burette and titrated against 10ml of the formulated sample with 3 drops of phenolphthalein indicator in a conical flask. Titration was done until when a pink color will be observed, and the corresponding burette reading was taken using the formulae:

$$\text{Titratable acidity} = \frac{\text{titer} \times \text{blank} \times \text{normality of base} \times \text{ml equivalent of lactic acid}}{\text{Weight of the sample}}$$

Where the ml equivalent lactic acid is equal to 0.009 (AOAC, 2012).

#### 4.2.4.2 Instrumental texture analysis

The textural properties of the formulated samples were analyzed using back-extrusion method using TA. XT plus texture analyzer (Stable Microsystems, Goldaming, UK) according to the method of Joon et al. (2017). The samples were dispensed in standard size back- extrusion containers of 50mm diameter approximately 75% full. Back extrusion was carried out with an extension bar of 5Kg load cell and extrusion disc of 35mm diameter, centrally placed over the sample container. The probe was first calibrated to a starting distance of 30mm above the sample surface and test speed set to 1mm/s. The pre-test speed of the texture analyzer was set to 1.0 mm/s while the post- test speed was set to 10.0mm/s Upon probe penetration into the samples firmness (g) (maximum positive force) and consistency ($gs^{-1}$) (area of positive region) measurements were recorded. As the probe returned to its original position, cohesiveness (g) (maximum negative force), and the index of viscosity ($gs^{-1}$) (area of negative region) was also recorded.

#### 4.2.4.3 Proximate composition

##### 4.2.4.3.1 Determination of moisture content

Moisture content determination was done based on AOAC 950.46 (AOAC, 2005). Five ml of the milk sample was weighed in a clean and dry moisture dish after which the weight of the sample and the dish was taken. The sample was transferred in a moisture oven and drying carried out for 3 hours at 105 ℃. The samples were removed and cooled in a desiccator and weight taken.

##### 4.2.4.3.2 Determination of crude protein

Crude protein level was determined according to AOAC (2005) 992.15 methodology. In a Kjedahl flask folded with a nitrogen free filter paper, 0.5 ml of the sample was measured and transferred in it. A catalyst tablet and sulphuric acid was carefully added to digest the sample, and this was carried out in a fume chamber. A few drops of phenolphthalein indicator were added to the mixture and the Kjedahl flask was connected to a distillation unit. Back titration using 0.1N NaOH was done and conversion to protein done by multiplication with 6.25 conversion factor.

##### 4.2.4.3.3 Determination of crude fiber

Crude fiber was determined according to AOAC (2005) 978.10 methodology. 10 ml of the milk samples was added to 200ml of 0.225N Sulphuric acid and was subjected to boiling for 30 minutes. The contents in the flask after boiling was filtered using glass wool and later washed with hot water to remove the acid. 200ml of 0.313 NaOH was preheated, and the contents of digestion transferred in the preheated NaOH and boiling of the mixture was done for 30 minutes.

The contents were filtered, dried, and weighed after boiling. The resultant residue was subjected to a temperature of 540 ℃ in a muffle furnace. % Crude fiber will be expressed as:

(Weight of Crude fiber/ Weight of sample × 100)

#### 4.2.4.3.4 Determination of crude fat

Crude fat was determined through the Soxhlet method according to AOAC, (2005) 954.02 method. 5ml of sample was accurately measured and transferred in a thimble containing cotton wool, after which the sample was transferred to a solvent extractor for extraction of crude fat in a tared flask using petroleum ether of 40-60 ℃ boiling point. The fat was then evaporated in a rotary evaporator and the resultant residue dried in an air oven at 105 ℃. Drying was done for 1 hour after which the weight was taken, and the crude fat expressed as a percentage of sample versus dry matter content.

#### 4.2.4.3.5 Determination of ash content

AOAC method 942.05 (AOAC, 2005) was used in the determination of the ash content of the milk samples. 5ml of the samples were first be charred in a fume chamber until smoking ceases. Charred samples were then transferred in a muffle furnace and heated to 525 $^{o}$c for 6 hours. The samples were removed from the furnace allowed to cool in a desiccator. The percentage ash content was determined by dividing the weight of the ash obtained and weight of the sample.

#### 4.2.4.3.6 Determination of total energy.

Carbohydrates was first determined by:

Carbohydrates = (100% – [% protein + % fiber + % moisture + % fat + % ash]).

The total energy was then calculated as:

Energy = [(4 kcal/g (protein)+ 9 kcal/g (fat) + 4kcal/g (carbohydrates)] AOAC, 2005).

### 4.2.5 Micronutrient composition of the baobab based cultured milk.

Analyses of Calcium, Iron and Zinc was determined using Atomic Absorption Spectrophotometry following the methods described by the AOAC (2010). Vitamin C was determined according to AOAC method 967.21 (AOAC, 2006).

### 4.2.6 Microbiological analysis

Total LAB counts, yeasts and molds, *Staphylococcus aureus* and total coliforms were determined in the formulated samples. Total LAB counts were determined using ISO 15214:1998 method while Yeasts and molds was determined according to ISO 215 27-2:2008 method, *Staphylococcus aureus* ISO 6888-1: 1999 and total coliforms ISO- 4832:2006. Serial dilutions were first made using sterile sodium chloride solution. Initially, 25mls of the formulated samples were added to 225 ml of sterile sodium chloride solution to form the first dilution. A series of six dilutions were then made by pipetting 1 ml of the first dilution into 9 ml of diluent. Pour plate technique was used in the determination of yeast and molds using Potato Dextrose Agar Media and total coliforms using VRBA. 1ml of each dilution in each test tube was pipetted into the petri dishes and approximately 15-20 mls of media added for inoculation. Spread plate technique on the other hand was used in the determination of total LAB counts using MRS agar and *Staphylococcus aureus* using Baird Parker Agar .0.1 ml of each serial dilution was inoculated into the media and a sterile glass spreader was used to evenly spread the sample inoculum. The processes were carried out under aseptic conditions and all samples analyzed in triplicate.

#### 4.2.6.1 Isolation and identification of LAB

Isolation of Lactic acid bacteria from the test samples was carried out according to ISO 15214:1998 method. Typical LAB colonies previously cultured were randomly selected and aseptically scooped using a sterile loop. The colonies were purified by streaking two to three times on fresh MRS media dispensed and allowed to set in petri dishes. The petri dishes were then anaerobically incubated at 32 ℃ for 48hours. Pure LAB isolates from the streak plates were further tested for cell morphology, motility, gram reaction, catalase production, acid production from glucose according to the methods described by Abegaz (2007).

#### 4.2.6.2 Molecular detection of LAB isolates

##### 4.2.6.2.1 DNA extraction

A loopful of pure bacterial isolate was aseptically picked from each of the petri dishes and was transferred to Eppendorf tubes containing sterile distilled water. The Eppendorf tubes containing the isolates were subjected to hot water bath .at 100 ℃ for 30 minutes. The Eppendorf tubes containing the isolates were then subjected to centrifugation at 1500 rpm for 5 minutes at 20 ℃. The supernatant was then drawn aseptically and served as DNA template for further analysis (Silva et al., 2012).

##### 4.2.6.2.2 PCR amplification

PCR amplification of the LAB isolates was carried out in a thermal cycler according to the method of Kaur, Lee and Sharma (2017). Four RAPD primers were used in this experiment for amplification of two microorganisms that is *Leuconostoc mesenteroides* 699 (GCTAAATACGTGCCAGCAGC and GATGATCTGACGTCGTCCCC) as forward and reverse primer respectively and *Lactococcus lactis* 460 (TCACCTATGCAAGCTCGGAC and

FTCACCTATGCAAGCTCGGAC) as forward and reverse primer respectively, at a concentration of 10µl. A master mix kit containing 10mM HCL, 4.0mM KCL, 1.5mM $MgCl_2$, 250µM dNTPs mix, 1 U Taq polymerase of a pH of 9.0 was used for amplification. 0.8µl of each primer and 5µl of template DNA were added into the 8µl premix vials and final volume made up to 16µl through addition of 1.4µl of distilled water. The PCR conditions involved pre-denaturation at 95 ℃ for 15 seconds, 35 cycles of denaturation at 94 ℃ for 30 seconds, annealing at 39 ℃ for 15 seconds, extension at 72 ℃ for 1 minute and final extension at 72 ℃ for 7 minutes for *Leuconostoc mesenteroides* and pre-denaturation at 94 ℃ for 15 seconds, 35 cycles of denaturation at 94 ℃ for 30 seconds, annealing at 45 ℃ for 15 seconds, extension at 72 ℃ for 2 minute and final extension at 72 ℃ for 8 minutes for *Lactococcus lactis*.

#### 4.2.6.2.3 Agarose gel electrophoresis

After amplification, the PCR products were fractionated on a 1.5% agarose gel using 100ml TBE buffer containing 10 mg/ml ethidium bromide. The products were visualized under UV light, and the gels were photographed using a UV gel documentation system (GELMAX-PC). Nuclease free water was used as the negative control. The band pattern was analyzed and confirmed using 100 base pair and 1kb ladders (Kaur, Lee, and Sharma, 2017).

### 4.3 Data Analysis

Data from the various experiments was subjected to two- way ANOVA since there were two independent variables being studied that is, baobab [pulp concentration and culture concentration The data was analyzed using STATA version 12 software whereby means were separated using Bonferroni's method at $p \leq 0.05$ and data reported in means and standard error at 95% confidence interval.

## 4.4 Results

### 4.4.1 Total Titratable acidity

The total titratable acidity increased with increase in baobab pulp concentration at $p \leq 0.05$. A statistically significant difference in total titratable acidity (**Table 4.2**) was observed in cultured formulations containing varying baobab pulp concentration and spontaneously fermented milk. In milk samples fermented using a culture concentration of 0.001% and 0.0005% the total titratable acidity increased with increase in baobab pulp enrichment with the highest values 1.28 ± 0.004 and 1.25 ± 0.004 g/100ml lactic acid being recorded in samples that had 3.0% baobab pulp. In milk samples subjected to spontaneous fermentation for 48 hours a significant increase in total titratable acidity with further increase in rate of baobab pulp addition with values ranging from 0.81 ± 0.004 to 1.05 ± 0.004 g/100ml lactic acid.

**Table 4.2: Total Titratable Acidity (g/100ml lactic acid) of cultured milk supplemented with baobab fruit pulp at different concentrations**

| Baobab concentration* | 0.001% culture | 0.0005 % culture | Spontaneous 48 hours |
|---|---|---|---|
| Control | $1.03^{a}$ | $1.03^{a}$ | $1.03^{a}$ |
| 1.0% | $1.12^{bc}$ | $1.13^{b}$ | $0.81^{n}$ |
| 1.5% | $1.14^{ce}$ | $1.12^{bc}$ | $0.90^{d}$ |
| 2.0% | $1.17^{f}$ | $1.16^{ef}$ | $0.92^{d}$ |
| 2.5% | $1.23^{g}$ | $1.19^{h}$ | $0.94^{n}$ |
| 3.0% | $1.28^{p}$ | $1.25^{g}$ | $1.05^{o}$ |
| P value | <0.0001 | | |
| SE | ± 0.004 | | |

*Means with different superscript letters along the columns and across the rows are significantly different at $p<0.05$.; spontaneous fermentation was done for 48 hours.SE- standard error

### 4.4.2 Texture measurements

#### 4.4.2.1 Firmness

The firmness of fermented milk samples was significantly affected by baobab pulp and culture concentrations ($p<0.0001$). In samples fermented using a culture concentration of 0.001% and

0.0005%, a significant increase in firmness from 29.31 ± 0.49 to 43.18 ± 0.49 and 35.03 ± 0.49 was observed upon supplementation with 1.0% baobab pulp. This was then followed by a significant decrease with further increase in baobab pulp with the least values 20.23 ± 0.49 and 20.19 ± 0.49 being observed in samples containing 3.0% baobab pulp as shown in **Table 4.3**. Interestingly in milk samples subjected to spontaneous fermentation, no significant differences were observed among formulations.

**Table 4.3: Firmness (g) of cultured milk supplemented with baobab fruit pulp at different concentrations**

| Baobab concentration* | 0.001% culture | 0.0005 % culture | Spontaneous 48 hours |
|---|---|---|---|
| Control | $29.31^{b}$ | $29.31^{b}$ | $29.31^{b}$ |
| 1.0% | $43.18^{d}$ | $35.03^{d}$ | $19.93^{a}$ |
| 1.5% | $25.14^{c}$ | $31.16^{b}$ | $18.94^{a}$ |
| 2.0% | $23.81^{c}$ | $24.18^{c}$ | $18.60^{a}$ |
| 2.5% | $20.38^{a}$ | $20.30^{a}$ | $19.68^{a}$ |
| 3.0% | $20.19^{a}$ | $20.23^{a}$ | $20.01^{a}$ |
| P value | <0.0001 | | |
| SE | ± 0.49 | | |

*Means with different superscript letters along the columns and across the rows are significantly different at $p<0.05$.; spontaneous fermentation was done for 48 hours.SE- standard error

#### 4.4.2.2 Consistency

Baobab pulp and culture concentration significantly affected the consistency of the samples as shown in **Table 4.4**. Compared to the control (714.92 ± 7.7 $gs^{-1}$), addition of 1% baobab pulp in 0.001% and 0.0005% cultured formulations resulted in a significant increase in consistency of 861.02±7.7 $gs^{-1}$ and 872±7.7 $gs^{-1}$respectively. This was followed by a significant decline in consistency with further addition of baobab pulp and least value (415.39 ± 7.7 $gs^{-1}$) recorded in milk fermented with 0.001% culture containing 3.0% baobab pulp. For milk samples subjected to spontaneous fermentation there was baobab pulp addition resulted to constant consistency with values ranging from 400.75 ± 7.7 $gs^{-1}$ and 427.40 ± 7.7 $gs^{-1}$

**Table 4.4: Consistency ($gs^{-1}$) of cultured milk supplemented with baobab fruit pulp at different concentrations**

| Baobab concentration* | 0.001% culture | 0.0005 % culture | Spontaneous 48 hours |
|---|---|---|---|
| Control | $714.92^{c}$ | $714.92^{c}$ | $714.92^{c}$ |
| 1.0% | $861.02^{e}$ | $872.32^{e}$ | $422.62^{ab}$ |
| 1.5% | $592.53^{d}$ | $766.73^{g}$ | $400.75^{a}$ |
| 2.0% | $499.95^{f}$ | $563.13^{d}$ | $408.73^{a}$ |
| 2.5% | $429.76^{ab}$ | $454.40^{b}$ | $407.13^{a}$ |
| 3.0% | $415.39^{ab}$ | $431.57^{ab}$ | $427.40^{ab}$ |
| P value | <0.0001 | | |
| SE | ± 7.7 | | |

*Means with different superscript letters along the columns and across the rows are significantly different at $p<0.05$.; spontaneous fermentation was done for 48 hours.SE- standard error

### 4.4.2.3 Cohesiveness

Cohesiveness was significantly affected by baobab pulp concentration and fermentation culture concentration ($p<0.0001$) as indicated in **Table 4.5**. In milk samples fermented using culture concentrations of 0.001% and 0.0005% there was a significant increase of 27.50 ± 0.49g and 28.35 ± 0.49g respectively in cohesiveness with 1.0% baobab pulp addition compared to the control (22.37 ± 0.49 g). Further baobab pulp addition resulted to a significant increase in cohesiveness with the highest value of 15.43 ± 0.49g being observed in milk samples containing 3.0% baobab pulp and 0.001% culture. In milk samples subjected to spontaneous fermentation there was a significant increase in cohesiveness up to 2.0% baobab pulp addition and further incorporation of baobab resulted to a varying cohesiveness.

**Table 4.5: Cohesiveness (g) of cultured milk supplemented with baobab fruit pulp at different concentrations**

| Baobab concentration* | 0.001% culture | 0.0005 % culture | Spontaneous 48 hours |
|---|---|---|---|
| Control | $-22.37^{d}$ | $-22.37^{d}$ | $-22.37^{d}$ |
| 1.0% | $-27.50^{f}$ | $-28.35^{f}$ | $-12.88^{b}$ |
| 1.5% | $-18.97^{e}$ | $-24.66^{d}$ | $-14.10^{ab}$ |
| 2.0% | $-17.17^{ce}$ | $-18.42^{e}$ | $-14.73^{abc}$ |
| 2.5% | $-14.77^{abc}$ | $-16.50^{ace}$ | $-14.06^{ab}$ |
| 3.0% | $-15.43^{abc}$ | $-13.92^{ab}$ | $-14.99^{abc}$ |
| P value | <0.0001 | | |
| SE | ± 0.49 | | |

*Means with different superscript letters along the columns and across the rows are significantly different at $p<0.05$.; spontaneous fermentation was done for 48 hours.SE- standard error

#### 4.4.2.4 Work of cohesion

There was no significant difference was observed in the work of cohesion in milk supplemented with 1.0% and 3.0% baobab pulp at the different culture concentrations ($p<0.0001$). However, significant differences existed in the cultured samples containing 1.5%, 2.0%, and 2.5% baobab pulp. In milk samples subjected to spontaneous fermentation, a varying work of cohesion was observed with further baobab pulp addition as shown in **Table 4.7**

**Table 4.7: Work of cohesion ($gs^{-1}$) of cultured milk supplemented with baobab fruit pulp at different concentrations**

| Baobab concentration | 0.001% culture | 0.0005 % culture | Spontaneous 48 hours |
|---|---|---|---|
| Control | $-30.52^{c}$ | $-30.52^{c}$ | $-30.52^{c}$ |
| 1.0% | $-51.96^{e}$ | $-55.90^{e}$ | $-22.55^{d}$ |
| 1.5% | $-11.57^{f}$ | $-39.65^{h}$ | $19.91^{abd}$ |
| 2.0% | $1.13^{g}$ | $-9.63^{f}$ | $15.75^{ab}$ |
| 2.5% | $14.34^{a}$ | $5.86^{g}$ | $20.31^{bd}$ |
| 3.0% | $15.47^{ab}$ | $16.5^{ab}$ | $15.49^{ab}$ |
| P value | <0.0001 | | |
| SE | ± 1.06 | | |

*Means with different superscript letters along the columns and across the rows are significantly different at $p<0.05$.; spontaneous fermentation was done for 48 hours.SE- standard error

### 4.4.3 Proximate composition of formulated samples

All proximate components of the fermented milk supplemented with baobab were significantly influenced by the baobab concentration and the culture concentration ($p < 0.05$). There was a significant decline in moisture content in all formulations, with values ranging between 84.28% to 87.91% at p value of 0.0004. In cultured formulations highest protein content (4.8 ± 0.07 g/100g) at $p<0.0001$ was recorded in milk samples fermented using a culture concentration of 0.001% at 3.0% baobab pulp supplementation. Similarly, in spontaneously fermented formulations, highest protein content of 4.44 ± 0.07 g/100g was observed in 3.0% baobab pulp supplemented milk. Higher values of crude fat were observed in all samples containing 3.0% baobab pulp enrichment ranging from 1.59 ± 0.02 g/100g to 2.69 ± 0.02 g/100g at $p<0.0001$. Similarly, higher crude fiber values were observed in all formulations containing 3.0% baobab pulp ranging from 1.64 ± 0.02 g/100g and 2.22 ± 0.02 g/100g at $p<0.0001$. Ash content in various formulations ranged from 0.72 ± 0.006 g/100g and 0.91± 0.006 g/100g at $p<0.0001$. In all samples highest energy levels at a p value of 0.0003 were yielded at 2.0%, 2.5% and 3.0% baobab pulp concentration as indicated in **Table 4.8**.

## Table 4.8: Proximate composition (g/100 dry weight) of cultured milk supplemented with baobab fruit pulp at different concentrations

| Culture concentration (%) | Proximate component | Baobab pulp concentration *(%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Control** | **1.0** | **1.5** | **2.0** | **2.5** | **3.0** |
| **0.001** | Moisture | 88.64 ± 0.28$^{c}$ | 86.17 ± 0.28$^{bd}$ | 85.32 ± 0.28$^{ab}$ | 85.09 ± 0.28$^{ab}$ | 84.91 ± 0.28$^{ab}$ | 84.50 ± 0.28$^{a}$ |
| | Fat | 0.56 ± 0.02$^{a}$ | 1.01 ± 0.02$^{b}$ | 1.25 ± 0.02$^{ef}$ | 1.31 ± 0.02$^{fg}$ | 1.51 ± 0.02$^{ch}$ | 1.59 ± 0.02$^{cd}$ |
| | Protein | 3.14 ± 0.07$^{d}$ | 3.60 ± 0.07$^{e}$ | 4.47 ± 0.07$^{abc}$ | 4.57 ± 0.07$^{ab}$ | 4.69± 0.07$^{ab}$ | 4.8 ± 0.07$^{b}$ |
| | Crude fiber | 0.94 ± 0.02$^{b}$ | 1.04 ± 0.02$^{bd}$ | 1.18 ± 0.02$^{cf}$ | 1.21 ± 0.02$^{ac}$ | 1.33 ± 0.02$^{ae}$ | 1.64 ± 0.02$^{g}$ |
| | Ash | 0.59 ± 0.006$^{d}$ | 0.72 ± 0.006$^{g}$ | 0.75 ± 0.006$^{e}$ | 0.79 ± 0.006$^{f}$ | 0.83± 0.006$^{a}$ | 0.84 ± 0.006$^{a}$ |
| | CHO | 6.14 ± 0.27$^{abc}$ | 7.47 ± 0.27$^{ab}$ | 7.03 ± 0.27$^{ab}$ | 7.02 ± 0.27$^{ab}$ | 6.73 ± 0.27$^{abc}$ | 6.63 ± 0.27$^{abc}$ |
| | Energy | 42.10 ± 1.1$^{e}$ | 53.34 ± 1.1$^{df}$ | 57.22 ± 1.1$^{acd}$ | 58.21 ± 1.1$^{abcd}$ | 59.3 ± 1.1$^{abcd}$ | 60.01 ± 1.1$^{abc}$ |
| **0.0005** | Moisture | 88.64 ± 0.28$^{c}$ | 85.59 ± 0.28$^{ab}$ | 84.85 ± 0.28$^{ab}$ | 84.79 ± 0.28$^{ab}$ | 84.52 ± 0.28$^{a}$ | 84.28 ± 0.28$^{a}$ |
| | Fat | 0.56 ± 0.02$^{a}$ | 1.07 ± 0.02$^{b}$ | 1.39 ± 0.02$^{gh}$ | 1.71 ± 0.02$^{d}$ | 1.91 ± 0.02$^{i}$ | 2.09 ± 0.02$^{j}$ |
| | Protein | 3.14 ± 0.07$^{d}$ | 3.93 ± 0.07$^{ef}$ | 4.15 ± 0.07$^{cf}$ | 4.33 ± 0.07$^{ac}$ | 4.56 ± 0.07$^{ab}$ | 4.69 ± 0.07$^{ab}$ |
| | Crude fiber | 0.94 ± 0.02$^{b}$ | 1.05 ± 0.02$^{bd}$ | 1.21 ± 0.02$^{ac}$ | 1.26 ± 0.02$^{ac}$ | 1.33 ± 0.02$^{ae}$ | 1.45 ± 0.02$^{e}$ |
| | Ash | 0.59 ± 0.006$^{d}$ | 0.78 ± 0.006$^{ef}$ | 0.84 ± 0.006$^{a}$ | 0.85 ± 0.006$^{ab}$ | 0.88 ± 0.006$^{bc}$ | 0.91 ± 0.006$^{c}$ |
| | CHO | 6.14 ± 0.27$^{abc}$ | 7.58 ± 0.27$^{a}$ | 7.57 ± 0.27$^{a}$ | 7.06 ± 0.27$^{ab}$ | 6.80 ± 0.27$^{abc}$ | 6.59 ± 0.27$^{abc}$ |
| | Energy | 42.10 ± 1.1$^{e}$ | 55.67 ± 1.1$^{cdf}$ | 59.36 ± 1.1 abcd | 60.96 ± 1.1$^{abc}$ | 62.63 ± 1.1$^{ab}$ | 63.88 ± 1.1$^{b}$ |
| **Spontaneous fermentation** | Moisture | 88.64 ± 0.28$^{c}$ | 87.91 ± 0.28$^{c}$ | 87.3 ± 0.28$^{cd}$ | 85.41 ± 0.28$^{ab}$ | 85.12 ± 0.28$^{ab}$ | 84.44 ± 0.28$^{a}$ |
| | Fat | 0.56 ± 0.02$^{a}$ | 1.14 ± 0.02$^{be}$ | 1.58 ± 0.02$^{cd}$ | 1.89 ± 0.02$^{i}$ | 2.44 ± 0.02$^{k}$ | 2.69 ± 0.02$^{l}$ |
| | Protein | 3.14 ± 0.07$^{d}$ | 2.14 ± 0.07$^{g}$ | 3.04 ± 0.07$^{d}$ | 3.59 ± 0.07$^{e}$ | 4.16 ± 0.07$^{cf}$ | 4.44 ± 0.07$^{abc}$ |
| | Crude fiber | 0.94 ± 0.02$^{b}$ | 1.06 ± 0.02$^{df}$ | 1.23 ± 0.02$^{ac}$ | 1.62 ± 0.02$^{g}$ | 2.03 ± 0.02$^{h}$ | 2.22 ± 0.02$^{i}$ |
| | Ash | 0.59 ± 0.006$^{d}$ | 0.76 ± 0.006$^{ef}$ | 0.83 ± 0.006$^{a}$ | 0.85 ± 0.006$^{ab}$ | 0.88 ± 0.006$^{bc}$ | 0.91 ± 0.006$^{c}$ |
| | CHO | 6.14 ± 0.27$^{abc}$ | 6.99 ± 0.27$^{ab}$ | 6.02 ± 0.27$^{bc}$ | 6.63 ± 0.27$^{abc}$ | 5.37 ± 0.27$^{c}$ | 5.31 ± 0.27$^{c}$ |
| | Energy | 42.10 ± 1.1$^{e}$ | 46.75 ± 1.1$^{eg}$ | 50.48 ± 1.1$^{fg}$ | 57.93 ± 1.1$^{abcd}$ | 60.07 ± 1.1$^{abc}$ | 63.18 1.1$^{ab}$ |

*Values are means ± SE. Means with different superscript letters along the rows are significantly different at $p<0.05$. 0.01and 0.005 grams of mesophilic culture was used; spontaneous fermentation was done for 48hours. P values include Moisture-0.0004, Crude fat, protein, fiber, and ash-<0.0001, Carbohydrates- 0.1307, Energy- 0.0003

### 4.4.4 Micronutrient content of formulated samples

Culture concentrations had a significant influence on the micronutrient content of the fermented milk supplemented with baobab fruit pulp ($p<0.05$). Higher levels of micronutrients were recorded in baobab supplemented milk samples containing 0.0005% culture. For vitamin C, the highest levels (10.09± 0.10 mg/100g) were reported in milk fermented using a culture concentration of 0.0005% supplemented with 3.0% baobab while the least value (2.47 ± 0.10 mg/100g) was reported in the control at $p<0.0001$. Spontaneously fermented milk supplemented with 3.0% baobab fruit pulp yielded the highest calcium content (36.25 ± 0.03mg/100g) at $p<0.001$, while milk fermented using a culture concentration of 0.0005% supplemented with 3.0% baobab pulp, yielded the highest iron content (1.51 ± 0.02 mg/100g) at $p<0.0001$. On the other hand, milk fermented using a culture concentration of 0.0005% supplemented with 3.0% baobab fruit pulp recorded the highest zinc content (1.19 ± 0.01 mg/100g) at $p<0.0001$ as shown in **Table 4.9.**

**Table 4.9: Micronutrient content in mg/100g dry weight of cultured milk supplemented with baobab fruit pulp at different concentrations**

| Culture concentration (%) | Nutrient | Baobab pulp concentration (%) * | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Control** | **1.0** | **1.5** | **2.0** | **2.5** | **3.0** |
| **0.001** | Vitamin C | 2.47 ± 0.10$^{a}$ | 5.82 ± 0.10$^{c}$ | 6.68 ± 0.10$^{d}$ | 6.99 ± 0.10$^{d}$ | 8.04 ± 0.10$^{e}$ | 9.61± 0.10 $^{fg}$ |
| | Calcium | 14.92 ± 0.03$^{a}$ | 30.87 ± 0.03$^{b}$ | 30.94 ± 0.03$^{b}$ | 31.25 ± 0.03$^{c}$ | 31.88 ± 0.03$^{d}$ | 33.11 ± 0.03$^{g}$ |
| | Zinc | 0.67 ± 0.01$^{a}$ | 0.74 ± 0.01$^{h}$ | 0.85 ± 0.01$^{bc}$ | 0.87 ± 0.01$^{cd}$ | 0.99 ± 0.01$^{f}$ | 1.08 ± 0.01$^{g}$ |
| | Iron | 0.25 ± 0.02$^{a}$ | 0.64 ± 0.02$^{f}$ | 0.77 ± 0.02$^{gh}$ | 0.84 ± 0.02$^{hi}$ | 1.09 ± 0.02$^{cd}$ | 1.16 ± 0.02$^{d}$ |
| **0.0005** | Vitamin C | 2.47 ± 0.10$^{a}$ | 5.89 ± 0.10$^{c}$ | 6.79± 0.10$^{d}$ | 7.67± 0.10$^{e}$ | 8.15± 0.10$^{e}$ | 10.09± 0.10$^{g}$ |
| | Calcium | 14.92 ± 0.03$^{a}$ | 32.18 ± 0.03$^{f}$ | 33.51 ± 0.03$^{e}$ | 33.87 ± 0.03$^{h}$ | 34.84 ± 0.03$^{i}$ | 35.75 ± 0.03$^{j}$ |
| | Zinc | 0.67 ± 0.01$^{a}$ | 0.81 ± 0.01$^{b}$ | 0.90 ± 0.01$^{de}$ | 0.98 ± 0.01$^{f}$ | 1.06 ± 0.01$^{g}$ | 1.19 ± 0.01$^{i}$ |
| | Iron | 0.25 ± 0.02$^{a}$ | 0.69 ± 0.02$^{fg}$ | 1.00 ± 0.02$^{bc}$ | 1.34 ± 0.02$^{e}$ | 1.42 ± 0.02$^{ek}$ | 1.51 ± 0.02$^{k}$ |
| **Spontaneous fermentation** | Vitamin C | 2.47 ± 0.10$^{a}$ | 4.43 ± 0.10$^{b}$ | 5.59 ± 0.10$^{c}$ | 7.03± 0.10$^{d}$ | 8.05± 0.10$^{e}$ | 9.21± 0.10$^{f}$ |
| | Calcium | 14.92 ± 0.03$^{a}$ | 31.24 ± 0.03$^{c}$ | 31.93 ± 0.03$^{d}$ | 33.37 ± 0.03$^{e}$ | 35.34 ± 0.03$^{k}$ | 36.25 ± 0.03$^{l}$ |
| | Zinc | 0.67 ± 0.01$^{a}$ | 0.84 ± 0.01$^{bc}$ | 0.92 ± 0.01$^{de}$ | 0.92 ± 0.01$^{e}$ | 0.98 ± 0.01$^{f}$ | 1.05 ± 0.01$^{g}$ |
| | Iron | 0.25 ± 0.02$^{a}$ | 0.87 ± 0.02$^{ij}$ | 0.95 ± 0.02$^{bj}$ | 1.04 ± 0.02$^{bc}$ | 1.15 ± 0.02$^{d}$ | 1.34 ± 0.02$^{e}$ |
| **P value** | | | <0.0001 | | | | |

*Values are means ± SE. Means with different superscript letters along the rows are significantly different at $p<0.05$. 0.01and 0.005 grams of mesophilic culture was used; spontaneous fermentation was done for 48hours

## 4.4.6 Microbial analysis of formulated products

### 4.4.6.1 Total coliforms

There were no total coliforms in cultured samples supplemented with baobab. (**Table 4.10**). However total coliforms were detected in spontaneously fermented milk containing 1.0%, 1.5% and 2.0% baobab pulp with the highest CFU of 3.19 ± 0.002 CFU$^{-}$G at $p \leq 0.05$ being observed in samples containing 1.0% baobab fruit pulp.

**Table 4.10: Total coliforms ($\log_{10}$ CFU in cultured milk supplemented with baobab fruit pulp at different concentrations**

| Baobab concentration * | 0.001% culture | 0.0005 % culture | Spontaneous 48 hours |
|---|---|---|---|
| Control | -ve | -ve | -ve |
| 1.0% | -ve | -ve | 3.19 ± 0.002$^{a}$ |
| 1.5% | -ve | -ve | 3.15 ± 0.009$^{a}$ |
| 2.0% | -ve | -ve | 2.44 ± 0.04$^{b}$ |
| 2.5% | -ve | -ve | -ve |
| 3.0% | -ve | -ve | -ve |

*Values are means ± SE. Means with different superscript letters along the columns and across the rows are significantly different at $p<0.05$.; spontaneous fermentation was done for 48 hours

### 4.4.6.2 *Staphylococcus aureus*

*Staphylococcus aureus* was not detected in any of the samples.

### 4.4.6.3 Yeasts and Mold counts

Yeasts and molds were not detected in any of the test samples.

### 4.4.6.4 Lactic Acid Bacteria

There was a significant difference in LAB concentration in milk containing varying baobab concentration and fermented using different culture concentration ($p< 0.0001$). A significant increase in CFU of LAB with increase in baobab concentration with LAB counts ranging from 6.22 ± 0.01CFU/G and 8.40 ± 0.01CFU/G as indicated in **Table 4.11**.

**Table 4.11: LAB ($\log_{10}$ CFU) in cultured milk supplemented with baobab fruit pulp at different concentrations**

| Baobab concentration | 0.001% culture | 0.0005 % culture | Spontaneous 48 hours |
|---|---|---|---|
| Control | $7.87^{b}$ | $7.87^{b}$ | $7.87^{b}$ |
| 1.0% | $8.03^{a}$ | $7.92^{b}$ | $6.22^{d}$ |
| 1.5% | $8.21^{e}$ | $8.05^{a}$ | $7.48^{i}$ |
| 2.0% | $8.31^{f}$ | $8.08^{ac}$ | $7.64^{j}$ |
| 2.5% | $8.34^{g}$ | $8.12^{c}$ | $8.03^{a}$ |
| 3.0% | $8.40^{h}$ | $8.17^{d}$ | $8.07^{ac}$ |
| P value | <0.0001 | | |
| SE | ± 0.01 | | |

*Means with different superscript letters along the columns and across the rows are significantly different at $p<0.05$; spontaneous fermentation was done for 48 hours.SE- standard error

### 4.4.6.5 Isolation and molecular identification of Lactic Acid Bacteria

Typical LAB colonies upon microscopic examination exhibited cocci cell morphology, non-motility and gram-positive reaction. Upon biochemical examination the colonies gave a negative catalase reaction and were capable of utilizing glucose. Based on these characteristics the isolates were considered as LAB. PCR amplification further confirmed *Leuconostoc mesenteroides* as the LAB present in the formulated samples whose length was slightly above 699 base pair (**Annex 7**). Base pairs are located in the DNA and RNA where hydrogen bonds occurring between the nucleobases making the double stranded structure possible (Hornum et al., 2019). On the other hand, they are vital in measuring the size of an individual gene within a DNA (Johnson et al., 2004).

## 4.5 Discussion

### 4.5.1 Physico-chemical characteristics of baobab-based formulations

The increase in total titratable acidity with increase in baobab concentration may be attributed to the fact that baobab fruit pulp contains organic acids such as malic, succinic, tartaric, citric, and ascorbic acids (Mpofu et al., 2014). Increased levels of total titratable acidity trigger post acidification in cultured milk products which consequently results to decreased storage stability and low consumer acceptability (Deshwal et al., 2021).The total titratable acidity range within the formulated samples was higher than recommended by KEBS standards (KS941:2018) of 0.7%. The fact that there were more additional fermentable sugars as a result of baobab pulp addition allowed more biochemical activity of the starter cultures resulting to increased levels of total titratable acidity (Dabora, 2016).

Textural characteristics in fermented dairy products are defined by firmness, adhesiveness, cohesiveness and springiness (Prajapati et al., 2016). Textural properties play an important role in determining food quality and acceptability and are characterized using force and deformation as the major parameters (Prajapati et al., 2016).. The textural properties in the formulated products were significantly affected by the baobab pulp and culture concentration. This is due to the fact that these properties are largely affected by the structure, spatial distribution, and bond strength of the casein micelles (Aluko et al., 2016). Increasing the baobab concentration in all formulated samples led to a decline in these textural properties since addition of the baobab may have resulted to interruption of the gel structure due to the rearrangement of the protein protein matrix in the products (Izadi et al., 2015). Therefore, it was established that increased baobab concentration in cultured milk products adversely affects the textural parameters, and this has an implication on low consumer acceptability.

The moisture content in all the samples ranged from 86.17% to 84.44% corroborating with a similar study carried out by Dabora, (2016) in yoghurt but lower than that reported by Aluko, (2017). A reduction in moisture content with an increase in baobab pulp concentration was due to the absorption of moisture by high solid content present in baobab pulp (Wairimu, Owaga and Koskei, 2022). Increasing the baobab pulp concentration led to an increase in protein in all samples agreeing with findings by Dabora, (2016). Higher protein levels were observed in cultured milk compared to spontaneously fermented milk since LAB are capable of increasing the protein availability in milk (Teshome, 2015) and the fact that LAB are capable secreting proteolytic enzymes that hydrolyze caseins to peptides and amino acids (Aluko et al., 2017; Zumunta and Umar, 2020). Incorporation of baobab fruit pulp in various formulations increases the protein quality and this is vital in addressing protein energy malnutrition issues (Kwamboka, 2018). However, a study conducted by Aluko, (2017) and Adelekan and Saleh (2020) reported a decrease in protein content with increase in baobab fruit pulp due to fermentation.

The fat content increased in all the samples with increase in baobab pulp concentration due to additional fat from the pulp that was imparted to the product. This finding is similar to a study conducted by Wairimu, Owaga and Koskei (2022). Spontaneously fermented milk and 0.001% cultured milk showed the highest levels of fat, which could be due to increased lipase activity which hydrolyses fat in fatty acids and glycerol (Adelekan and Saleh, 2022). Fat content has a positive effect on mouthfeel in fermented food products but negatively affects the shelf life of the product (Ndife et al., 2014). The fat content in the formulated samples comply to the KEBS standards (KS941:2018) minimum of 10%. The increase in fiber content in all the samples with increase in baobab pulp concentration was similar to a study conducted by Chipchura, (2021). This its due to the fact that baobab pulp is a rich source of dietary fiber 8.68g/100g dry weight (Muthai et al., 2017). Baobab pulp is comprised of both soluble and insoluble fibers all of which are vital in achieving desirable textural properties and stabilization of fermented milk (Aluko,2017). LAB are capable of synthesizing polysaccharides (Korcz et al., 2018) hence the higher fiber content in spontaneously fermented milk and 0.001% cultured milk enriched with baobab pulp. Dietary fiber improves the human health by modulating the composition of gut microbiota and this has a vital implication on gastrointestinal disorders (Gill et al., 2021; Cai et al., 2020). The increase in ash content implies that baobab pulp has a high mineral content therefore, further addition in milk raises the ash content (Aluko, 2017). The findings are similar to results reported in baobab pulp enriched goat milk yoghurt which similarly reported high ash content (Wairimu, Owaga and Koskei, 2022). LAB utilize minerals for growth and metabolic activity (Nduti et al., 2018) this could be the reason why lower ash content values were recorded in 0.001% cultured milk compared to 0.0005% and spontaneously fermented. Lactose is the main carbohydrate that occurs in milk and during fermentation it is hydrolyzed by LAB resulting in the production of lactic acid (Ihemeje et al., 2015). This therefore accounts for the low carbohydrate content observed in the formulated sample. This works corroborates with Aluko, (2017) and Zumunta and Umar, (2020).

### 4.5.2 Micronutrient content of the baobab-based formulations

According to Zah'rau et al. (2014) baobab pulp is an amenable source of calcium and can actually be utilized for calcium supplementation. Calcium is vital for bone formation and mineralization and the requirements are high during growth, pregnancy, and lactation (Adelekan and Saleh, 2020). Addition of baobab therefore resulted in increased calcium content in all the cultured milk samples and in the spontaneously fermented. Iron is vital as it is responsible for various metabolic processes in the body such as DNA synthesis, oxygen, and electron transport (Abbaspour et al., 2014). Iron is the most abundant microelement in the baobab fruit pulp (Muthai et al., 2017) and an increase in baobab pulp concentration resulted to increased iron levels in the products under study. On the other hand, zinc is an essential trace element that promotes enzymatic activity, DNA synthesis, immune system function and tissue growth and maintenance (Deshpande et al., 2013). Zinc is also responsible for the development of male reproductive organs (Kwamboka, 2018). Zinc in the formulated samples ranged from 0.74-1.19 mg/100g quite similar to results in a study reported by (Aluko, 2017). Baobab pulp has an outstanding content of Vitamin C (238mg/100g), an antioxidant with biochemical and molecular roles in the body (Habte and Krawinkel, 2017). Even though the Vitamin C increases with increase in baobab concentration, the Vitamin C content is lower. This is due to the fact that Vitamin C is heat labile and quantities may have been lost during pasteurization (Tembo, Holmes and Marshall, 2017). Supplementation of milk with baobab fruit pulp provides a formulation that is capable of supporting vulnerable communities by combating micronutrient deficiencies.

### 4.5.3 Microbiological characteristics of the baobab-based formulations

Spontaneous fermentation of milk is conducted by natural microflora in the environment consisting of yeasts, coliforms and LAB (Galli et al., 2022). Coliforms participate in this kind of fermentation and tend to multiply rapidly since the numbers of LAB are very low (Mwangi et al., 2016). Total coliforms were not detected in milk fermented with mesophilic cultures supplemented with baobab. This could be due to the fact that LAB used in fermentation secrete antimicrobial metabolites which include: bacteriocins, hydrogen peroxide and organic acids creating an unfavorable environment for coliforms and yeasts and molds which could be pathogenic or cause spoilage (Teshome, 2015). The formulated products were free from *Staphylococcus aureus* indicating that the samples were processed under hygienic conditions. LAB are the predominant microorganisms utilized as starter cultures in the manufacture of various fermented dairy products (Chen et al., 2017). They mostly comprise of either *Streptococcus theremophilus, Lactobacillus bulgaricus* (thermophilic), *Leuconostoc spp, Lactococcus acidophilus* (mesophilic) (Sanelier et al., 2019). When used during milk fermentation, LAB are capable of conferring preservation and detoxification effects to the product (Teshome, 2015). All formulated products met the minimum CFU/g of $10^8$ according to KEBS standards (KS 941:2018). LAB were also evident in spontaneously fermented milk samples containing baobab fruit pulp since they form part of the inherent mixed microflora in milk (Mwangi et al., 2016). LAB CFU/g increased with increase in baobab pulp concentration since the pulp possesses up to about 25% of soluble fiber capable of stimulating the proliferation and metabolic activities of the LAB (Abdalla, Muhammed and Mudawi, 2010). *Leuconostoc mesenteroides* characteristics include non-motility, inability to form spores, facultative anaerobe, gram positive and cocci in shape (Kaur et al., 2017). The microorganism has amenable health benefits and plays an important role in the fermentation of buttermilk, cheese, butter and kefir (Kaur et al., 2017; Dan et al., 2014). When applied in dairy products, this microorganism is capable of enhancing the product's textural and aromatic properties. This is achieved through secretion of EPS responsible for the viscous and creamy nature of fermented milk products (de Paula et al., 2015). Desirable aroma is achieved through metabolic production of organic acids and conversion of citrate in milk to diacetyl compounds (de Paula et al., 2015). According to De Paula et al. (2015), *Leuconostoc mesenteroides* has superior functional properties compared to other strains as well as high probiotic potential.

## 4.6 Conclusion

Incorporation of the baobab pulp as a food ingredient in various formulations increases the consumption and commercial value of the highly underutilized baobab fruit. When incorporated in cultured milk an increase in nutritional value was witnessed. The developed product exhibited acceptable physicochemical properties as well as a high microbial quality. Therefore, cultured milk supplemented with baobab pulp is a safe product that serves as a vehicle in the delivery of all essential nutrients to support vulnerable populations. In addition, the product possesses the qualities of a functional based drink due to the presence of probiotic bacteria (*Leuconostoc mesenteroides*) besides functional properties of baobab pulp (antioxidant, antidiabetic, anti-inflammatory and anticancer). Therefore, this product can offer health benefits beyond basic nutritional value thereby promoting the health and wellness of such populations living along baobab growing regions. Baobab based cultured milk when adopted for commercialization will have a greater market potential as consumer needs are changing to convenient and healthier versions.

# CHAPTER FIVE: CONSUMER ACCEPTABILITY AND SHELF STABILITY OF DEVELOPED CULTURED BOVINE MILK SUPPLEMENTED WITH BAOBAB FRUIT PULP

## 5.0 Abstract

Consumers demand food products that are consistently high in quality elicited by desirable sensory attributes (appearance, aroma, taste, and texture). Linking these sensory attributes to formulations and other process variables therefore facilitates manufacture of products with a high degree of consumer acceptability. Recently, incorporation of fruit and plant extracts in fermented dairy product is an emerging trend in the dairy industry driven by the need to improve the nutritional and sensory properties of cultured dairy products. Therefore, to determine the success of such developed products, consumer acceptability tests and conclusions drawn from the tests are considered critical. The objective of this study was to assess the consumer acceptability and shelf stability of a cultured bovine milk product supplemented with baobab fruit pulp at varying concentrations of 1.0%, 1.5%, 2.0%, 2.5% and 3.0% containing 0.001% and 0.0005% culture. A cross sectional study design involving 30 untrained panelists was used in the evaluation of sensory attributes of the formulations. Sensory attributes such as mouthfeel, taste, aroma, appearance, consistency and overall acceptability were rated against a five-point Hedonic scale. Data was subjected to Bonferroni test at $p<0.05$ for mean separation and further explored using principal component analysis to determine the formulations with high consumer acceptability. Formulations selected for shelf-life analysis comprised of milk fermented using 0.001% culture supplemented with 2.0% baobab and milk fermented with 0.0005% culture supplemented with 2.0% baobab and 3.0% baobab. Selection was based on overall acceptability scores and nutritional profile. Products were subjected to real time storage for 14days at 4 °C while packaged in three types of packaging materials (glass, plastic, and carton) and a longitudinal study design used in monitoring selected parameters. Parameters monitored included, total titratable acidity, vitamin C, aroma and yeasts and molds. Data from the samples was subjected to two-way ANOVA and means separated at $p \leq 0.05$ at 95% confidence interval. Findings indicated that the levels of vitamin C declined during storage from 10.5±0.05 and 8.91±0.05 to 5.91±0.05 and 4.96±0.05 mg/100g at $p<0.0001$, while variations were observed in total titratable acidity with the values ranging from 0.84±0.01 and 1.20±0.01g/100ml lactic acid. This study was necessary in determining how well consumers appreciate incorporation of baobab in cultured milk as well as the storage stability of formulations. This is important because consumers have a preference for healthier versions of foods that excite their senses. To validate the satisfactory maintenance of the sensory attributes from the point of manufacture to the point of production, storage stability studies are paramount. The study therefore concluded that, cultured milk supplemented with baobab fruit pulp is shelf stable and displays a high degree of acceptance among consumers.

**Key words**: baobab pulp, aroma, shelf life, packaging, acceptability

## 5.1 Introduction

In Sub-Saharan Africa, a variety of milk products are fermented spontaneously and consumed by local households to support their nourishment (Akinyemi et al., 2021). Similarly, in Kenya, a wide range of spontaneously fermented milk products have been reported among various communities in Kenya. Spontaneously fermented milk products are staple and are part of cultural heritage among diverse Kenyan communities (Nduko et al., 2016). Spontaneously fermented milk products are however inconsistent in quality and have demonstrated potential health hazards such as pathogenic bacteria and toxins, largely affiliated with poor processing and storage, which ultimately hastens contamination and spoilage of these products (Jans et al., 2017). Since spontaneously fermented milk products are widely consumed in Africa, their improvement is vital to ensure food safety and security (Moonga et al., 2022). Commercial processing of fermented milk at an industrial scale is an intervention that has been exploited to improve the quality and safety of such dairy products. This has been made possible through utilization of starter cultures, well managed and standardized production procedures to carry on the fermentation process in a controlled manner (Schutte, 2013). Milk is highly perishable in its normal state but upon addition of LAB, shelf life is extended, nutrients made more available and quality of milk improved (Rakhmanova et al., 2018). The use of LAB in fermentation results in products with a greater sensory appeal and an enhanced microbial safety due to the production of antimicrobial metabolites (Bayili et al., 2023).

Lactic acid bacteria perform biochemical conversions of the milk components resulting in release of flavor compounds (organic acids, alcohols, diacetyl compounds, aldehydes) (Chen et al., 2017). These compounds are responsible for the characteristic aroma and flavor evident in cultured milk. In addition, LAB secrete extracellular polysaccharides from their cell walls thereby enhancing the textural properties of mesophilic cultured milk (Behare et al., 2009).

Supplementation of fermented milk products with plant and fruit extracts has become an emerging trend. Inclusion of such extracts has an impact on the overall product composition, sensory characteristics, and shelf stability (Prestes et al., 2021). It is therefore important to carry out shelf life and consumer acceptability studies before releasing such formulated products to the market. This study therefore aimed at determining the consumer acceptability and shelf life of various formulations of milk fermented using different culture concentrations and enriched with various baobab pulp concentrations.

Shelf-life determination in foods is a critical aspect, since such studies ascertain the maintenance of certain quality aspects from the time of purchase to the point of consumption (Kilcast, 2011). Shelf life of food is defined as the period in which food products can be stored until when they become unsuitable for human consumption based on microbiological, nutritional, and sensory perspectives (Giménez et al., 2012). Shelf life of dairy products is dependent on factors such as pH, length of storage, packaging material, storage temperature and presence of spoilage microbiota (Odeyemi et al., 2020). Foods undergo various chemical changes during storageinvolving the loss of nutrients such as Vitamin C due to localized pH changes and hydrolytic reactions (Sanya, 2020). Yeasts and molds are the major microorganisms that initiate spoilage in fermented dairy products leading to off flavors and off odors (Odeyemi et al., 2020). Packaging of food using various materials is an intervention meant to protect food products against deteriorative factors besides containing the product (Singh et al., 2011). However, due to leakages or interaction of food with the packaging material, packaging can serve as a shelf life limiting factor (Brown and Williams, 2003). Previous studies have reported that upon addition of baobab pulp in formulations, shelf-life extension of products is observed as a result of bioactive components present (Abdelhai et al., 2019). Consumer acceptability is an important aspect to consider in the product profile as it is affected by various factors such as the source of protein, textural properties, fat and sugar content (Gupta et al., 2022). When baobab pulp is incorporated into yoghurt, it has been reported to have a positive effect on the texture and appearance of the product (Mădălina and Adriana, 2022) while increased baobab concentration has negative implications on the flavor component of yoghurt (Chipurura et al., 2014).

## 5.2 Materials and Methods

### 5.2.1 Cultured milk formulation

Formulation of the milk was done according to the method of Ndife et al. (2014) and Aluko, (2017) with slight modification as shown in **Figure 5.1**. The temperature of the milk was slightly raised to 30 °C after which a small portion of the milk was blended with the required amount of fruit pulp. The mixture was transferred back to the larger volume of milk and temperature raised to 85 °C to achieve pasteurization. The milk was rapidly cooled to 25 °C and mesophilic starter culture added to aid in fermentation. Incubation was carried out at ambient temperature for 16 to 18 hours after which the curd was broken, and the product cooled to 4 °C to stop further fermentation. The product was held at 4 °C until further analysis.

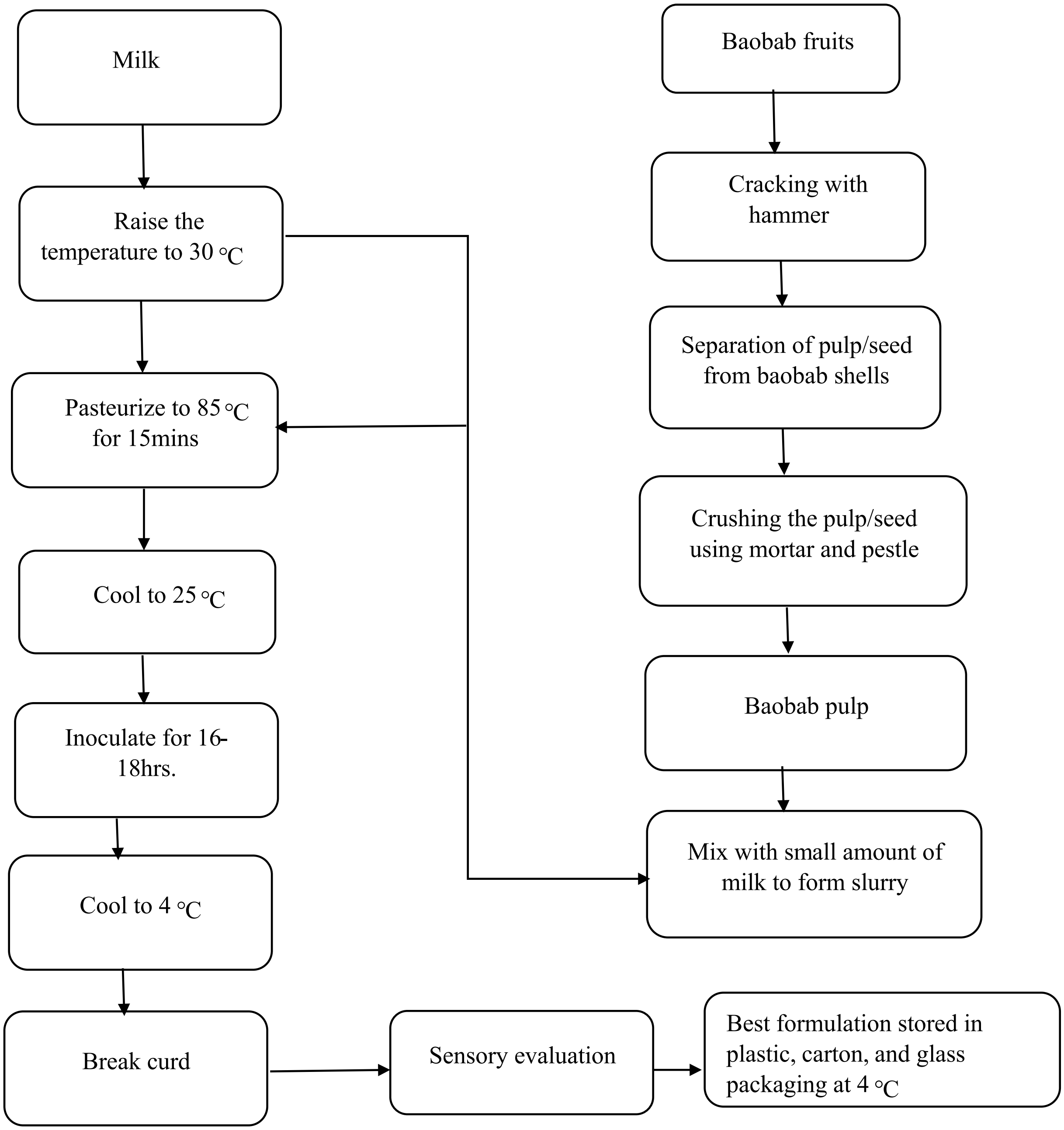


**Figure 5.1: Flow diagram of production of baobab based cultured milk**

### 5.2.2 Consumer acceptability

A cross sectional study design was used to determine the consumer acceptability of formulations using the method adapted from (Olusanya et al., 2020). Consumer acceptability test was carried out at The University of Nairobi sensory evaluation laboratory. The test involved 120 untrained panelists to whom three-digit coded products were uniformly served in sampling cups to avoid bias. The samples were presented in a randomized order and six attributes namely: mouthfeel, taste, aroma, appearance, consistency, and overall acceptability were assessed by each panelist. Rinse water was provided for expectoration in between tasting samples. A five-point hedonic scale ranging from 1 (Dislike extremely) to 5 (Like extremely) was used by panelists to score the product attributes.

### 5.2.3 Shelf-life determination

A longitudinal study design was used to determine shelf life of formulated samples. Real time monitoring was performed on nine formulated samples according to the method of Yimenu et al. (2019). After carrying out the initial analysis immediately after processing, the samples were subjected to cold storage at 4$^{o}$C while packaged in glass, carton, and plastic containers. The samples were stored for 14 days, and sampling done at intervals of two days. Parameters monitored throughout storage included Vitamin C, total titratable acidity, yeasts and molds and aroma.

### 5.2.4 Analytical methods

#### 5.2.4.1 Determination of Total Titratable Acidity

50ml of 0.1 M NaOH was filled in a burette and titrated against 10ml of the formulated sample with 3 drops of phenolphthalein indicator in a conical flask. Titration was done until when a soft pink color will be observed, and the corresponding burette reading was taken using the formulae:

Titratable acidity = titer ×blank ×normality of base ×ml equivalent of lactic acid/ Weight of the sample. Where the ml equivalent lactic acid was equal to 0.009 (AOAC, 2012).

#### 5.2.4.2 Determination of Vitamin C

Vitamin C levels in the formulations were determined using AOAC (2006) 967.21 method for determination of vitamin C and values expressed in mg$100^{-1}$.

#### 5.2.4.3 Determination of Yeasts and Molds

Yeasts and molds were determined according to ISO 215 27-2:2008 method. Briefly, serial dilutions were first made using sterile sodium chloride solution. Initially, 25mls of the formulated samples were added to 225 ml of sterile sodium chloride solution to form the first dilution. A series of six dilutions were then made by pipetting 1 ml of the first dilution into 9 ml of diluent. Pour plate technique was used in sample inoculation whereby 1ml of sample dispensed in a petri-dish was thoroughly mixed with 15-20mls of Potato Dextrose Agar acidified with 10% tartaric acid. All samples were inoculated in triplicate. Inoculated media was incubated at 25 ℃ for 3 to 5 days. Colonies were counted and expressed in $CFU^{-1}g$ as per the formula below:

$CFU^{-1}g$ = (Volume of dilute suspension × number of colonies) / (dilution factor)

### 5.3 Data Analysis

Data on both consumer acceptability and shelf stability was subjected to two -way ANOVA using STATA version 12 since there were two independent variables under study (type of packaging material and baobab concentrations). Means were separated using Bonferroni's method at $p \leq 0.05$. Data analysis was carried out at 95% confidence interval. Consumer acceptability data was further explored using Principal Component Analysis.

## 5.4 Results

### 5.4.1 Consumer acceptability of formulations

Statistical analysis revealed a statistical significance difference at $p \leq 0.05$ and at 95% confidence interval in various sensory attributes among the five formulations supplemented with baobab pulp. In the five formulations fermented using a culture concentration of 0.001%, high sensory scores were recorded in samples containing 2.0% baobab fruit pulp as shown in **Table 5.1**.

**Table 5.1: Sensory attributes of milk fermented with 0.001% culture supplemented with baobab pulp**

| Baobab pulp (%) | Mouthfeel | Taste | Aroma | Appearance | Consistency | Overall acceptability \|* |
|---|---|---|---|---|---|---|
| **Control** | 3.63± 1.07$^{b}$ | 3.00± 1.31$^{abcd}$ | 3.47± 1.17$^{ab}$ | 4.63 ± 0.23$^{e}$ | 4.07 ± 0.22$^{a}$ | 3.63 ± 0.19$^{a}$ |
| **1.0** | 3.33± 1.12$^{abcd}$ | 3.37± 1.27$^{ab}$ | 3.53± 0.97$^{ab}$ | 3.83 ± 0.23$^{de}$ | 3.47± 0.22$^{acd}$ | 3.53 ± 0.19$^{ad}$ |
| **1.5** | 2.83± 1.51$^{abcde}$ | 3.07± 1.44abc | 3.07± 1.46$^{abcd}$ | 3.20± 0.23$^{abcd}$ | 3.20± 0.22$^{abcd}$ | 3.23 ± 0.19$^{acd}$ |
| **2.0** | 3.63 ± 1.1$^{b}$ | 3.63± 1.13$^{a}$ | 3.83± 0.91$^{b}$ | 3.73± 0.23$^{cde}$ | 3.97 ± 0.22$^{a}$ | 3.67 ± 0.19$^{a}$ |
| **2.5** | 2.57± 1.04$^{abcde}$ | 2.73± 1.01$^{abcde}$ | 3.17± 1.02$^{abd}$ | 2.50 ± 0.23$^{ab}$ | 2.53± 0.22$^{bcde}$ | 2.77 ± 0.19$^{abcde}$ |
| **3.0** | 2.4± 1.04$^{ace}$ | 2.83± 1.21$^{abcde}$ | 3.00± 0.21$^{abcd}$ | 2.43 ± 0.23$^{ab}$ | 2.40± 0.22$^{bce}$ | 2.50 ± 0.19$^{bce}$ |
| **P value** | 0.0047 | 0.0465 | 0.0224 | 0.0003 | 0.0001 | 0.0006 |

Values are means ± SE. Means with different superscript letters along the rows are significantly different at $p<0.05$.

In the five samples fermented using a culture concentration of 0.005% and supplemented with different baobab concentrations, higher sensory scores were recorded in samples containing 1.5% baobab fruit pulp. However, the control samples were highly rated compared to the formulated samples as indicated in **Table 5.2**.

**Table 5.2: Sensory attributes of milk fermented with 0.0005% culture supplemented with baobab pulp**

| Baobab pulp (%) | Mouthfeel | Taste | Aroma | Appearance | Consistency | Overall acceptability * |
|---|---|---|---|---|---|---|
| **Control** | 3.63± 0.22$^{a}$ | 3± 0.22$^{abcd}$ | 3.47± 0.21$^{ab}$ | 4.63 ± 0.23$^{e}$ | 4.07 ± 1.17$^{a}$ | 3.63 ± 0.96$^{a}$ |
| **1.0** | 2.9± 0.22$^{abcd}$ | 3.0± 0.22$^{abcde}$ | 3.43± 0.21$^{ab}$ | 3.27± 0.23$^{acd}$ | 3.13± 1.20$^{abcd}$ | 3.10 ± 1.03$^{abcd}$ |
| **1.5** | 3.53± 0.22$^{ac}$ | 3.63± 0.22$^{a}$ | 3.73± 0.21$^{b}$ | 3.70± 0.23$^{cde}$ | 3.97 ± 1.22$^{a}$ | 3.70 ± 0.79$^{a}$ |
| **2.0** | 3.47± 0.22$^{ac}$ | 3.33± 0.22$^{ab}$ | 3.63± 0.21$^{ab}$ | 3.33± 0.23$^{acd}$ | 3.60 ± 1.10$^{ad}$ | 3.50 ± 0.82$^{ad}$ |
| **2.5** | 3.3± 0.22$^{abc}$ | 3.23± 0.22$^{abc}$ | 3.3± 0.21$^{abc}$ | 2.83± 0.23$^{abcd}$ | 3.07± 1.11$^{abcd}$ | 3.10 ± 0.92$^{abcd}$ |
| **3.0** | 3.17± 0.22$^{abc}$ | 3.00± 0.22$^{abcd}$ | 3.3± 0.21$^{abc}$ | 3.07± 0.23$^{abcd}$ | 3.20± 1.06$^{abcd}$ | 3.00 ± 1.08$^{abcd}$ |
| **P value** | 0.0047 | 0.0465 | 0.0224 | 0.0003 | 0.0001 | 0.0006 |

*Values are means ± SE. Means with different superscript letters along the rows are significantly different at $p<0.05$.

Compared to cultured formulations, the five spontaneously fermented formulations supplemented with baobab had lower sensory scores. Formulations containing 1.0% baobab had the lowest score on all sensory attributes as illustrated in **Table 5.3**.

**Table 5.3: Sensory attributes of spontaneously fermented milk supplemented with baobab pulp**

| **Baobabpulp (%)** | **Mouthfeel** | **Taste** | **Aroma** | **Appearance** | **Consistency** | **Overall acceptability *** |
|---|---|---|---|---|---|---|
| **1.0** | $2 \pm 1.08^{e}$ | $1.87 \pm 0.94^{e}$ | $2.10 \pm 1.21^{c}$ | $2.07 \pm 1.11^{b}$ | $1.93 \pm 1.14^{e}$ | $1.93 \pm 0.87^{e}$ |
| **1.5** | $3.07 \pm 1.31^{abcde}$ | $2.7 \pm 1.18^{abcde}$ | $3.13 \pm 1.17^{abcd}$ | $3.00 \pm 1.38^{abcd}$ | $3.27 \pm 1.34^{abcd}$ | $3.03 \pm 1.16^{abcd}$ |
| **2.0** | $2.5 \pm 1.33^{acde}$ | $2.30 \pm 1.34^{bcde}$ | $2.60 \pm 1.38^{acd}$ | $2.67 \pm 1.32^{abc}$ | $2.77 \pm 1.41^{bcde}$ | $2.53 \pm 1.22^{bce}$ |
| **2.5** | $2.23 \pm 1.19^{ae}$ | $1.93 \pm 1.17^{de}$ | $2.23 \pm 1.30^{cd}$ | $2.70 \pm 1.44^{abcd}$ | $2.23 \pm 1.17^{be}$ | $2.27 \pm 1.11^{be}$ |
| **3.0** | $2.27 \pm 1.41^{ae}$ | $2.13 \pm 1.25^{cde}$ | $2.63 \pm 1.33^{acd}$ | $2.53 \pm 1.20^{ab}$ | $2.97 \pm 1.50^{abcde}$ | $2.60 \pm 1.22^{bcde}$ |
| **P value** | 0.0047 | 0.0465 | 0.0224 | 0.0003 | 0.0001 | 0.0006 |

* Values are means ± SE. Means with different superscript letters along the rows are significantly different at $p<0.05$

### 5.4.2 Principal Component Analysis of formulations

Two principal components were generated i.e., pc1 and pc2 which accounted for 96% of the variation. Mouthfeel, taste, aroma, consistency, and overall acceptability had a strong loading on pc1 while appearance had a strong loading in pc2 as shown in **Table 5.4**.

**Table 5.4: Principal components (eigenvectors)**

| Variable | Comp 1 | Comp 2 |
|---|---|---|
| Mouthfeel | 0.4192 | -0.0012 |
| Taste | 0.3978 | -0.5538 |
| Aroma | 0.4102 | -0.4028 |
| Appearance | 0.3823 | 0.6649 |
| Consistency | 0.4119 | 0.2975 |
| Overall acceptability | 0.4265 | 0.0218 |

Regarding the principal component scores, WHO and HOB had the highest pc1 scores which implies that the two products had the highest rating in regard to Mouthfeel, taste, aroma, consistency and overall acceptability. Furthermore, PRE (control) had considerably high pc1 scores as well as the highest pc2 score (appearance) which implies that when considering all the sensory attributes PRE had the best rating as shown in **Figure 5.2**.

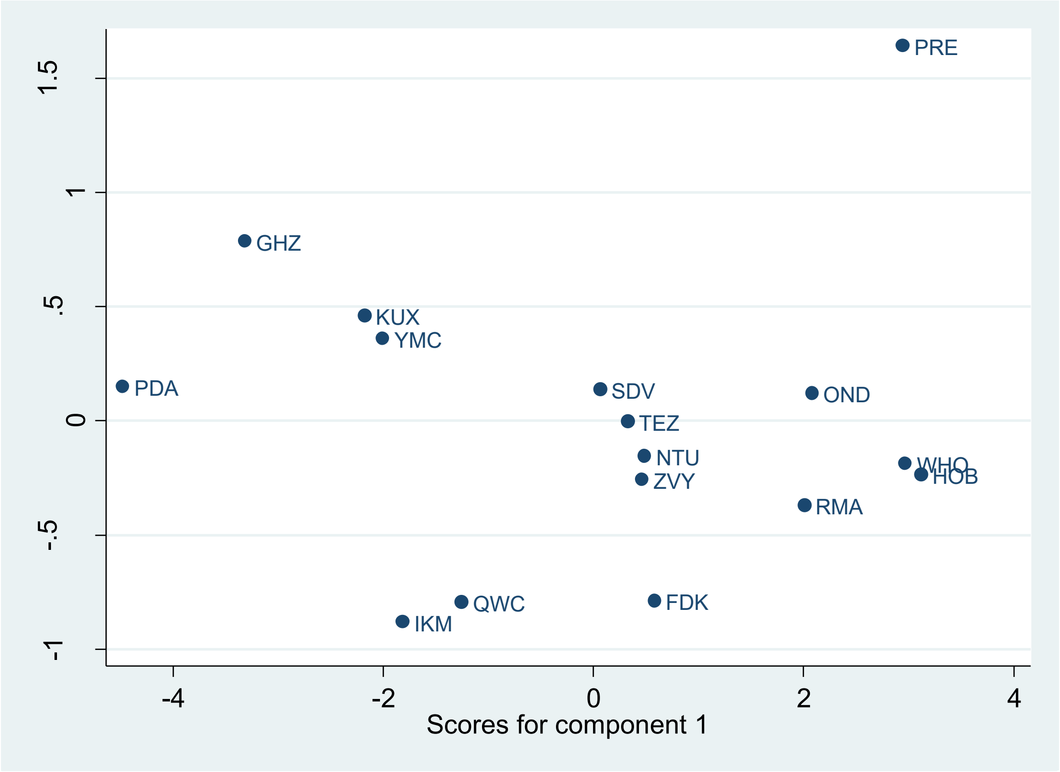


**Figure 5.2: Scores for cultured formulations supplemented with baobab fruit pulp.**

***Legend**

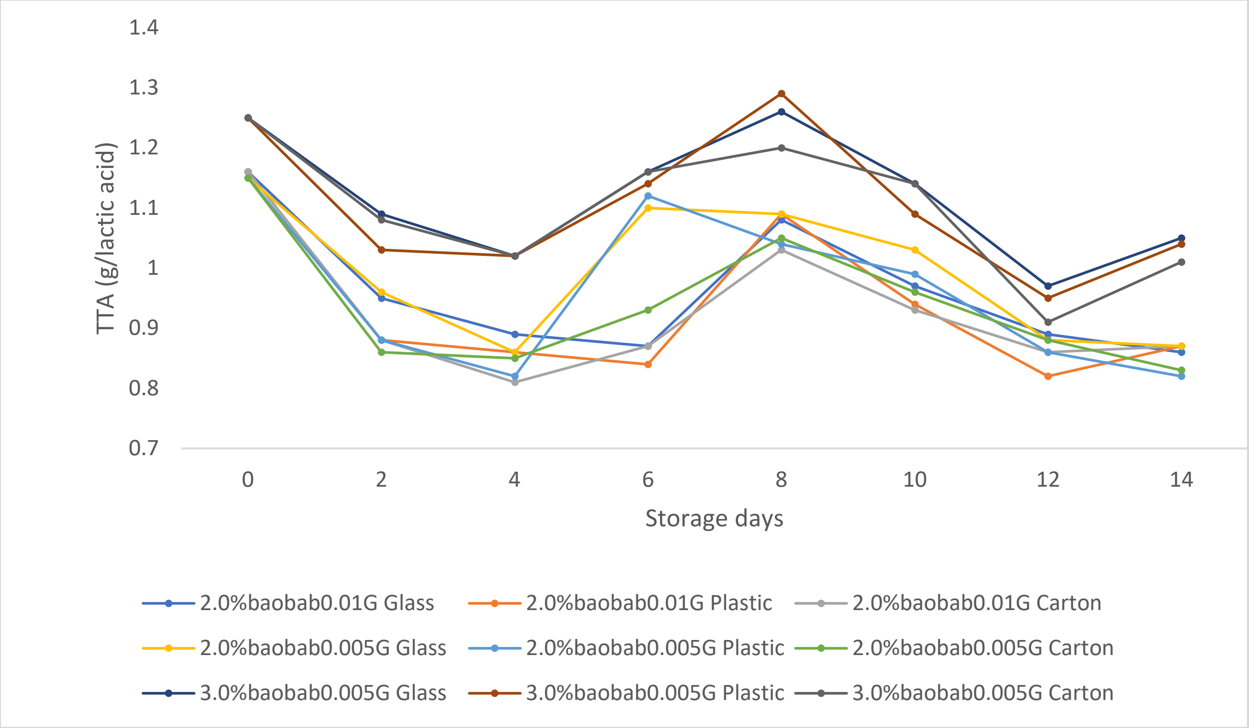
**PRE-**Control; **OND**- 1.0%baobab, 0.001% culture; **RMA**- 2% baobab, 0.0005% culture; **SDV**-1.5% baobab, spontaneous fermentation; **FDK**- 2.5% baobab, 0.0005% culture; **YMC**-2.0%baobab, spontaneous fermentation; **ZVY**- 3.0% baobab, 0.0005% culture; **KUX**-3.0%baobab, spontaneous fermentation; **NTU**- 1.0% baobab, 0.0005% culture; **GHZ**-2.5%baobab, spontaneous fermentation; **TEZ**- 1.5% baobab, 0.001% culture; **PDA**-1.0%baobab, spontaneous fermentation; **WHO**-1.5%baobab, 0.0005% culture; **HOB**-2.0%baobab, 0.001% culture

### 5.4.2 Shelf-life determination

#### 5.4.2.1 Effect of packaging and storage time on Total Titratable Acidity in cultured milk supplemented with baobab fruit pulp

The total titratable acidity of the selected formulations was significantly affected by the storage period and type of packaging material at $p<0.0001$ and 95% confidence interval. The total titratable acidity of samples fermented with 0.001% culture and supplemented with 2.0% baobab packaged using glass and plastic showed a decrease in total titratable acidity in day 2 (0.95 ± 0.01and 0.88 ±

0.01g/100ml lactic acid) followed by constant total titratable acidity in days 4 (0.89 ± 0.01 and 0.86 ± 0.01g/100ml lactic acid) and 6(0.87 ± 0.01 and 0.84 ± 0.01g/100ml lactic acid). At day 8 of storage a significant increase in total titratable acidity to 1.08 ± 0.01g/100ml lactic acid and 1.09 ± 0.01g/100ml lactic acid in fermented milk samples packaged using glass and plastic respectively, followed by a significant decline until day 12 (0.89 ± 0.01 g/100ml lactic acid and 0.82 ± 0.01g/100ml lactic acid) was observed at $p \leq 0.05$ and 95% confidence interval. Similarly, the total titratable acidity of fermented milk samples packaged in carton decreased significantly from day 0 up to day 4 from 1.16 ± 0.01g/100ml lactic acid to 0.81± 0.01g/100ml lactic acid followed by a significant increase to 1.03 ± 0.01g/100ml lactic acid on day 8. Additionally, the total titratable acidity of the fermented milk samples packaged using carton further significantly decreased with increase in storage time up to day 12 (0.86 ± 0.01g/100ml lactic acid). In milk fermented using a culture concentration of 0.0005% supplemented with 2.0% baobab pulp, total titratable acidity of the samples packaged using glass and plastic significantly decreased from 1.15 ± 0.01 g/100ml lactic acid with increase in storage up to day 4 to 0.86 ± 0.01 g/100ml lactic acid and 0.82 ± 0.01 g/100ml lactic acid respectively. This was then followed by an increase in day 6 and then a significant decline until day 12. Similarly, the total titratable acidity of the fermented milk samples packed in carton significantly decreased to 0.86 ± 0.01 g/100ml lactic acid with increase in storage time up to day 2 followed by a stagnation of total titratable acidity in day 4 then a significant increase up to day 8 and finally a significant decline until day 12 as shown in **Figure 5.3.** Milk fermented using a culture concentration of 0.0005% and supplemented with 3.0% baobab pulp recorded highest total titratable acidity of 1.15 ± 0.01 g/100ml lactic acid in day 0 and 1.20 ± 0.01 g/100ml lactic acid in day 8 in fermented milk samples packaged using glass, plastic and carton while the least values of 0.97 ± 0.01,0.95 ± 0.01and 0.91 ± 0.01 g/100ml lactic acid were observed at day 12 in fermented milk samples packed in glass, plastic and carton containers.



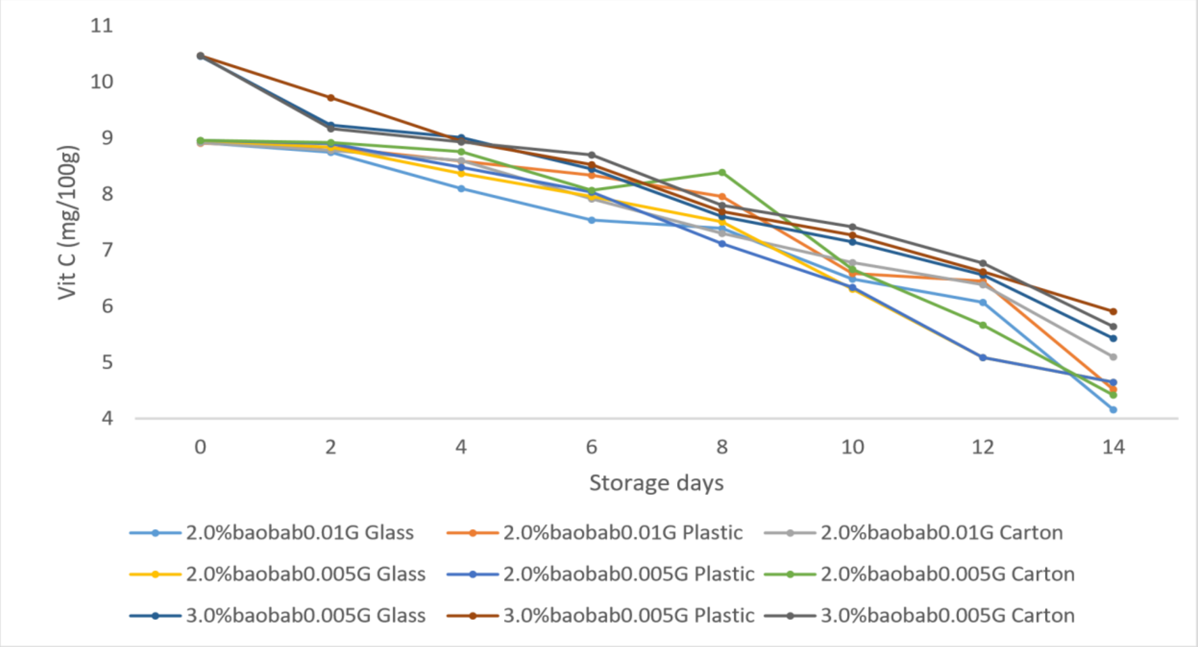
*0.001%-0.01 grams mesophilic LAB culture; 0.0005%- 0.05 grams mesophilic LAB culture; Percent values indicate rate of baobab fruit pulp addition

**Figure 5.3: Changes in total titratable acidity (g/100ml lactic acid) in cultured formulations supplemented with baobab during storage**

### 5.4.2.2 Effect of packaging and storage time on Vitamin C in in cultured milk supplemented with baobab pulp

The vitamin C content of the fermented milk samples supplemented with baobab fruit pulp was significantly affected by storage period and type of packaging material at $p<0.0001$ and 95% confidence interval. The highest vitamin C value in all formulations ranging from 10.50 ± 0.05 and 8.91 ± 0.05 mg/100g were observed at day 0. This was then followed by a significant decline until the 14th day of storage with values ranging from 5.91 ± 0.05 and 4.96 ± 0.05 mg/100g. Interestingly, in samples fermented using 0.001% culture and supplemented with 2.0% baobab fruit pulp, vitamin

C in samples packaged in plastic and carton stagnated up to day 4 followed by a significant decline up to day 14. In samples containing 2.0% baobab pulp fermented with a culture concentration of 0.0005% vitamin C levels decreased with increase in storage time with highest vitamin C content being recorded in samples packaged in carton 8.92 ± 0.05 mg/100g and 4.92 ± 0.05 mg/100g. Similarly, the vitamin C content in milk containing 3.0% baobab pulp fermented using a culture concentration of 0.0005% in samples packaged using glass, plastic and carton decreased with an increase in storage period with the highest values being observed at day 0 (10.46 ± 0.05 mg/100g, 10.50 ± 0.05 mg/100g and 10.47 ± 0.05 mg/100g respectively) and the least values being observed at day 14 (5.43 ± 0.05, 5.91 ± 0.05 and 5.64 ± 0.05 mg/100g respectively)of storage as shown in **Figure 5.4**.

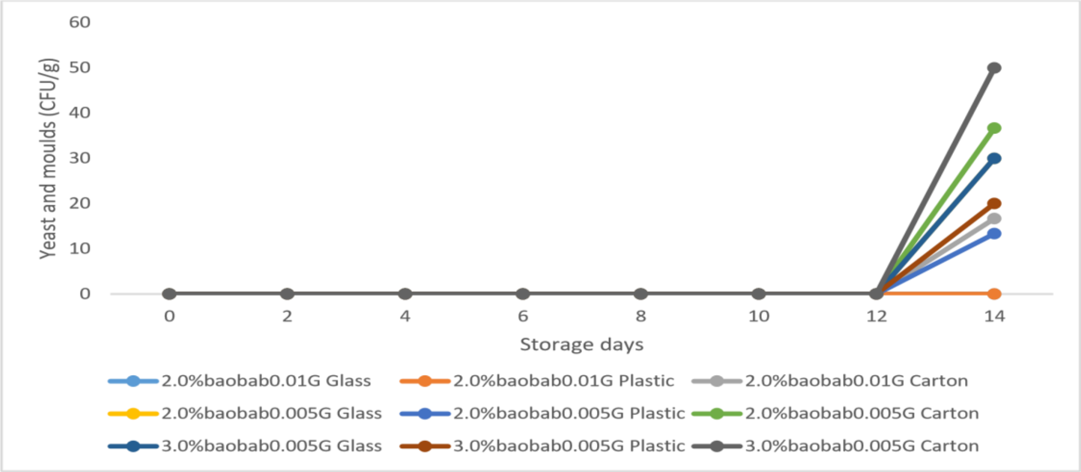


*0.001%-0.01 grams mesophilic LAB culture; 0.0005%- 0.05 g mesophilic LAB culture; Percent values indicate rate of baobab fruit pulp addition

**Figure 5.4: Changes in vitamin c levels (mg/100g) in cultured formulations supplemented with baobab during storage**

### 5.4.2.3 Effect of packaging and storage time on yeasts and molds development in cultured milk supplemented with baobab pulp

In samples containing 2.0% baobab pulp fermented using culture concentration of 0.001%, yeast and molds were not observed in fermented milk samples packaged using glass and plastic in the entire storage period. However, in samples packaged using carton tubs, yeast and molds were observed on the 14th day of storage. Similarly, in samples containing 2.0% baobab fermented with 0.0005% culture and packaged using glass, plastic and carton yeast and molds were not observed from day 0 to day 12 while at day 14 yeast and molds were observed with carton packaged samples recording the highest number of yeasts and molds. In 3.0% baobab enriched milk fermented with 0.0005% culture, yeast and molds were not observed from day 0 to day 12 in all samples in glass, carton and plastic packaging. However, at day 14 yeast and molds were observed, with samples packaged using carton recording the highest levels of yeast and molds while samples packaged using glass and plastic recording the least amounts as shown in **Figure 5.5**.

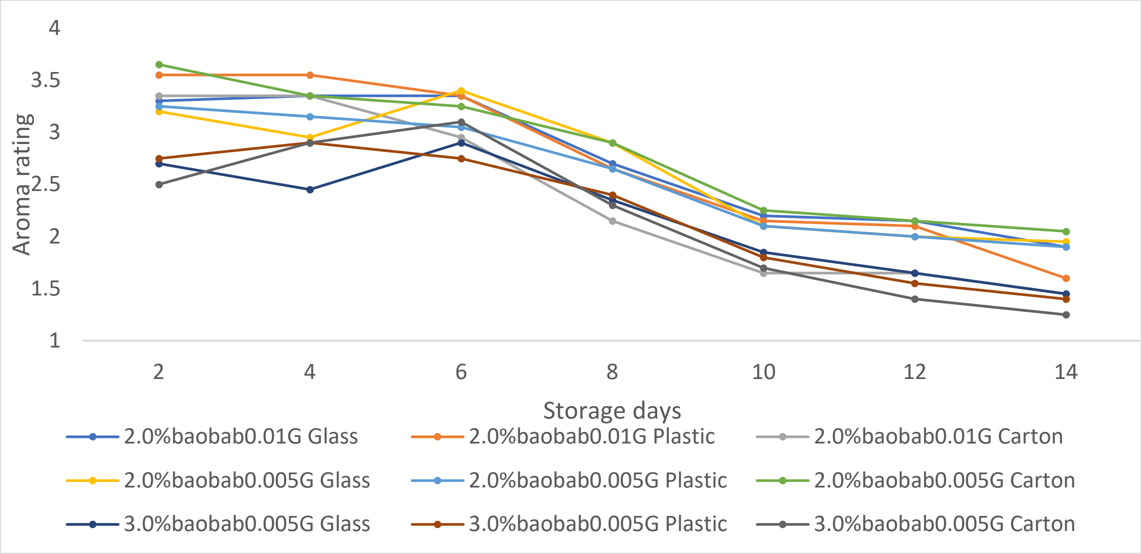


*0.001%-0.01 grams mesophilic LAB culture; 0.0005%- 0.05 grams mesophilic LAB culture; Percent values indicate rate of baobab fruit pulp addition

**Figure 5.5: Development of yeasts and molds in cultured formulations supplemented with baobab fruit pulp during storage**

#### 5.4.2.4 Effect of packaging and storage time on aroma in baobab pulp enriched cultured milk

Storage period and the type of packaging material had a significant effect on the aroma of cultured formulations supplemented with baobab fruit pulp at $p \leq 0.05$and 95% confidence interval. Highest aroma values were observed on the 2nd day of storage in milk containing 2.0% baobab and fermented using 0.001% and 0.05g culture packaged in plastic and carton respectively. Plastic PET bottle packaging is a common packaging product for dairy products since they have good oxygen and moisture barrier properties hence are able to preserve aroma (Barukčić et al., 2021).The least aroma was observed on the 14th day in samples containing 2.0% baobab pulp and 0.001% culture packaged in carton and in samples containing 2.0% baobab pulp and 0.0005% culture packaged in glass and plastic In samples containing 3.0% baobab pulp and 0.0005% culture, highest aroma scores were observed on the 6th day in samples packaged using carton while the least value was observed in day 14 in fermented milk samples packaged using carton as shown in **Figure 5.6**.



*0.001%-0.01 grams mesophilic LAB culture; 0.0005%- 0.05 grams mesophilic LAB culture; Percent values indicate rate of baobab fruit pulp addition

**Figure 5.6: Aroma changes in cultured formulations supplemented with baobab fruit pulp during storage**

## 5.5 Discussion

### 5.5.1 Consumer acceptability

Sensory characteristics often have a strong influence on the consumer perception of food products quality as well as overall consumer acceptability (Sharif et al., 2017). Sensory characteristics of a given food is crucial since this is what determines success of products in the market segment (Mihafu, Issa and Kamiyango, 2020). Baobab fruit pulp incorporation and varying culture concentration significantly influenced the sensory characteristics of the formulations. Baobab fruit pulp and varying culture concentration particularly affected the mouthfeel, taste, aroma, consistency and appearance. Mouthfeel plays a pivotal role in acceptability and is defined as the tactile properties perceived when a food or beverage is placed in the mouth until it is swallowed (Stokes et al., 2013). The high total solids and pectin content which imparts gelling characteristic in the milk may have resulted to higher scores in mouthfeel in 2.0% baobab enriched milk fermented with 0.001% baobab (Ndabikunze et al., 2011). However, further addition of baobab resulted to lower mouthfeel scores as a result of low water holding capacity resulting to a weaker gel due to aggregation of casein micelles and whey syneresis (Chipurura, et al., 2014). Compared to controlled fermentation, spontaneous fermentation results in inconsistencies in terms of texture, flavor, and aroma (Moslehishad et al., 2013) therefore recording low scores in the formulations. A similar study carried out by Valentina Mădălina et al. (2022), indicated that baobab fruit pulp at the rate of 2% in yoghurt boosts the sensory appeal of the product in relation to texture and appearance. Baobab fruit pulp concentration as well as the fermentation method had an influence on the taste of the formulations. This may be attributed to the slightly tart taste evident in the pulp due to the presence of organic acids in it such as tartaric acid, malic acid and citric acids (Oludara and Bamidele, 2019). Therefore, when applied in products in sufficient quantities it can impart a desirable taste. A study conducted by Chipurura et al. (2014), established that higher pulp concentrations in yoghurt result to an astringent taste this is due to increased levels of acidity brought about by the pulp and LAB culture. Higher scores for aroma were recorded in 2% baobab enriched milk fermented with culture concentration of 0.001% and in 1.5% baobab supplemented milk fermented with culture concentration of 0.0005%. This can be attributed to the evolution of the acetyl aldehyde and diacetyl compounds produced by LAB (Adelekan and Saleh, 2020). Baobab fruit pulp on the other hand contains volatile compounds such as organic acids, aromatics, aldehydes, ketones, and aliphatic hydrocarbons all of which contribute to desirable organoleptic characteristics (Baky et al., 2021). Regarding appearance, the control scored higher compared to formulated samples as panelists may not have been familiar with the off-white colour in cultured milk. This is because baobab pulp imparted a light brown to reddish brown color in the study samples due to the red fibres present in the pulp (Odoom, 2021). A study done by Adelekan and

Saleh, (2020) reported higher scores on appearance and overall acceptability when baobab is added to cultured milk at the rate of 1%. Scores for consistency in the formulations was lower than in the control since addition of baobab may have interrupted the gel matrix of the enriched samples (Aluko,2017). Compared to controlled fermentation, spontaneous fermentation results in inconsistencies in terms of texture, flavor, appearance, and aroma (Moslehishad et al., 2013) forming part of the reason for low scores in the spontaneously fermented formulations. Generally, the control scored better in all the sensory attributes compared to enriched samples. This may have been as a result of increased acidity, color alteration and texture changes as a result of baobab addition. However, 2.0% baobab enrichment and 0.001% culture and 1.5% baobab enrichment and 0.0005% culture scored higher in terms of overall acceptability. This further indicates that baobab and culture levels used during fermentation have an influence on consumer preference.

### 5.5.2 Shelf-life analysis

#### 5.5.2.1 Effect of packaging and storage time on Total titratable acidity in cultured milk supplemented with baobab fruit pulp

Total titratable acidity is the measure of all the total intrinsic acids present in a food and serves as a better predictor of the implications of these on the flavor component of foods compared to pH (Sadler and Murphy, 2010). In all the three best formulations, the total titratable acidity was significantly affected by packaging and storage time ($p<0.0001$). In the initial days of storage, the 4th or 6th day of storage, a decrease in the total titratable acidity was observed. This may be as a result of lactose is being hydrolysed, whey separation occurring consequently resulting to slow acid production (Aluko, 2017). Further increase in total titratable acidity could be due to the activity of the starter cultures on the available fermentable sugars present in baobab pulp (Wairimu et al., 2022). Additionally, baobab contains organic acids such as malic acid, succinic, ascorbic acid among others which would have influenced variations in total titratable acidity during storage (Kamatou et al., 2011). On the 14th day an increase in total titratable acidity may be attributed to presence and activity of yeasts and molds (Aluko, 2017; Larsonn,2009). Higher total titratable acidity values were recorded in glass and plastic packaging which could have been due to the overgrowth of LAB (Rasul et al., 2022). Post acidification in cultured milk products is a common phenomenon that occurs as a result of activity of LAB at low refrigeration temperatures of 4 °C (Sigdel et al., 2018).

#### 5.5.2.2 Effect of packaging and storage time on Vitamin C in cultured milk supplemented with baobab fruit pulp

Vitamin C is an important component in nutrition due to its antioxidant capacity (Essodolom et al., 2020). Vitamin C is critical in the healing of injuries, calcium absorption in the body and in cell development (Masamba and Mnadalira et al., 2013). Therefore, Vitamin C is utilized as an index of nutrient quality during processing and storage since research has previously shown that if Vitamin C is well retained, all the other nutrients are also retained (Abioye et al., 2013). However, Vitamin C is easily degraded either aerobically or anaerobically by factors such as oxygen, heat and light (Essodolom et al., 2020). In the present study, vitamin C was significantly affected by packaging material as well as storage time ($p<0.0001$). Vitamin C levels decreased with storage as a result of the low pH changes which promote the degradation of ascorbic acid into furfural, 2-furoesic acid and 3-hydroxy-2-pyrone (Znamirowska et al., 2021). Lower Vitamin C values were recorded in glass packaging since light penetration may have caused leaching out of the nutrient (Tamuno and Onyedikachi, 2015).

### 5.5.2.3 Effect of packaging and storage time on development of yeasts and molds in cultured milk supplemented with baobab fruit pulp

Yeasts and molds are considered to be frequent natural contaminants in fermented dairy products and also responsible for their spoilage (Nwagu and Amadi, 2014). Their occurrence in such kind of products could be as result of increased acidity with increased storage time as well as reduction of potential oxygen during fermentation (Sengupta et al., 2013). In all the test samples, yeasts and molds were observed on the 14th day of storage. These findings agree with a similar study conducted by Aluko, (2017) who also reported yeasts and molds development on the 14th day of storage in yoghurt fortified with baobab fruit pulp. Carton packaging material was not an ideal candidate for the keeping quality of the test samples due to high number of yeasts and molds counts. Carton packaging are permeable to gases and when there is lack of oxygen and carbon IV oxide balance proliferation of yeasts and molds occurs (Singh et al., 2012).

### 5.5.2.4 Effect of packaging and storage time on aroma in cultured milk supplemented with baobab fruit pulp.

Aroma compounds in cultured dairy products develop during the fermentation process (BeltránBarrientos et al., 2019). The fermentation process yields volatile bacterial metabolites which have an overall contribution to product aroma (Routray and Mishra, 2011). These volatile compounds are solely responsible for the characteristic aroma and play a pivotal role in the determination of product's sensory quality (Dan et al., 2018). In the current study, aroma of the test samples was significantly affected by type of packaging and storage time. Aroma scores declined with increase in storage duration with the least values being recorded with carton packaging in 3.0% baobab enriched, 0.0005% cultured milk and in 2.0% baobab enriched 0.001% cultured milk. Despite carton being environmentally friendly due to their biodegradability, limitations exist in their use in packaging acidified liquid dairy products. This is due to their high permeability to gases and moisture as well as their vulnerability to leakage (Karaman et al., 2015) all of which result into considerable losses in volatile compounds during storage. Plastic PET packaging is preferably used in the dairy industries to package liquid milk and fermented milk products due to their mechanical, gas barrier properties and less adverse effects on milk flavour (Barukčić et al., 2021). Interestingly, lower aroma scores were recorded using glass and plastic packaging in 2.0% baobab enriched and 0.0005% cultured milk. Culture concentrations used in this case were low, hence other volatiles present in the baobab pulp may have masked the characteristic aroma of the fermented milk (Chipurura et al., 2014). Active packaging technologies are a sustainable option in the extension of shelf life, enhancement and preservation of sensory properties this therefore involves coating packaging materials with antimicrobial compounds to suppress the growth of deteriorative microbes (Gogliettino et al., 2020). Further, to ensure survival of lactic acid bacteria which contribute to desirable aroma, laminates fitted with oxygen scavengers to favor the anaerobic lactic acid bacteria as well as innovative technologies such as microencapsulation of the LAB and ultrasonication of products (Abesinghe et al., 2020.

## 5.6 Conclusion

Enrichment of cultured milk with various baobab concentrations affected the appearance, aroma, consistency, mouthfeel, taste, and overall acceptability of the formulations. Milk fermented using a culture concentration of 0.001% and enriched with 2.0% baobab pulp was the most acceptable. This therefore indicates that; this product has a great potential of being adopted for commercialization. In addition to that, baobab enriched cultured milk has a high shelf life of up to 14 days and can be conveniently packed in either glass or plastic bottles.

# CHAPTER SIX: GENERAL CONCLUSIONS AND RECOMMENDATIONS

## 6.1 General Conclusions

From this research, considerable consumption of the baobab fruit pulp at household level exists but processing and value addition activities are carried out to a limited extent. This is an indication that the baobab tree is largely unexploited since it is largely regarded as children's food and monkey food causing its full potential to remain untapped. At household level the fruit is particularly utilized through its addition in porridge, milk and juices thereby contributing to dietary diversity of the rural poor (Stadlmayr et al., 2020)

Processing activities are done by few small-scale MSME's with the main role players being women. The major processed product is "*mabuyu* sweets" widely perceived as a snack for children. Processing of "*mabuyu* sweets" can be a lucrative venture according to Jäckering et al. (2019) whereby the sales of this commodity can accrue upto 40,000 KES alongside other economic activities. However, negative perception accounts for the lack of interest in consumption by the wider population and low profits derived from sales, despite nutritional benefits accompanying the pulp/seed sweets.

Several challenges encompass these MSME's making it impossible to seize market opportunities. This mainly involves the lack of proper processing set ups, lack of proper knowledge on the benefits of baobab products consumption and lack of market access. Poor market access by the fruit processors is the major problem faced in the sales and marketing of baobab products both in this study and a study conducted by Mwema et al. (2013).

Development of cultured bovine milk enriched with baobab fruit pulp, is a promising food that could enhance the utilization of baobab products. Most households were involved in spontaneous fermentation of milk using baobab fruit pulp and the developed product in this research is an upgraded version in terms of safety, nutrition, and shelf stability. The developed product has a high potential for commercialization and once adopted it can improve household incomes while consequently promoting better nutrition.

### 6.2 General recommendations

Research based organizations should create awareness on the nutritional benefits of baobab products- Dissemination of information on the nutritional profile of baobab products will promote incorporation of these products into the local diets for sustainable and healthier diets among the rural populations.For instance, sensitization on consumption of the baobab leaves owing to their nutritional value will lead to appreciation of the leaves as an alternative source of food and income when all other crops have failed and subsequently promoting food security.

The national government should promote domestication of the baobab tree-This involves natural conservation of the tree in their natural habitat and legal action taken against baobab tree felling. Further, selection, vegetative propagation of suitable varieties and establishing baobab tree nurseries should be necessitated in order to diversify farming systems and promote consumption of baobab leaves.

County governments should consider empowering community groups involved in small scale value addition – empowering the women associations involved in processing can serve as a major driver towards promoting the consumption, processing, and marketing of baobab products.This can be achieved through adequate training to improve their knowledge on baobab processing operations and capacity building through equipping small holders with sufficient resources necessary for production of high-quality products with a higher market value will ultimately result to better income.

Workshops facilitated by research organizations or non-governmental organizations should ensure the development of high-quality value-added baobab products- This will enhance utilization of baobab tree products and foster economic development through overcoming overreliance on existing traditionally processed products whose returns are meagre, and consumption associated with a particular group of people i.e., school going kids, poor people, or monkeys.

National and county governments should create an enabling environment for baobab value addition activities- This includes provision of credit services, access to the right markets, developing sustainable markets for baobab products, provision of certification for their products, market expansion for baobab products through creating linkages between baobab processors with domestic and international markets to ensure their active participation in the baobab value chains.

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# ANNEXES

## Annex1: Focus group discussion guide

1. Are you familiar with the baobab tree?
2. Which parts of the baobab tree do you utilize?
3. How do you use the parts of the baobab tree?
4. When do you use the parts of the baobab tree?
5. Have you been involved in any baobab processing?
6. What are the main products processed in this area from baobab?
7. What are the main methods of preparation/processing techniques for the main products derived from baobab?
8. Do you sell baobab processed products?
9. Which baobab product do you sell the most?
10. If yes in above, how much income is generated from the sale of processed baobab products?
11. What are the monthly/daily volumes of production?
12. What are the challenges experienced in baobab processing?
13. What do you think could be done to address the challenges?

## Annex 2: Key informant interview guide

Name of Key informant ……………

Enumerator's name …………

Key informant phone number……………………………

Date of interview……………………

Time…………………………………

Designation……………………

Place………………………….

1. How do you process baobab?
2. For how long have you been in baobab processing?
3. What are the capital requirements of processing baobab?
4. What volumes of processed baobab products are produced monthly/daily?
5. In a week/month, how many times do you do processing?
6. Do you believe that the above processing can be increased?
7. What are the main ingredients used in baobab processed products?
8. Are the raw materials readily available?
9. Can the raw materials be substituted?
10. How do you measure the ingredients used in processing of baobab-based products?
11. What challenges do you experience?

## Annex 3: Survey questionnaire for assessment of the current status of production, processing, utilization and marketing of baobab in Makueni county

County........................................................ GPS coordinates ………………………

Sub-county.................................................. Longitude...........................................

Ward........................................................... Latitude..............................................

Village........................................................ Altitude............................................

Name of Enumerator....................................

Enumerator Tel. no...................................

Name of Interviewee...................................... Date of Interview..................................

Interviewee Tel. no….....................................

I have accepted to take part in providing information on this work…………….....................

General introduction of the researcher. Topic introduction. Inform of intention to record

**<u>Section 1: Socio- demographic characteristics</u>**

1. Age in years: 1. 18-24 [ ] 2. 25-34 [ ] 3. 35-44 [ ] 4. 45 and above [ ]
2. Gender: 1. Male [ ] 2. Female [ ]
3. Marital status: 1. Married [ ] 2. Single [ ] 3.Divorced [ ] 4. Widowed [ ] 5. Separated [ ]
4. Level of education: 1. Primary [ ] 2. Secondary [ ] 3. Tertiary Education [ ] 4. No education [ ]

5. Do you have a family? 1. Yes [ ] 2. No [ ]

6. Household size and composition

| **Class** | **Male** | **Female** | **Total** |
|---|---|---|---|
| >18yrs. | | | |
| Adult (18-60) yrs. | | | |
| <60yrs. | | | |

## Section 2: Socio-economic Information

7. What is your average household income? 1. Less than 20000 ksh per month [ ] 2. 20000-30000 ksh per month [ ] 3. More than 30000 ksh per month [ ]
8. What are the three (3) main sources of your income throughout the year? 1.Crop farming [ ] 2. Salaried employee [ ] 3.Wages from piece works [ ] 4. Business [ ] 5.Tourism [ ]

   6. Mixed farming [ ] 7. Livestock keeping [ ] 8. Bee keeping [ ] 9. Fishing[ ] 10. Mining and Manufacturing [ ] 11. Baobab Farming [ ] 12. Others (specify)................

## Section 3: Production and Consumption patterns of Baobab

9. Do you know the baobab tree? 1. Yes [ ] 2. No [ ]
10. Do you have the baobab tree in your farm? 1. Yes [ ] 2. No [ ]
11. If yes how many baobab trees do you have in your farm?
12. If you do not own any baobab are you able to access it at all? 1. Yes [ ] 2. No [ ]
13. How are you able to access baobab if you do not own any? 1.Neighbourhood trees [ ] 2. Community tree [ ] 3. Others (specify)....................
14. Do you use baobab tree parts? 1. Yes [ ] 2. No [ ]
15. If yes in above, for what purpose do you use the baobab parts?1.Food [ ] 2.Nonfood[ ] 3. Both [ ]
16. Which parts of the baobab tree do you consume often? 1. Leaves [ ] 2. Fruit [ ] 3. Seeds [ ] 4. All parts [ ]

17. If you consume the fruit often, what is the main reason for consumption of baobab fruit/ why do you like baobab fruit? 1. Nutritional/ health benefits [ ] 2. Cultural food [ ] 3. Good taste [ ]
18. How many times do you consume the baobab fruit? 1. Rarely (once every month) [ ] 2. Sometime (one to three times a month) [ ] 3. About once a week [ ] 4. More than once per week (two to four times) [ ] 5. Every day (five to seven times a week) [ ]
19. How many people in your household consume baobab fruit? 1. All family members [ ] 2. Only children [ ] 3. Only adults [ ]
20. If not, why don't you consume the fruit? 1. Bitter [ ] 2. Hard to crack [ ] 3. Stringent taste [ ] 4. Considered as poor men food [ ] 5. Food taboos [ ] 6. Others [ ]
21. If you often use the leaves, please describe how you use them? 1. Substitute for other vegetables [ ] 2. Thickening soups [ ] 3. Livestock fodder [ ] 4. Softening coarse vegetables [ ] 5. Others (specify)…….
22. If you do not use leaves, please describe the reason why? 1.Bitter [ ] 2. Slimy [ ] 3. Considered as poor men food [ ] 4. Food taboos [ ] 5. Others (specify)………
23. If you use seeds, describe how you use the seeds after harvesting? 1. Thickening soups [ ] 2. Extract cooking oil [ ] 3. Roast [ ] 4. Ferment [ ] 5. Others (specify)………..
24. If you use baobab parts for nonfood purposes, describe how you use them? 1. Medicinal purposes [ ] 2. Commercial purposes [ ] 3. Cultural and religious purposes [ ] 4. Cosmetic purposes [ ] 5. Others (specify)………..

**Section 4: Processing of Baobab products**

25. Do you process baobab products? 1. Yes [ ] 2. No [ ]
26. Which part of the baobab tree do you use for processing mostly? 1. Leaves [ ] 2. Seeds [ ] 3. Fruits [ ] 4. Others (specify)…..
27. How do you process baobab fruit pulp after harvesting? 1. Local beer production [ ] 2. Jam production [ ] 3. Production of juice [ ] 4. Processing of 'Mabuyu' sweets [ ] 7. Production of wine [ ] 8. Freeze into sweetened ice [ ] 9. Production of spice and flavoring agent [ ] 10. Others (please specify)………..
28. How do you process the leaves after harvesting? 1. Process into leaf powder [ ] 2. Others

(specify)……..

29. How do you process the seeds after harvesting? 1. Extraction of cooking oil [ ] 2. Roast for use as coffee substitute [ ] 3. Roast to snack [ ] 4. Cosmetic products [ ] 5. Others (specify)

30. How important are the following sensory attributes, color, taste, appearance, mouthfeel and acceptability in baobab based processed products?

**Importance scale**

1. Of no importance
2. Of little importance
3. Important
4. Very important

| | **Importance** | | | | |
|---|---|---|---|---|---|
| **Sensory attributes** | **No** | **Li** | **Im** | **Vi** | **Response** |
| Colour | 1 | 2 | 3 | 4 | |
| Taste | 1 | 2 | 3 | 4 | |
| Mouthfeel | 1 | 2 | 3 | 4 | |
| Aroma | 1 | 2 | 3 | 4 | |
| Appearance | 1 | 2 | 3 | 4 | |

## Section 5: Marketing potential

31. Are you involved in income generation from baobab processed products? 1. Yes [ ] 2. No [ ]

32. How long have you been involved in the income generation from baobab processed products? 1. <5 yrs.[ ] 2. 5-9 yrs.[ ] 3. 10-20 yrs. [ ] 4. > 20yrs. [ ]

33. Which is the main reason for engaging in the sale of processed baobab products? 1. Generate a major source of income [ ] 2. Generate some supplementary income [ ] 3.

Others (specify)……….

34. How often do you sell baobab processed products? 1. Everyday [ ] 2. Once a week [ ] 3. 2-3 times a week [ ] 4. More than three times a week [ ]
35. Where do you sell the processed baobab products? 1. Shops [ ] 2. Streets [ ] 3. Restaurants and Hotels [ ] 4. Supermarkets [ ] 5. Others (specify)………
36. How has the demand been for processed baobab products over the years? 1. Increasing/ higher [ ] 2. Decreasing/ lower [ ] 3. Fluctuating [ ] 4. Has been the same/ not changed []
37. How important are the sales of baobab processed products to your overall income? 1. <20% [ ] 2. 20-39% [ ] 3. 40-59% [ ] 4. 60-79% [ ] 5. >80% [ ]
38. Who are the main buyers of the baobab processed products? 1.Individual customers [ ] 2. Retailers [ ] 3. Others (specify)……..
39. Are you always able to meet the market demands of the processed baobab products? 1. Yes [ ] 2. No [ ]
40. If not, what are the main reasons for not being able to meet the market demands for these baobab based products? 1. Financial constraints [ ] 2. Lack of adequate manpower [ ] 3. Transportation issues [ ] 4. Others (specify)……..
41. What is the average price per kg of whichever baobab processed product that you are actively involved in selling?
42. How do you determine the unit selling price of the baobab processed products? 1. Cost of raw materials [ ] 2. Prices are offered by the consumers [ ] 3. Others (specify)……
43. How much profit do you earn on average per month from the sale of baobab processed products? 1. Less than 5000kshs [ ] 2. 5000- 10000kshs [ ] 3. More than 10000kshs [ ]
44. With the profits generated from the sale of processed baobab products, how do they contribute to the needs of the household? 1. Buy food [ ] 2. Education [ ] 3. House rent [ ] 4. Healthcare [ ] 5. All the above [ ] 6. Others (specify)…….

45. Which are the capital developments that have been acquired from the sale of baobab products? 1. Buying land [ ] 2. Expanded business [ ] 3. Bought a vehicle [ ] 4. Built houses [ ] 5. Others (specify)……..
46. What are the potential buyers that you wish to target in future?1. Restaurants [ ] 2. Schools [ ] 3. Hospitals [ ] 4. Supermarkets [ ] 5. Others (specify)…….
47. If you do not make reasonable profits from the sale of processed baobab products, why then are you still engaging in the business? 1. Don't have any other skills [ ] 2. Don't have any other business ideas [ ] 3. Others (specify)……
48. Do you have an association for baobab processors in your area? 1. Yes [ ] 2. No [ ]
49. If yes to the above question, give the benefits of the association? 1. To share information on price or set price [ ] 2. To socialize [ ] 3.Credit services [ ] 4.Training [ ] 5.Savings services [ ] 6. Others (specify)………..
50. Which challenges do you face as a seller of baobab processed products? 1. Financial constraints [ ] 2. Few customers [ ] 3. Limited market space [ ] 4. Minimum returns [ ] 5. Others (specify)……..

**Annex 4: Consent Form**

**UNIVERSITY OF NAIROBI**
**Department of Plant Science and Crop Protection**
**ESSA Form: Focused Group Discussions ()/Field Survey ()/Key Informants () (Tick the relevant)**

**Acceptance form to participate and provide necessary information during Survey for assessment of the status of production, processing, utilization, and marketing of baobab in Makueni county under ESSA Project:**

**Name of Enumerator:** **ID.** **Mobile number:**

**Date:** **Signature………………………………………...**

| **Numerical No. eg1** | **Name of Farmer** | **ID** | **Age** | **Gender (F or M)** | **Signature (for Yes/acceptance)** |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
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| | | | | | |
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## Annex 5: Sensory Evaluation Score sheet

**Sensory evaluation score sheet. Score sheet number …………………………………………**

**Date of analysis ……/……/2022 Name/initials of analyst ……………………………………....**

You are provided with coded samples of cultured milk (*maziwa mala*). Please evaluate the samples presented to you for the following sensory attributes namely: **Mouthfeel**, **Taste**, **Appearance**, **Aroma**, **Consistency** and **Overall acceptability** using the Hedonic scale provided.

1. Dislike extremely
2. Dislike moderately
3. Neither like nor dislike
4. Like moderately
5. Like extremely

Score each attribute using the scale provided above and record the score of your response in the appropriate space on the grid provided below. Please give a general comment on the sensory properties of the samples at the end of the exercise.

| **Sample** | **Mouthfeel** | **Taste** | **Aroma** | **Appearance** | **Consistency** | **Overall acceptability** |
|---|---|---|---|---|---|---|
| OND | | | | | | |
| NTU | | | | | | |
| PDA | | | | | | |
| SDV | | | | | | |
| TEZ | | | | | | |
| WHO | | | | | | |
| IKM | | | | | | |
| KUX | | | | | | |
| ZVY | | | | | | |
| RMA | | | | | | |
| HOB | | | | | | |
| YMC | | | | | | |
| GHZ | | | | | | |
| FDK | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| QWC | | | | | | |
| PRE | | | | | | |

Comments.........................................................................................................................................
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## Annex 6: Sensory Evaluation Score sheet for Aroma

**Sensory evaluation score sheet.**

**Score sheet number ………………………………………**

**Date of analysis ……/……/2022**

**Name/initials of analyst …………………………………....**

You are provided with coded samples of cultured milk (*maziwa mala*). Please evaluate the samples presented to you for the following sensory attributes namely: **Aroma** using the Hedonic scale provided.

1. Dislike extremely
2. Dislike moderately
3. Neither like nor dislike
4. Like moderately
5. Like extremely

Score each attribute using the scale provided above and record the score of your response in the appropriate space on the grid provided below. Please give a general comment on the sensory properties of the samples at the end of the exercise.

| **Sample** | **Aroma** |
|---|---|
| PRT | |
| GLC | |
| BOH | |
| AMR | |
| DNG | |
| HNE | |
| YQF | |
| VIJ | |
| KQZ | |

Comments.......................................................................................................................................
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## Annex 7: *Leuconostoc mesenteroides* isolates and PCR bands.