ASSESSMENT OF THE SAFETY OF SELECTED LOCALLY PROCESSED BAOBAB PRODUCTS AND HACCP DEVELOPMENT FOR BAOBAB PULP VALUE CHAIN IN KENYA

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Assessment of the Safety of Selected Locally Processed Baobab Products and HACCP Development for Baobab Pulp Value Chain in Kenya

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

Signature……………………………… Date………………………………………

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This thesis has been submitted for examination with our approval as university supervisors.

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DEDICATION

I dedicate this work to my husband, my family, and my friends for their love, support, and encouragement.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

LIST OF ABBREVIATIONS/ACRONYMS

KEBS Kenya Bureau of Standards

EU European union

CFU Colony forming unit

TAC Total aerobic count

HACCP Hazard analysis critical control point

AOAC Association of Official Agricultural Chemists

IAC Integral Activity Capacity

USAID United States Agency for International Development

AFTER African Food Revisited by Research

BFCS Baobab Company of Senegal

EC European Commission

ICRAF International Centre for Research in Agroforestry

CCP Critical Control Point

OPRP Operational Prerequisite Program

CL Critical Limit

GMP Good Manufacturing Practices

GHP Good Hygiene Practices

SSOP Sanitation Standard Operating Procedure

PCA Plate Count Agar

PDA	Potato Dextrose Agar
VRBGA	Violet Red Bile Glucose Agar
ISO	International Organization for Standardization
LOD	Limit of Detection
RSD	Relative Standard Deviation
HPLC	High Performance Liquid Chromatography
RPM	Revolutions Per Minute
SE	Standard Error
EAC	East African Community
QA	Quality Assurance
FAO	Food and Agriculture Organization
WHO	World Health Organization
DON	Deoxynivalenol
FIFO	First In First Out

ABSTRACT

Demand for baobab fruits and baobab-derived foods has recently surged as a result of a growing ready market both locally and internationally, especially after both the European Union and the United Nations approved it as a new food ingredient and a functional food. However, in order to meet the growing demand, many farmers engage in rush fruit harvesting, and since there is a lack of knowledge regarding the handling of the baobab fruits, poor handling techniques like inadequate drying and unhygienic handling occur along the baobab value chain, which may not only result in fruits wastage through spoilage but also pose a food safety risk to consumers. It is against this backdrop that this research was conducted to investigate the microbial and aflatoxin contamination levels in ready-to-eat baobab products as well as develop a HACCP (Hazard Analysis Critical Control Point) plan for baobab pulp processors in Kenya. The study involved selected formal and informal processors in specific counties of Kenya. Processed baobab product samples were randomly collected from formal and informal processors and analyzed for the total aerobic count, *Enterobacteriaceae*, yeast and molds, ergosterol, aflatoxins, moisture, and water activity on wet basis. This was followed by the HACCP development study which was conducted at Vokenel Enterprises Ltd (Kibwezi, Kenya) from January to March 2021. The HACCP plan was developed using the seven principles laid out by Codex Alimentarius. Before commencing on the seven principles, HACCP training was completed to define the steps involved in developing and implementing HACCP for baobab pulp. The moisture and water activity of baobab pulp and candies from formal processors ranged between 7.73±0.33% - 23.47±0.09 % and 0.532±0.03 - 0.740±0.09 compared to those from informal processors which ranged from 10.50±0.18% - 23.47±0.62% and 0.532±0.01 - 0.751±0.04 respectively. The Kenya Bureau of Standards (KEBS) has set the microbial count limits of 1000, 100, and 10000 cfu/g for total aerobic bacteria, *Enterobacteriaceae*, and yeast and molds respectively. In this study, 33.3% of candies from informal processors were above the total aerobic count and *Enterobacteriaceae* limits, while 66.7% were above the set yeast and molds limit. Candies from the formal processors were all below the set limits. The baobab pulp from the formal processors had 12, 12.5, and 25% of samples exceeding the total aerobic counts, *Enterobacteriaceae* and yeast and molds set limits. In the informal sector, 75% of the samples were above the total aerobic count and the *Enterobacteriaceae* limits. Baobab pulp from informal processors had significantly higher ($p<0.0001$, $p<0.0001$) *Enterobacteriaceae*, yeast, and molds counts (3.1±0.70 $\log_{10}$ CFU/g and 5.3±0.11 $\log_{10}$ CFU/g) than those from formal processors (0.7±0.29 $\log_{10}$ CFU/g and 3.1±0.38 $\log_{10}$ CFU/g) respectively. Candies from informal processors had *Enterobacteriaceae* contamination (1.8±0.56 $\log_{10}$ CFU/g), however, no *Enterobacteriaceae* counts were detected in candies from the formal processors. The ergosterol content in the baobab product samples ranged from 0.46±0.01 to 1.92±0.05 mg/100g while the total aflatoxin content ranged from 12.79±0.02 to 23.15±0.01 × 10^3 μg/kg respectively. All the samples contaminated with aflatoxin were above the set limits of 10 μg/kg for total aflatoxins. Fungal and aflatoxin contamination was detected in 25%, 5%, and 5% of the pulp from formal processors, informal processors, and candies from informal processors respectively. Microbial analysis of swab samples obtained from hands, surfaces, equipment, and storage materials was done before and after HACCP training and development. Changes such as the wearing of aprons and hairnets were observed throughout the manufacturing process after the HACCP training resulting in a significant ($P<0.05$) reduction of the microbial load. One critical control point was identified at the reception with the hazard of focus being aflatoxin contamination. The complete HACCP plan and the required pre-requisite programs were developed to deal with the identified hazards. HACCP training proved to be the foundation of effective HACCP development. Without HACCP implementation, achieving the objective of consistent, safe food production would be far more difficult. Products sourced from the Informal processors' products recorded the highest microbial contamination in terms of *Enterobacteriaceae* and TAC, which could be associated with unhygienic handling during processing. The results of this study incriminate the unhygienic postharvest practices along the baobab value chain as the source of contamination of the baobab pulp and candies. The food safety risks could be effectively mitigated by initiating training along the baobab value chain on; good hygiene practices, good manufacturing practices, hazard analysis critical control points as well as appropriate postharvest handling of baobab fruit and its pulp.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Kenya still battles with food and nutrition security issues with 2.6 million people reported being severely food insecure (USAID, 2021). One way to alleviate this could be the use of wild edible plants and their derived food products. These indigenous fruits are locally available and are often packed with micronutrients that can be used in food fortification (Stadlmayr et al., 2013). Baobab (*Adansonia digitata*) is an indigenous tree that grows in marginal regions of sub-Saharan Africa. Its fruit pulp is mostly used as a food ingredient in Africa whereas in the EU and America it is used as a dietary supplement (AFTER, 2011). The fruit pulp has been used locally to formulate several products which include; candies, ice cream, and juices among others. The baobab leaves are equally nutritious and are utilized locally in making vegetable dishes (Jäckering et al., 2019).

Baobab candies and pulp are ready-to-eat snacks processed from baobab fruit mostly consumed in several sub-Saharan African countries (Stadlmayr et al., 2013). The baobab fruit pulp is naturally dried and is rich in vitamin C, calcium, and antioxidants. In vitro studies have also indicated that it aids in the uptake of iron, which could be linked to the high vitamin C and other organic acids (Charlotte et al., 2020). The pulp has prebiotics and inflammation-reduction functions and is hence categorized as a functional food (United Nations, 2005). The European Commission and the US Food and Drug Administration classified baobab as a novel and functional food in the year 2008 contributing to an increase in baobab import volumes due to a significant increase in demand (Buchmann et al., 2010). The rise in baobab imports has led to an increase in demand from African countries with high baobab tree populations, including Kenya, Sudan, Malawi, and Ghana (Buchmann et al., 2010; Darr et al., 2016).

Baobab tree populations are found abundantly traversing the Kenyan counties of Tharaka Nithi, Kitui, Makueni, Kilifi, Lamu, Kwale, and Taita Taveta. These are semi-arid lands that are hotspots for food and nutritional insecurity, as well as high poverty levels. Their livelihoods are primarily dependent on subsistence farming, but due to inadequate and unreliable rainfall, harvests from farming activities are poor and relief food is a common feature (Momanyi et al., 2019). In Kenya, the baobab tree is considered a high-priority food tree for future domestication due to its multiple uses (Stadlmayr et al., 2013). In addition, the baobab value chain has a high potential for product development, value addition, and economic development for the people who inhabit the areas where baobab is native (Darr et al., 2016). So far, baobab is largely harvested from wild trees, and domestication of the species may increase the quantity and quality of baobab fruit pulp for domestic and export markets (Buchmann et al., 2010). Baobab farmers in the fore mentioned countries are engaged in trading in baobab pulp albeit with challenges along the baobab value chain. These include poor harvesting practices and drying, as well as poor post-harvest handling leading to microbial contamination and overall quality loss.

The baobab fruit dries naturally, falling off the tree when completely mature and fully dried with a moisture content of about 11% (Chadare et al., 2009). Due to the recent high demand for baobab, farmers and middlemen have resorted to premature harvesting before the fruits are fully dried (Kaboré et al., 2011). Once the baobab pulp has been extracted from the fruit, it is generally subjected to sun drying to ensure an acceptable moisture content. Sun drying is a slow process and is often carried out in open, making it susceptible to contamination (Trucksess & Scott, 2008). Some of the baobab products derived from baobab pulp are mainly consumed in raw form, without being subjected to any thermal treatments. The final moisture content and hygienic handling conditions during processing determine the safety and degree of deterioration of these products (Bourdoux et al., 2016).

Some of the handling practices of baobab pulp may also expose the pulp to extrinsic environmental factors such as high humidity. The pulp is hygroscopic and is thus susceptible to moisture absorption leading to mold growth and subsequent spoilage, and/or contamination by mycotoxins rendering the commodity unsafe for consumption (Bourdoux et al., 2016). *Aspergillus parasiticus* and *Aspergillus. flavus* L strains were recovered from baobab fruit obtained from the market in Zambia, though the average aflatoxin concentrations in the baobab were below maximum allowable levels in food (Kachapulula et al., 2019). However, from the study, it was not clear whether the baobab fruits were cracked in the market or in the laboratory to obtain the pulp. There is a high likelihood of baobab contamination along the baobab value chain considering the current post-harvest handling practices. However, there is limited knowledge on the safety of the widely available ready-to-eat processed baobab products in Kenya. So far, the studies that have been carried out on baobab focus more on the nutritional aspect, utilization as well as trade with limited reporting on product safety. This study aimed at investigating the microbial and aflatoxin contamination levels in ready-to-eat baobab products from selected formal and informal processors in specific counties of Kenya and developing a HACCP plan for baobab pulp processors in Kenya.

1.2 Problem Statement

The baobab fruit dehydrates naturally as it ages, falling off the tree when completely mature and fully dried with a moisture content of about 11% (Chadare et al., 2009). However, the increase in demand for baobab has stimulated the need to harvest baobab fruits before they fully attain adequate dryness. The downside of this act is that it could lead to the provision of a suitable environment for the growth of yeast and molds due to elevated moisture levels. This necessitates drying, which is done by the majority of farmers in farms and aggregation centers who are unfamiliar with standard hygiene practices along the value chain. As a consequence, fruits are dried in the open, exposing them to dust, insects, and animals which could serve as carriers of microbes. Poor post-harvest handling techniques of baobab are reported as one of the main contributors to postharvest losses and/or reduced quality of these products (Mumanyi Dorah, 2019).

In the export market, for instance, in the EU market, it is a requirement for baobab products to meet the desired safety standards. This requires the determination of the raw material quality to ensure that the requirements for this market segment are met. Exporters of baobab products should, for instance, provide analytical results for microbial contaminants including mycotoxins, *Staphylococcus aureus*, *Salmonella*, *Enterobacteriaceae*, and *Enterococci* and ensure that they meet the required regulatory limits (phytotrade, 2016). However, in Kenya, there is a lack of published data on the microbial quality of locally processed baobab products to show the safety of these products. Furthermore, since most local processors go into the baobab production sector without being trained in good manufacturing practices, there is a lack of awareness among actors throughout the baobab value chain on the proper handling of baobab fruits. This has led to concerns about safety and particularly microbial safety. Baobab candy processing has dominated the market in Mombasa, Kilifi, Nairobi, and Kitui. However, since they are not licensed by the Kenya Bureau of Standards, the processing is done arbitrarily, with no record of how it is done, and the goods are sold in local markets without a standard label.

1.3 Justification

Baobab trees are found abundantly in the counties of Kitui, Kilifi, Kwale, Taita Taveta, Makueni, Tharaka Nithi, and Lamu. These are poverty-stricken areas with high food and nutrient insecurity. They generally rely on subsistence farming for a living, although harvests of staple foods are poor due to erratic rainfall (Mumanyi Dorah, 2019). The upgrading of the baobab value chain brought about by the development of the HACCP plan in this study may lead to the recognition that the baobab can serve as a financial safety net and a remedy for food insecurity in these areas. Additionally, it can result in food nutrition security. This is because in vitro studies showed that baobab fruit pulp increased the bio-accessibility from cereals, likely as a result of the fruit's high vitamin C and other organic acid contents. This suggests that consuming baobab pulp may help populations most at risk for iron deficiency increase their non-heme iron absorption (Charlotte et al., 2020).

This study will shed light on the safety of locally processed baobab products. This will help inform the baobab pulp and candies consumers to make informed decisions while doing their purchases. Given that HACCP is one of the safety management systems that is being promoted in Kenya, it will also give the companies processing baobab pulp an opportunity to adhere to the rules and regulations set forth by the government. This study will also be providing a great opportunity for the baobab processors to grow the local market and the international market by developing a HACCP plan applicable to the baobab pulp value chain in Kenya. Marketing safe baobab products is key in the increasing acceptance of these products in international markets for better sales and producers' livelihood. Such sales will in turn improve the income and livelihoods of most local processors.

1.4 Objectives

1.4.1 Main Objective

To determine the safety of selected locally processed baobab products and develop a HACCP plan for the baobab pulp value chain in Kenya

1.4.2 Specific Objectives

i. To determine the microbial quality of selected locally processed baobab products from formal and informal processors in Kenya
ii. To determine the aflatoxin content of selected locally processed baobab products from formal and informal processors in Kenya
iii. To develop a HACCP plan for microbial safety of baobab pulp along the value chain

1.5 Hypothesis

i. There is no significant difference in microbial quality between baobab products from formal and informal processors in Kenya
ii. There is no significant difference in the aflatoxin levels between baobab products from formal and informal processors in Kenya

iii. A HACCP plan does not assure microbial safety of the baobab pulp along the value chain

1.6 Significance of the study

The significance of this study is to shed light on the safety of locally processed baobab products. The study will provide knowledge on the handling of baobab fruits during processing and highlight the sources of contamination in the formal and informal industries. The study will be providing a great opportunity for the baobab processors to grow the local market and the international market by developing a HACCP plan applicable to the baobab pulp value chain in Kenya. Marketing safe baobab products is key in the increasing acceptance of these products in international markets leading to improved income from the sales and producers' livelihood. The development of the HACCP plan also brings about the upgrading of the baobab value chain.

1.7 Scope of study

The study explored the microbial quality and aflatoxin contamination of the locally processed baobab products (i.e., candies and pulp) as well as the HACCP development for baobab pulp processors in Kenya.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

2.1 Baobab tree description

The baobab tree (*Adansonia digitata* L) is also known as the upside-down or monkey-bread tree. *Adansonia* belongs to the family *Bombacacea* and is categorized into two varieties in Africa: tetraploid, which is a lowland baobab, and diploid, which is a hill baobab. The tree is of massive size, approximately 18-25m high with a smooth bark of greyish-brown, reddish-brown, and purplish-grey color. The baobab grows in drier areas of sub-Saharan Africa, which are often associated with food and nutrition insecurity as well as socioeconomic deprivation (Buchmann et al., 2010). Among the African countries where baobab can be found are Benin, Burkina Faso, Nigeria, Tanzania, Kenya, Malawi, and Mali (Namratha V & Sahithi P, 2015).

The baobab fruit pulp has gained a lot of interest in Europe and North America where it is marketed as a super fruit because of its high nutritional profile (Baobab Fruit Company Senegal, 2010). In response to the increase in demand, there is market growth for baobab fruits in Kenya and the other aforementioned African countries. Baobab has proved to be a source of revenue particularly for women and youth and a solution to food insecurity in rural areas. Farmers, collectors, wholesalers, processors, and retailers are the main actors of the Kenya baobab value chain where 72% are female (Kaimba, 2020).

2.2 Traditional baobab utilization in Africa

While the baobab has sparked a lot of curiosity in the present times, it has been used in several ways in the past. Almost all parts of the baobab tree are used as a food source. The baobab fruit pulp is consumed raw in Kenya, and for its sour taste, it is combined with milk or used to spice porridge (Buchmann et al., 2010). Gruel and sourdough are also made from baobab pulp combined with cereals (Namratha V & Sahithi P, 2015). The sourdough is made from baobab pulp that has been fermented by soaking it in water and then adding cereal flour (maize, sorghum, or millet) (Namratha V & Sahithi P, 2015). In western Sudan and Senegal, baobab pulp is used for medicinal purposes as anti-infectious Phyto-therapies (United Nations., 2005). In Kenya and Tanzania, the baobab fruit shells are used as a source of fuel and as water dippers. The ash obtained from the burning of the shells is used to disinfect wounds, while the smoke generated during the combustion of the baobab shells is used as an insect repellant (Van Damme, 2015). Baobab seeds are eaten whole or dried and ground into a powder for use as a thickener in stews and soups. Furthermore, the seeds are roasted and ground into a paste and used as soup thickeners (Almustafa, 2003).

In the coastal region of Kenya, young baobab leaves are consumed as a vegetable. The leaves are also dried and used as a thickening ingredient in dishes and sauce preparation. Baobab leaves and beans are also mixed to make a salad called "Afos" in western Sudan (Almustafa, 2003). Ropes and baskets are also made from the bark of the tree for Commercial purposes (Namratha V & Sahithi P, 2015). Baobab roots have been used to make potash solution, a food ingredient made from the ash left over after the roots have been burned. The roots are also cooked and consumed in West Africa, particularly during times of food scarcity (Van Damme, 2015).

2.3 Global baobab utilization

The EU and USA have approved baobab fruit pulp as a novel food ingredient, resulting in increased marketing opportunities for baobab (Ireland, 2008). Baobab pulp is within the novel food regulation (EC) no 258/97. The Baobab Fruit Company of Senegal (BFCS) has outlined various product formulations derived from the fruit pulp, including fortified yogurt with prebiotic fibers, fortified yogurt with probiotic fibers, bread, cakes, bars and biscuits, ice creams smoothies, and health/functional foods. Several products derived from baobab pulp have also been developed in Kenya, Malawi, and western Sudan, including juices, jelly, porridge, candy, oil, and craft products (phytotrade, 2016) Table 2.1. The baobab fruit market in the EU has been segmented into three categories: food and beverage, botanical remedies and nutraceuticals, and natural cosmetics. In the food and beverage sector, it is considered the product class of rare edible dried fruit (United Nations., 2005). It is also often used as an ingredient in breakfast cereals like cereal bars, granola, and crunches. Due to its mealy consistency, other products such as ice creams have been made.

Table 2.1: Uses of baobab fruits, Leaves, and Bark

Fruit Part	Categories	Use
Baobab fruits	Fruit pulp	Drinks and beverages, confectionery
	Pulp on seed	Candies
	Seed	Oil,
	Seed cake	Animal feed, fertilizer
	Fruit shell	Briquettes &pellets, Soil conditioner
	Fibers	Beverage
Leaves	Leaves	Food, medicine
Bark	Fibers	Handicraft

Source (Meinhold, 2021)

Most beverages derived from pulp, such as juices, probiotic yogurt, and smoothies, have been shown to have unique health benefits and are thus referred to as functional drinks (United Nations., 2005). The baobab pulp has a wide demand in botanical remedies and nutraceuticals as well due to its anti-inflammatory, antipyretic, and anti-diarrheic properties (Almustafa Khalid Abdelrahim Abdelgadir, 2003). In France, the baobab cosmetic industry now accounts for 5% of all cosmetics, while in the UK and Spain it accounts for 5.6% (United Nations., 2005).

2.4 Baobab production and utilization in Kenya

Kenya has a relatively high density of baobab trees with a mean stem density of 0.285 stems/ha in the coastal region and 0.429 stems/ha in the lower Eastern region. The baobab tree produces between 200 to 225 fruits per tree (Orina et al., 2021). The productivity differs with the geographical location of the tree. The growing demand for the baobab fruit pulp on local and worldwide markets may constitute a threat to the natural resource base since baobab is only harvested from wild trees, and researchers have detected a shortage of juvenile baobabs, signaling a probable reduction of natural stands (Van Damme, 2015). In Kenya however, 39% of the baobab tree population are juvenile baobab strands and therefore there is no concern about the natural resources being depleted (Orina et al., 2021).

Baobab trade has become a key income generation in the rural areas and the urban regions of Kenya. Kitui county has the highest number of baobab farmers, followed by Kilifi and Makueni counties (Jäckering et al., 2019; Kaimba, 2020). Baobab farmers are now engaged in trading; where after harvesting the fruits they crack them open and pack the seeds in sacks or package them without cracking. The choice of whether to crack them or not before selling is solely dependent on the buyers' preference. Assemblers, rural wholesalers, and urban wholesalers are some of the marketing channels available to baobab farmers. Farmers sell their fruits to brokers/assemblers on the farm to avoid the labor, transport, and packaging costs associated with selling to wholesalers in urban centers. A kilogram of cracked baobab fruits costs 10 Kenya shillings at the farm (Kaimba, 2020). The major urban towns where the cracked baobab fruits are sold in bulk are Mombasa (Zamzam stores), Nairobi (Mwanga stores and Khalif stores) (Kaimba, 2020). These stores are the main suppliers of baobab processors in cities. In the event of a baobab shortage in Kenya, these stores import baobab from Tanzania to ensure a steady supply of to the processors (Kiprotich et al., 2019).

Baobab processing in the rural areas of Kitui, Kibwezi, and Kilifi, as well as other parts where baobab grows has emerged as a great source of income, particularly for women. It is majorly done under small scale with production of products such as baobab porridge, baobab juice, baobab ice cream, and baobab candies. The mabuyu, "a baobab candy made from the pulp-covered seeds," is the most popular baobab product and it dominates the local Kenyan market (Jäckering et al., 2019; World Agroforestry Center, ICRAF, 2018). The various factors that influence the success of increasing baobab product use include market factors, socioeconomic and demographic variables, consumer perceptions among others (Kiprotich et al., 2019). For instance, the level of income and awareness of baobab products positively impacts the consumption of baobab products. Baobab candies, for example, are considered treats, and only those with money to spare consume them. The efficient use of organic foods or natural food ingredients like baobab is aided by positive attitudes and perceptions. Negative attitudes diminish the likelihood of consuming a product, whereas positive attitudes increase the likelihood of consuming a product (Kiprotich et al., 2019).

2.5 Baobab products in Kenya

2.5.1 Baobab porridge

Baobab porridge is one of the popular baobab products made by adding the pulp as an ingredient in the already cooked porridge. Though this is done traditionally, people have also ventured into the business of baobab porridge production (Jäckering et al., 2019).

2.5.2 Baobab juice

The juice is basically made by mixing water with the baobab pulp or the baobab seeds with attached pulp. The drink has a tart taste and sugar or honey is added as a sweetener. Commercially, the baobab juice is produced by boiling pulp on seeds with sugar until all the pulp detaches from the seeds. Vimto (E122, E124, E1520, and E415) is added as a colorant (Adiara et al., 2020). Alternatively, the baobab powder may be blended with milk until uniform. After which, a sweetener is added. Since the juice is best served chilled in coastal areas, addition of ice cubes or refrigeration after processing is necessary (Adiara et al., 2020).

2.5.3 Baobab candies

Baobab candies also known as "mabuyu" are made in local areas of Kilifi, Kibwezi, Mombasa and Kitui. As observed, the processing of baobab candies entails: dissolving sugar in a small amount of water and heating it with a food color and flavor (pepper, cardamom or artificial flavors). Throughout the cooking process, this mixture is constantly stirred until it is ready. It is then poured over fresh baobab seeds and swirled until evenly coated, then set aside to cool (World Agroforestry Center, ICRAF, 2018). The baobab candies are then packaged into sachets for sale, with prices ranging from KES 5 to 50 depending on the sachet size (Jäckering et al., 2019).

2.5.4 Baobab pulp and oil

Commercially the baobab fruit pulp and baobab oil are processed for the high-end market. They have greatly dominated the market and can be found in different selling points in the urban areas which include Nairobi (Sarit center, Yaya center, Karen, etc.), Mombasa, and Kilifi (wild living company) among others. The baobab pulp is made from the baobab seeds with pulp attached onto them. After harvesting or the collection of the baobab fruits, the hard shell is cracked open. Some of the pulp is already formed as a result of the physical activity of harvesting and transportation so it detaches from the seeds. The separation of the pulp from the seeds is done by the use of milling machines (EU, 2006). The pulp is then sieved to obtain the fine powder and then packaged. Small-scale producers of baobab pulp who cannot afford the milling machines use mortar and pestle to separate the powder from the seeds. They also use the local sieves to filter out any unwanted materials.

The baobab oil is made from the core of the seed. After milling the powder from the seeds, they are hammer-milled to remove the outer coat and then cold-pressed. The oil is then filtered to obtain a clear golden liquid oil (Dass et al., 2014).

2.6 Nutritional composition

2.6.1 The nutritional composition of baobab Fruits

Baobab fruits are rich in vitamin C, potassium, calcium, magnesium, iron, zinc and antioxidants (Stadlmayr et al., 2013). In every 100g baobab fruits pulp there is up to 300mg of vitamins C, 195.1 mg of magnesium, 1790mg of potassium and 300mg of calcium (Stadlmayr et al., 2013). It contains 75.6% of total carbohydrates, 2.3 % of proteins and a very low content of lipids. They are also high in vitamin B3, niacin, and riboflavin, with B3 and niacin ranging from 1.8 to 2.7 mg/100g and riboflavin from 0.07 to 0.14 mg/100g. Tyrosine (8.5g/100g protein) is the most abundant amino acid in baobab fruits, followed by glutamic acid 8.4, aspartic acid 7.5, arginine 6.8, glycine 6.2 g, methionine 1.9 g, and cysteine 1.3 g. Anti-nutrients such as tannins are present in the pulp, but their concentrations are too low (0.0051 percent) to cause any damage (Chadare, 2010).

2.6.2 Antioxidant capacity of baobab fruit compared to other fruits

The baobab fruit has been dubbed a super fruit because of the baobab fruit nutritional composition, with its antioxidant capability being one of the main reasons. According to research, baobab pulp has a high antioxidant capacity when compared to other fruits Table 2.2. For instance, it contains ten times the antioxidant capacity of oranges (Kaimba, 2020). The antioxidant property of fruits is measured as the Integral Activity Capacity (IAC – value). It is the total amount of hydrophilic and lipophilic antioxidants in mmol equivalent in trolox activity (Vertuani & Manfredini, 2002). A high antioxidant diet can prevent or minimize oxidative damage since antioxidants scavenge free radicals from body cells.

Table 2.2: Antioxidant capacity of baobab pulp compared to other fruits

Products	IAC (mmol Trolox equivalent/g fresh weight)
Baobab fruit pulp	11.1
Baobab dry leaves	8.7
Kiwi fruit pulp	0.34
Orange fresh pulp	0.10
Strawberry fresh pulp	0.91
Apple fresh pulp	0.16

Key: IAC- Integral Activity Capacity

Source (Vertuani & Manfredini, 2002)

2.7 Microbial safety of Processed dried fruits

Dried fruits fall under the category of low moisture foods, which are defined by the FAO as foods with naturally low moisture content or foods whose moisture content has been reduced through drying or dehydration (Witthuhn et al., 2005). Drying of fruits significantly lowers the moisture content and the water activity which inhibits the growth and multiplication of microorganisms. However, complete microbiological safety is not guaranteed by low moisture and water activity. Insufficient drying could be disastrous as well and in combination with unsanitary drying and processing can significantly lead to microbial contamination (Alp & Bulantekin, 2021). Microorganisms such as bacteria of the *Enterobacteriaceae* family can be opportunistic whereby they remain alive on dried products until suitable conditions are provided for and they begin to grow and multiply (Berthold-Pluta et al., 2021). Baobab fruits are mostly sundried after harvesting to lower the moisture content. Sun drying is a time consuming process and is frequently done in the open, leaving baobab fruits prone to contamination (James et al., 2022).

The baobab pulp processing entails cracking of the baobab shell and scooping the seeds, followed by milling (Chadare, 2010). The scooping and milling processes involve a lot of handling, which raises the risk of bacterial contamination. The hygienic conditions of the two stages of processing must be routinely monitored to ensure the safety of baobab pulp. This is mostly accomplished in the formal sector through the application of good manufacturing techniques and good hygiene standards by food handlers (Alp & Bulantekin, 2021). The baobab pulp is consumed without thermal processing and therefore its safety is solely dependent on hygiene along the entire value chain. This disadvantages processors that source already cracked baobab fruits since they have limited control over what happens in the fields before they acquire the baobab fruits. Addressing that would imply training their suppliers on appropriate baobab handling during harvesting, cracking, scooping, and transportation, as these activities are critical in ensuring the safety of the baobab pulp (Shelke et al., 2019). Baobab candy production, on the other hand, involves a lot of handling; fortunately, there is thermal treatment that significantly reduces the microbial load (World Agroforestry Center, ICRAF, 2018). This is not to say that hygienic handling is unnecessary. Hygienic handling is necessary throughout the value chain to ensure the safety of baobab candies. Following the thermal treatment during processing, the post-heating processes, such as chilling and packaging, must be constantly monitored to ensure that microbes are not reintroduced. Since baobab is hygroscopic and can quickly absorb moisture from the environment, it should be packaged in airtight containers (Darr et al., 2020).

Baobab fruits are also susceptible to fungal and aflatoxin contamination as aflatoxin fungi producing strains *Aspergillus parasiticus* and *Aspergillus flavus* have been isolated from the baobab pulp (Kachapulula et al., 2019). The moisture content of baobab fruits is another decisive element even before processing in order to ensure their safety. Elevated levels of moisture can stimulate favorable conditions for the growth of microorganisms. The EU market has specified a maximum of 12% (loss on drying) moisture on baobab pulp. This is one of the requirements along with analytical results of aflatoxins, *Staphylococcus aureus,* Salmonella, *Enterobacteriaceae,* and *Enterococci* and ensure that they meet the required regulatory limits (phytotrade, 2016).

2.8 HACCP (Hazard Analysis Critical Control Point)

(HACCP) is a food safety system set to control and ensure the safety of food throughout the food value chain (Citraresmi & Wahyuni, 2018). Food safety in any nation brings about economic and health development, growth of bi-lateral and international trade, and the production, consumption, distribution, and consumption of safe food (Nwaiwu & Ibekwe, 2017). The introduction of a HACCP framework in the food industry enhances participation, awareness, and commitment to a hazard management perspective in food production. Globally, the adoption of HACCP-based regulations as the most appropriate food safety scheme is becoming more mandatory. There are 5 preliminary steps prior to HACCP development (Quinn & Marriott, 2002). They include; assembling a HACCP team, describing the food, identifying the intended use of the food, construction of a flow diagram of the food production or the value chain and the on-site confirmation of the flow diagram (Kokkinakis & Fragkiadakis, 2007). The preliminary steps are followed by the seven principles which drive HACCP development.

- Conduct a Hazard Analysis and Risk Assessment
- Determine critical control points (CCP)
- Establish Critical Limits (CL) for each CCP
- Establish Monitoring procedures for each CCP/CL
- Establish Corrective Actions
- Establish Verification Procedures
- Establish a Recordkeeping System

For HACCP to be effective, it needs to be built upon a strong foundation of supporting initiatives. These programs, which include Sanitation Standard Operating Procedures (SSOPs), Good Manufacturing Practices (GMPs), and Good Hygiene Practices (GHPs), among others, offer the fundamental conditions required for the production of safe food (Semos & Kontogeorgos, 2007).

It is essential to develop a HACCP system for the baobab pulp value chain since the government of Kenya mandates everyone operating food business to have a safety management system. It is also necessary to raise awareness and upgrade the entire value chain. The local and international markets have shown a great deal of interest in baobab pulp, thus the processors must offer both markets safe products (Kiprotich et al., 2019). The HACCP system will effectively ensure that the fruits are properly handled during harvest, cracking, scooping, distribution, and storage along the entire value chain (Darr et al., 2020). This will be accomplished by shining a light on sound hygiene and manufacturing practices throughout the value chain. Processing of baobab pulp commences in the farms, particularly for processors who use already cracked fruits (James et al., 2022). Farmers and other actors in the value chain must therefore be trained in proper handling in order for HACCP development to be effective. This guarantees that every potential source of contamination is covered (Quinn & Marriott, 2002).

2.9 Research gaps

Local communities in Kenya have identified baobab as a high priority food tree for future domestication due to its numerous uses, therefore income-generating prospects for the rural communities where baobab is native might be expected (Stadlmayr et al., 2013). It has also demonstrated a great deal of potential in terms of product development, value addition, and profitability. As a result, there has been an increase of interest as research is carried out across the baobab value chain. Majorly, the focus has been channeled to the agriculture, nutrition, market and consumer sectors leaving the safety side of the baobab value chain under-explored.

CHAPTER THREE

MATERIALS AND METHODS

2.1 Sample size determination and sample collection

This study involved the use of two classification groups; the formal and the informal baobab processors. The term formal was used in this study to indicate baobab processors registered with the Kenya Bureau of Standards (KEBS), whereas informal represents processors not registered with KEBS. Total population sampling was applied for formal processors (control) due to the manageable size of the population and systematic sampling for informal processors. Details of the formal baobab product processors were obtained from KEBS where a sampling list of 15 processors was obtained with only 10 of the processors selected for this study being fully operational. For formal processors, eight processors were located in Nairobi, one in Kilifi, and one in Mombasa Counties. The details of the informal processors were gathered from a baobab processor survey carried out under the project "A value chain analysis of baobab (*Adansonia digitata* L.) products in eastern and coastal Kenya" (Jäckering et al., 2019). The proportion formula below was used to systematically sample a similar number of informal baobab product processors in different counties whereby (American Journal of Sociology, 2019); two processors were located in Nairobi, three in Mombasa, and five in Kilifi counties.

$$\boldsymbol{p' = \frac{x}{n}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{1}$$

Where, p' = proportion ratio, x = the size of the proportion, and n = the size of the total population.

Samples were collected in June and July 2019. From each processor, three samples were collected resulting in 60 products. All the samples (baobab candies and pulp) weighed between 100 to 200 grams. Samples were packed in sterile plastic zip lock bags and appropriately labeled. The bags were placed in cooler boxes with ice packs and transported to Food Microbiology Laboratory at Jomo Kenyatta University of Agriculture and Technology for analysis. Samples were stored at 4°C and analyzed within 24 hours.

2.2 Determination of moisture and water activity of baobab products

All samples were subjected to water activity (a_w) and moisture content measurements. The water activity was measured as described by Nyangena et al., (2019) (Nyangena et al., 2019), using HygroPalm HP23-AW-A Portable Water Activity Analyzer (Rotronic AG, Bassersdorf, Switzerland). The water activity meter was set at a_w-Quick mode and sealed samples were kept at a relatively constant temperature (22 ± 3 °C) for 5 minutes to allow for the temperature conditions of the sample and the probe to stabilize before the displayed a_w reading was recorded.

The moisture content was determined as per the AOAC method number IS 4333 (AOAC International, 2002). Five grams of baobab samples in triplicates were weighed and placed in a clean dry moisture dish and the weight of the sample and dish were taken. These were placed in an oven set at a temperature of 105°C and dried for three hours, removed, cooled in a desiccator, and weighed. The amount of moisture in the samples was calculated using the formula:

% Moisture content (wet basis) = $\frac{w1-w2}{w1} \times 100$

Where; W1=weight before drying and W2 = weight after drying.

2.3 Microbial analysis of baobab products

The baobab samples were each analyzed in duplicates for the total aerobic count, *Enterobacteriaceae*, and yeast and molds according to the AOAC microbiological methods method number ISO 4833, ISO 21528-2, and ISO 7954 respectively (AOAC International, 2002). All media was purchased from Sigma-Aldrich (England, UK). Ten grams of the sample was transferred into 90 ml of 0.1% sterile peptone water and mixed uniformly using a bench vortex Mixer® (AHN, Nordhausen – Germany) after which three tenfold serial dilutions (10^{-1} to 10^{-3}) were made and analyzed for: total aerobic count, *Enterobacteriaceae* and yeast and molds. Total aerobic counts were enumerated on plate count agar (PCA), yeasts and molds on potato dextrose agar (PDA – 10% sterile tartaric acid was incorporated to inhibit bacterial growth), and *Enterobacteriacea*e on Violet red bile glucose agar (VRBGA). The spread plate method was used as the plating technique for the three microbial analyses where 0.1 ml of sample serial dilutions were plated in duplicates. The total aerobic count, *Enterobacteriaceae*, and yeast and molds counts were assessed after incubating PCA plates at 37°C for 48 hours, VRBGA plates at 37°C for 24 hours, and PDA plates at 25°C for 5 days (Park et al., 2015; Witthuhn et al., 2005) respectively. The results were expressed as the number of colony-forming units per gram of baobab sample (CFU/g). Data were transformed into logarithm to facilitate statistical analysis.

2.4 Ergosterol and aflatoxin standard solutions and generation of standard curves

Ergosterol standard (E6510-5G) was obtained from Sigma-Aldrich (England, UK). The ergosterol stock solution was prepared at a concentration of 1mg/ml, and further working standards were prepared by serial dilutions with ethanol. A standard calibration curve was then generated and a correlation coefficient of (r^2) of 0.999 was used to demonstrate linearity. Based on the signal-to-noise ratios (S/N) of 3:1 and 10:1 respectively, the limit of detection (LOD) and limit of quantification (LOQ) was determined (Yuan et al., 2007). Precision was calculated as relative standard deviation (%RSD) for repetitive measurements. The Aflatoxin standards solution (Fujifilm Wako pure chemical corporation, Osaka, Japan) comprised of aflatoxins mixture of AFB1, AFB2, AFG1, AFG2 each 25ug/ml in acetonitrile solution. Working standards were prepared by serial diluting with acetonitrile and a 6-point calibration curve was generated covering the range of 1.25 – 12.5 ppm for each aflatoxin group.

2.5 Ergosterol analysis of baobab products

Extraction and quantification of ergosterol was carried out on each of the 60 baobab samples. Two grams of the sample was placed in the saponification solution composed of 15ml of methanol and 5 ml of potassium hydroxide solution (40g/l KOH in ethanol) and agitated for 30 minutes. This was then filtered into evaporation tubes using a 0.2 µm pore size syringe filter. The mixture was evaporated to 1ml using a gentle stream of nitrogen (Verma et al., 2002). The ergosterol concentration was determined by injecting 20µl of the extract into the HPLC System (Shimadzu Corp, Model LC-20AD/T LPGE, Kyoto, Japan). The HPLC system consisted of an auto-sampler model SIL-20A HT, quaternary pumps (Shimadzu model LC-20AD), a reverse-phase SUPELCO C-18 (5µm 260mm × 4.6 mm) Column, CTO-10AVP column oven, and a photodiode detector (SPD-M20A). The separation was achieved through isocratic elution at a flow rate of 2mls /min, with a linear gradient solvent (Methanol: water, 80:20, v/v).

2.6 Aflatoxin analysis of baobab products

Twenty-five grams of the baobab samples were added to an extraction solution comprising of 1 g sodium chloride in 25 ml (methanol: water 80:20 v/v) and centrifuged at 10,000 rpm for 5 minutes. Five milliliters of supernatant was transferred to a 50 ml centrifuge tube and diluted with 40ml of 2% PBST (phosphate-buffered saline with tween) solution (Karaca & Nas, 2006). The solution was filtered through 0.2 µm Millipore filters into vials. Aflatoxin quantification was done by injecting 20 µl of the samples into a SHIMADZU HPLC system (Shimadzu Corp, Model LC-20AD/T LPGE, Kyoto, Japan) equipped with; RF20A fluorescence detector operated at an excitation wavelength of 350nm and an emission wavelength of 450nm; Auto-sampler SIL 20AHT, a reverse-phase SUPELCO C-18 (5µm 260mm × 4.6 mm) Column, CTO 10ASVP column oven set at 40°C and LC20AD quaternary pump. A mobile phase of acetonitrile: methanol: water (10:30:60 v/v) was used at a flow rate of 1ml/min.

2.7 HACCP development

2.7.1 Study site

The study on HACCP development for baobab pulp in Kenya was conducted at Vokenel Enterprises Ltd; a company that processes and packages organic baobab fruit powder and organic baobab oil located in Kibwezi, Kenya, from the month of January to June 2021. The support of the management of the company for food safety was sought and obtained prior to the commencement of the study. Before the first visit to the company, comprehensive training materials were developed and reviewed by the HACCP consultant personnel.

2.7.2 Development and review of HACCP training material

The review of the HACCP training materials involved assembling the food safety-related documents and purchasing a copy of the KEBS HACCP standards. Documents were prepared on practical knowledge of how the process works at all times during production (including breakdowns) and a thorough understanding of all aspects of the equipment design and operation. It also covered a thorough understanding of the likely reservoirs of hazards (microbiological, chemical, and physical) in the raw materials as well as a processing environment. Finally, the factors that would enable a rise or decrease in the number/level of hazards under examination were discussed, as well as an understanding of the consequences of the presence of such hazards on product safety.

2.7.3 HACCP training

The training was done before HACCP development during the first visit to Vokenel Enterprises Ltd. A HACCP consultant and a food scientist conducted the training at the factory premises. The training was provided to the production team since they are in charge of controlling the manufacturing processes and, as a result, their role in ensuring food safety and implementing HACCP is vital. The training was aimed at describing the steps towards HACCP development and implementation for the baobab pulp at the company.

It covered the following aspects:

- The main sources of hazards in the product and their impact on product safety as well as the control required at the point of occurrence.
- Critical control points (CCPs) and their role in ensuring product safety.
- The monitoring procedures for the critical control points and the capturing of accurate and relevant readings for monitoring purposes.

- The remedial action to be taken when a CCP deviates from the critical limit.
- Proper record-keeping processes

The steps used to develop the HACCP system for the baobab pulp processing unit were described by East Africa Community (Barbut, 2001) as shown in Figure 3. 1.

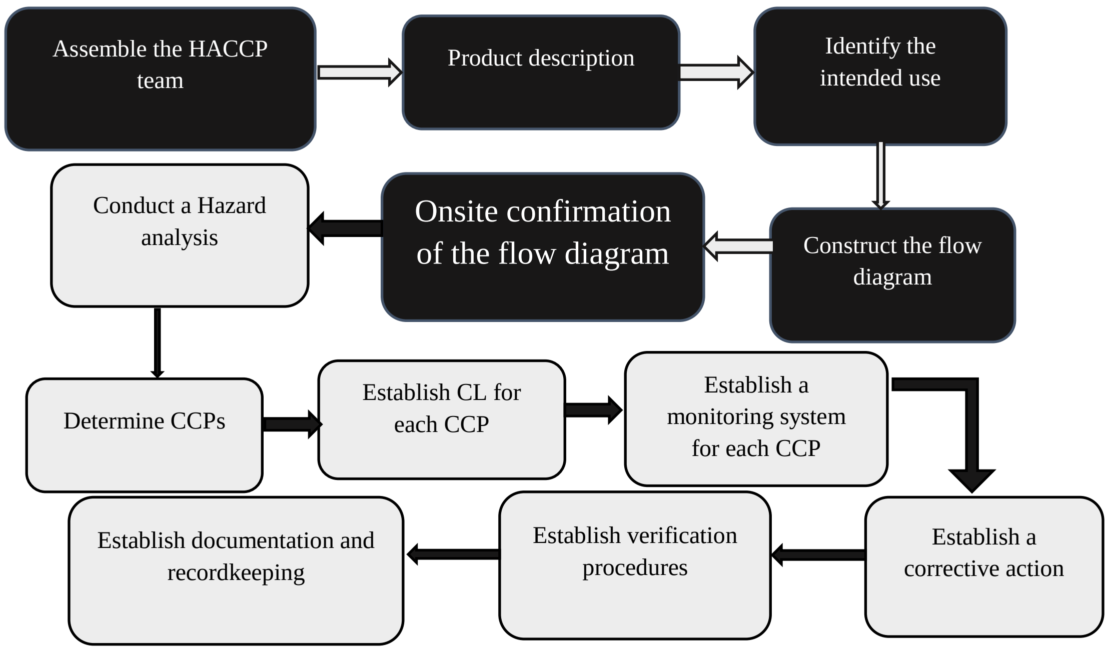


Figure 3. 1: The twelve steps were followed in developing the HACCP plan

Notes; CCPs- critical control points, CL- critical limits

2.7.4 The steps used to develop the HACCP system in the baobab pulp processing unit were in two categories;

2.7.4.1 Preliminary steps to enable with hazard analysis

Step 1: HACCP team formation A team was formed comprising of a production manager, production engineer, a food scientist, HACCP consultant, and the production team.

Step 2 and 3: Product description

The product description included information such as how the product is processed, a list of ingredients (if any), preservation methods, primary packaging, storage conditions, and shelf life.

Steps 4 and 5: By observing and using the information provided by the HACCP team members, the baobab pulp flow diagram was created. Each process step from raw material reception, through processing all the way to dispatch was outlined in a flow diagram sequentially. The flow diagram was then confirmed onsite.

2.7.4.2 HACCP principles steps

Principles 1 and 2: Hazard analysis and Determine Critical Control Points (CCPs)

These steps involved a listing of all potential hazards according to the verified flow diagram, conducting hazard analysis, and identification of the control measures. A Decision tree with likelihood and severity scale scores of 1-3 was used to identify potential hazards at each process step and to label the step as a CCP or not Figure 3. 2.

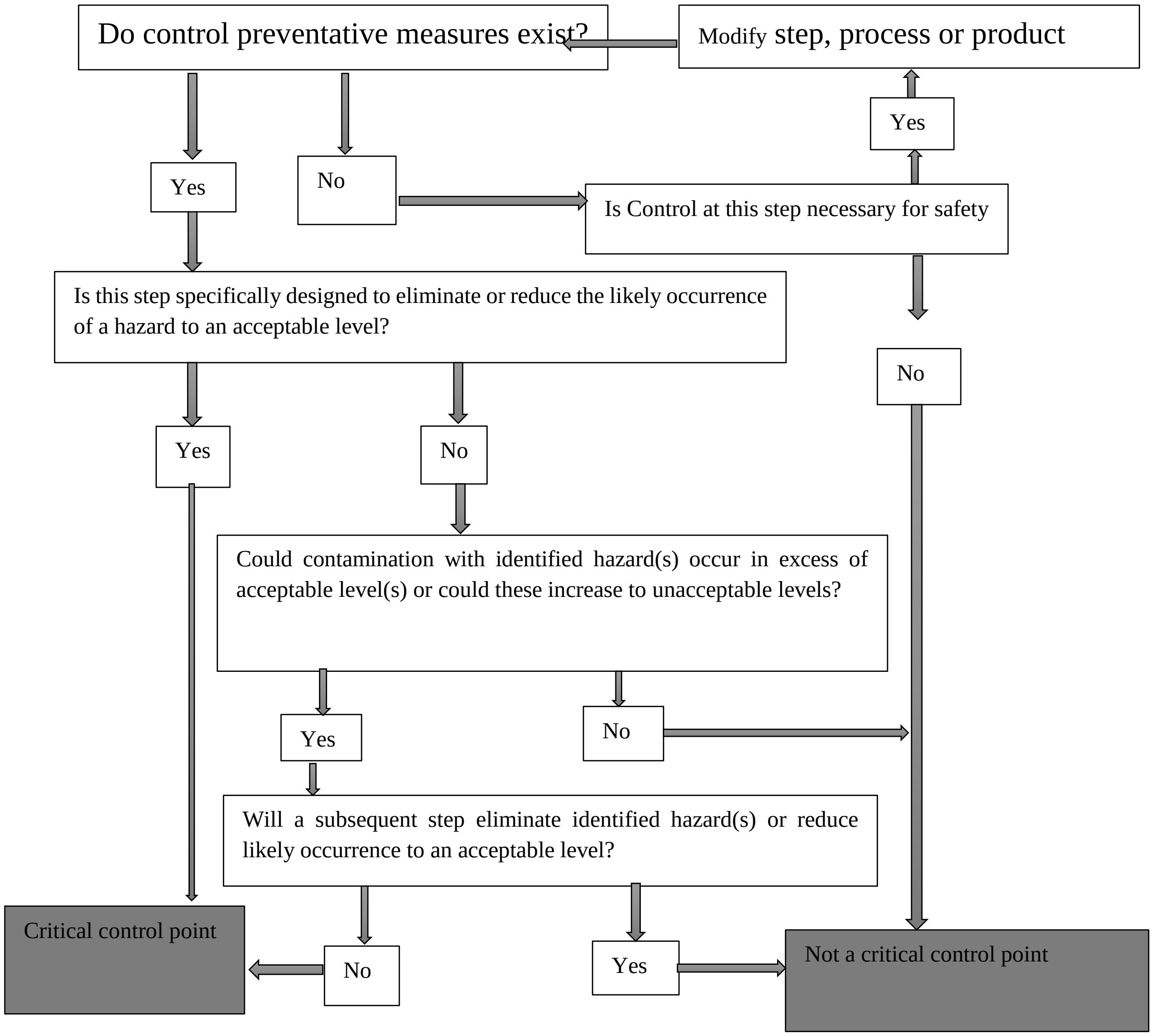


Figure 3. 2: **Decision tree used to identify potential hazards at each process step and to label the step as a CCP or not**.

Source (Allata et al., 2017)

Principles 3 and 4: Establishing critical limits for CCPs and Establishing a monitoring system for the CCPs

In these steps, critical limits were established for the identified CCPs to indicate when a CCP is in or out of control and a reliable monitoring system was established.

Principles 5, 6 and 7 Establishing corrective action, verification procedures and documentation

Corrective action steps were assigned to the identified CCPs to ensure rectification in case of deviations. And finally, a verification system and record-keeping procedures were suggested to ensure the efficiency and manageability of the developed HACCP.

2.7.5 Microbial analysis

To determine the state of hygiene of the processing environment microbial analysis was done before HACCP training and five months after the HACCP training. Swabs were collected from the personnel's hands, preparation surfaces, milling equipment, and storage materials before and after HACCP training and development. Sterile cotton pre-moistened with peptone water was used in collecting the swabs and a sterile ruler was used to demarcate a 25 cm^2 sampling area. The swabs were then aseptically reinserted into their respective tubes; the tubes were then tightly closed, stored, and transported to the laboratory in a cool box at 4°C. The swabs were each analyzed in duplicates for the *E. coli*, total coliforms, total plate count, and yeasts and molds according to the AOAC microbiological methods (AOAC International, 2002). All media was purchased from Sigma-Aldrich (England, UK).

The swabs were transferred into 1 ml of 0.1% sterile peptone water and mixed uniformly using a bench vortex Mixer® (AHN, Nordhausen –Germany) after which two serial dilutions (10^{-1} and 10^{-2}) were made *E. coli* was enumerated on sorbitol-MacConkey plates, total coliforms on violet red bile agar (VRBA), total aerobic counts on plate count agar (PCA), and yeasts and molds on potato dextrose agar (PDA - 10% sterile tartaric acid was incorporated to inhibit bacterial growth). The spread plate method was used as the plating technique for the three microbial analyses where 0.1 ml of sample serial dilutions were plated. The *E. coli*, total coliforms, total plate count, and yeasts and molds were assessed after incubating sorbitol-MacConkey plates at 37°C for 24 hours, VRBA plates at 35 °C for 48 hours, PCA plates at 37°C for 48 hours, and PDA plates at 25°C for 5 days (Park et al., 2015; Witthuhn et al., 2005) respectively. The results were expressed as the number of colony-forming units per gram of baobab sample (CFU/g).

2.7.6 Aflatoxin analysis

Aflatoxin contamination is one of the potential risks at the reception, and it is primarily influenced by how long the baobab fruit remains on the tree once it has matured. Aflatoxin analysis was done to determine the safety and concentrations in and outside the fruits due to the nature of the baobab fruits storage structure, which exposes the fruits to humidity, particularly during the rainy seasons. In triplicate, Twenty-five grams of powdered baobab shell (outer) and baobab pulp (inner) samples were weighed and added to an extraction solution containing 1 g sodium chloride in 25 ml (methanol: water 80:20 v/v). This was centrifuged at 10000 rpm for 5 minutes. Five millilitres of the supernatant were then transferred to a 50 ml centrifuge tube and diluted with 40 ml of the 2% PBST (phosphate-buffered saline with tween) solution (Karaca & Nas, 2006). This was then filtered into vials using a 0.2 µm pore size syringe filter. Aflatoxin quantification was done by injecting 20 µl of the samples into a SHIMADZU HPLC system equipped with a fluorescence detector RF 20A operated at an excitation wavelength of 350 nm and an emission wavelength of 450 nm, Auto-sampler SIL 20AHT, CTO 10ASVP column oven set at 40°C and LC20AD quaternary pump. A mobile phase of acetonitrile: methanol: water (10:30:60 v/v) was used at a flow rate of 1 ml/min.

2.8 Data analysis

Data were analyzed using STATA for windows version 12.1, 2011 package by StataCorp Inc., USA. The data collected from the study were subjected to independent sample t-test to assess significant differences in water activity, moisture content, and microbial counts between formal and informal processor's products. The microbial data from different regions was also subjected to analysis of variance. Differences among means was separated using Bonferroni test at a significance level of 0.05. Spearman's correlation was done to test the correlation between water activity, ergosterol content and aflatoxin content. An independent sample t-test was used to assess differences in aflatoxin levels between the inner surface (Baobab fruit's interior content) and outer surfaces of baobab fruits at significant levels of $p \leq 0.05$. To determine significant differences microbiological data collected before and after the HACCP training and development, a paired sample t-test was used.

CHAPTER FOUR

RESULTS

4.1 Moisture content, water activity, and microbial loads of baobab products

Moisture, water activity, and microbial content of baobab pulp and candies from formal and informal processors are shown in Table 4.1. The highest moisture content observed in baobab pulp was 15.6±0.05 % whereas in baobab candies it was 23.47±0.09%. No significant differences ($p<0.05$) were observed in both moisture content and water activity levels between baobab pulps from formal and informal processors. However, the moisture content and water activity of baobab candies from informal processors (17.18±3.8%, 0.704±0.06) was significantly higher ($p=0.015$, 0.049, respectively) than those from formal processors (11.84±2.3%, 0.619±0.10). Baobab pulp from informal processors had significantly higher ($p<0.05$) *Enterobacteriaceae* (3.1±0.70 $\log_{10}$ CFU/g) and yeast and molds counts (5.3±0.11 $\log_{10}$ CFU/g) than those from formal processors (0.7±0.29 and 3.1±0.38 $\log_{10}$ CFU/g, respectively). Similarly, a significant difference ($p<0.05$) was observed in terms of *Enterobacteriaceae* counts between candies from formal (ND) and informal processors (1.8±0.56 $\log_{10}$ CFU/g).

Table 4.1: Moisture content, water activity and microbial content of baobab products from formal and informal processors.

Product	Source	Moisture content (%)	Range	Water activity	Range	$\log_{10}$ CFU/g Tac	$\log_{10}$ CFU/g E	$\log_{10}$ CFU/g Y+M
Baobab pulp	Formal	11.8±2.30[a]	7.73-15.06	0.65±0.071[a]	0.532-0.740	3.1±0.08[a]	0.7±0.29[b]	3.1±0.38[b]
	Informal	13.5±1.90[a]	10.50-15.60	0.69±0.043[a]	0.585-0.741	4.3±0.22[a]	3.1±0.70[a]	5.3±0.11[a]
Baobab candies	Formal	11.3±2.60[b]	8.99-13.57	0.62±0.101[b]	0.551-0.687	5.0±0.24[a]	ND[b]	3.5±0.46[a]
	Informal	17.2±3.80[a]	14.66-23.47	0.70±0.062[a]	0.709-0.751	3.6±0.27[a]	1.8±0.56[a]	3.M±0.25[a]

Key: SD = Standard deviation; Tac= total aerobic count; E= *Enterobacteriaceae* counts; YM= yeast and molds counts. Values are means of duplicates replicates and those with the same superscript along the column for each baobab products are not significantly different at $P\leq0.05$. Moisture is on wet basis.

Figure 4. 1 indicates the percentage of baobab products that were microbiologically safe in terms of total aerobic count, *Enterobacteriaceae*, yeasts, and molds. The safety of the baobab products was determined using the Kenya Bureau of Standards (KEBS) standards. The KEBS has set a limit of 1000, 100, and 10000cfu/g for the total aerobic count, Enterobacteriaceae, and yeast and molds counts, respectively. All candies from formal processors and 66.7% of those from informal processors had a safe total aerobic count. When compared in terms of Enterobacteriaceae, 100% of candies from formal and 33% of those from informal processors were found to be below the microbiological limit. Yeast and mold counts revealed that all of the candies from formal and 66.7% from informal processors were safe.

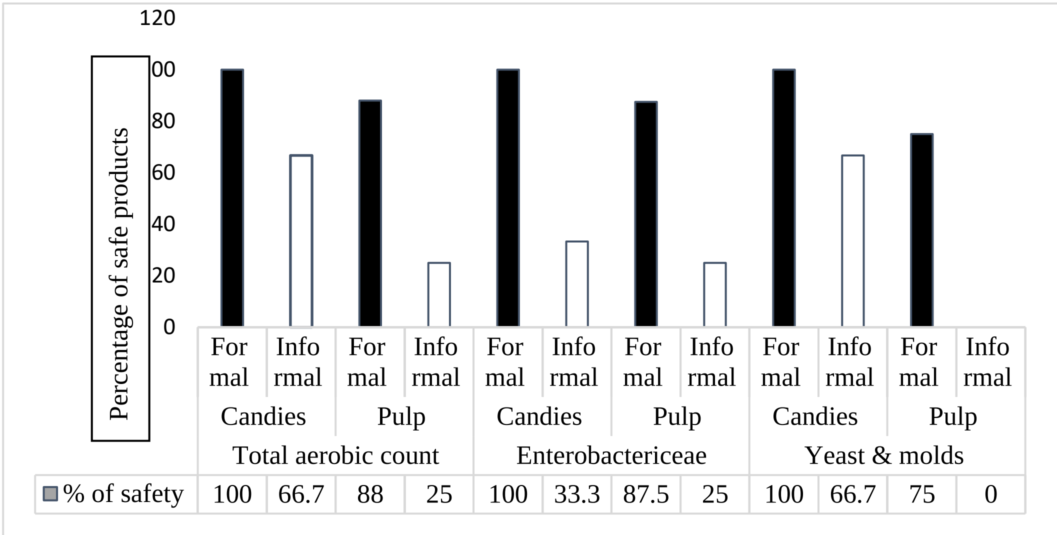


Figure 4. 1: **The percent of microbiologically safe baobab products in regards to total aerobic count Enterobacteriaceae and yeasts and molds. The percentages represent the baobab products below the microbiological limit as recommended by the KEBS.**

In the case of baobab pulp, 88% of samples from formal processors and 25% of those from informal processors were below the set limit for total aerobic count. In terms of *Enterobacteriaceae*, 87.5% and 25% of pulp from formal and informal processors, respectively, were below the microbiological limit. Yeast and mold counts revealed that 75% of formal processors were below the microbiological limit, while all informal processors' pulp was above the KEBS microbiological limit.

The highest yeast and mold contamination was recorded in baobab pulp from informal processors in Mombasa and Kilifi, with 5.4±0.30 log_{10} CFU/g and 5.1±0.01 log_{10} CFU/g, respectively. Likewise, candies from informal processors in Mombasa and Kilifi also recorded the highest levels of yeast and molds counts 4.3±0.98 log_{10} CFU/g and 3.6±0 log_{10} CFU/g. respectively as shown in Table 4.2.

A significant difference ($p < 0.05$ was observed in *Enterobacteriaceae* and TAC counts between baobab pulp from informal processors from Kilifi (3.3±0.11, 3.9±0.21 $\log_{10}$ CFU/g) and those from Mombasa (2.9±2.30, 5.4±0.28 $\log_{10}$ CFU/g) respectively. In yeast and molds counts, there was a significant difference between pulp from informal processors in Nairobi and those from Mombasa and Kilifi (5.4±0.30 and 5.1±0.01 $\log_{10}$ CFU/g), respectively. Baobab candies from informal processors in Nairobi (3.3±0.52 $\log_{10}$ CFU/g) had significantly lower yeast and molds counts than those from Kilifi (4.3±0.98 $\log_{10}$ CFU/g).

Table 4.2: Comparison of the microbial content of baobab products based on region.

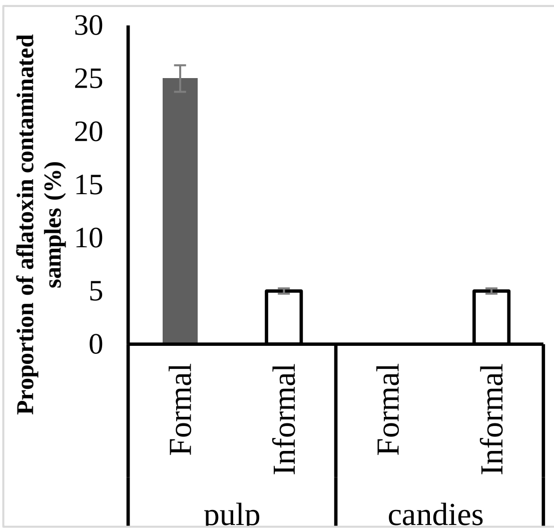
Product	**Source**	**Region**	**$\log_{10}$ CFU/g Tac**	**$\log_{10}$ CFU/g E**	**$\log_{10}$ CFU/g Y+M**
Baobab pulp	Formal	Nrb	$4.4±0.98^{b}$	$0.5±1.20^{a}$	$3.6±1.10^{b}$
		Msa	$4.2±0.04^{b}$	$0.3±0.60^{a}$	$1.2±0.05^{a}$
	Informal	Msa	$5.4±0.28^{b}$	$2.9±2.30^{a}$	$5.4±0.30^{b}$
		Kilifi	$3.9±0.21^{a}$	$3.3±0.11^{b}$	$5.1±0.01^{b}$
Baobab Candies	Informal	Nrb	$3.4±0.51^{b}$	$2.4±0.08^{a}$	$3.3±0.52^{a}$
		Msa	$2.4±0.10^{a}$	$1.4±0.20^{a}$	$3.6±0.05^{ab}$
		Kilifi	$4.2±0.81^{b}$	$2.1±2.50^{a}$	$4.3±0.98^{b}$

Key: SD= Standard deviation, Tac= total aerobic count, E= *Enterobacteriaceae*, Y+M = yeast and molds, Nrb = Nairobi, Msa =Mombasa. Values are means of two duplicate replicates and those with the same superscript along the column for each baobab products are not significantly different at $P \leq 0.05$.

4.2 Fungal and aflatoxin contamination of baobab products.

There was no aflatoxin detection in baobab candies from formal processors on the other hand shows Figure 4.3 the mean comparisons of aflatoxin content between products from formal and informal processors. Aflatoxin AFB1 was only detected in the informal sector.

Between the formal and informal sectors, there were no significant differences in AFB2 and AFG1, although a significant difference in AFG2 was found Figure 4. 3.



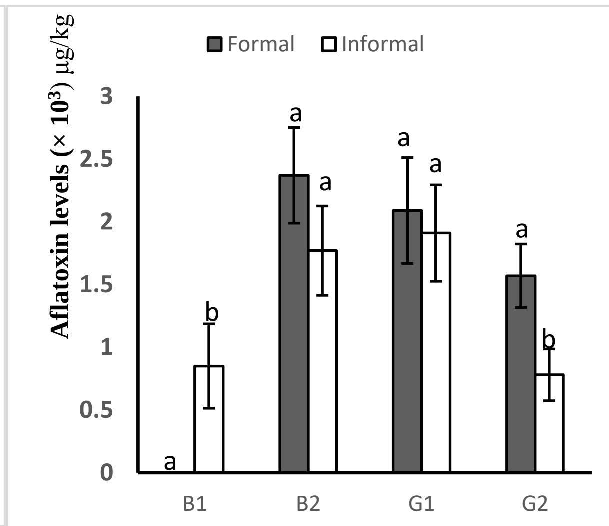


Figure 4. 3a: The proportion of aflatoxin contaminated samples from formal and informal baobab processors

Figure 4. 3b: The aflatoxin AFB1, AFB2, AFG1, and AFG2 mean comparison between formal and informal baobab

Table 4.3 shows the ergosterol and aflatoxin content of baobab products. The ergosterol content ranged between 0.46 to 1.92 mg/100g while the total aflatoxin content ranged from 12.79±0.02 to 23.15±0.01 × 10^3 µg/kg respectively. All the samples contaminated with aflatoxin were above the set limits of 10 µg/kg for total aflatoxins.

Table 4.3: Ergosterol and Aflatoxin content (mean ±SE) of baobab products

Intrinsic properties				Aflatoxin (× 10^3 μg/kg)	
Sample	**Moisture**	**aw**	**Ergosterol (mg/100g)**	**AFB1**	**Total Aflatoxins**
			Pulp –Formal		
S7	15.06±0.09	0.74	1.68±0.13	ND	23.15±0.01
S5	11.49±0.33	0.62	0.91±0.08	ND	21.18±0.03
S3	11.46±0.52	0.61	1.06± 0.05	ND	21.25±0.06
S1	14.98±0.19	0.74	0.67± 0.04	ND	12.79±0.02
			Informal		
S16	12.30±0.34	0.64	1.87±0.04	ND	15.92±0.01
			Candies –Informal		
S12	18.80±0.16	0.749	1.92±0.02	ND	16.23±0.03
S14	14.65±0.35	0.71	0.46±0.19	11.09±0.30	21.12±0.04

Notes; AF- Aflatoxin, ND – not detected, Results are expressed as mean±SD of three replications, moisture is on wet basis

The correlations between water activity, amount of ergosterol, and amount of aflatoxins are presented in Table 4.4. There was a positive correlation between the amount of ergosterol and amount of AFB2, AFG1, and AFG2 in baobab samples ($r = 0.8362$, $p<0.0001$), ($r = 0.8692$, $p<0.0001$), and ($r = 0.8393$, $p<0.0001$) respectively. A positive correlation was also observed between water activity and the ergosterol content among the baobab products ($r = 0.5019$, $p = 0.04$) Table 4.4.

Table 4.4: Correlations between water activity, ergosterol and aflatoxin content in baobab products

			Aflatoxin			
	aw	**Ergosterol**	**B1**	**B2**	**G1**	**G2**
aw	1.000					
Ergosterol	0.5019	1.0000	.			
p-value	0.0476					
B1	.	.	.			
B2	0.4038	0.8362	.	1.0000		
p-value	0.1209	0.0001				
G1	0.1415	0.8692	.	0.7688	1.0000	
p-value	0.6012	0.0000		0.0005		
G2	0.4077	0.8393	.	1.0000	0.7703	1.0000
p-value	0.1170	0.000		0.0000	0.0005	

4.3 HACCP development

4.3.1 Preliminary steps to enable hazards analysis

Product description

Description of the baobab pulp included processing, packaging, storage and shelf life, intended use, and the target customers as shown in Table 4.5. This would aid in identifying all potential hazards related to the product.

Table 4.5: The baobab pulp description along the Kenyan baobab value chain

Baobab pulp	Product description
Processing	The hard shells are cracked open and the pulp is separated from the seeds and the shell. This is milled, separated into coarse and fine lots (particle size 3 to 600 μm), and then packaged.
Storage conditions	Refrigeration
Shelf life	3 years under refrigeration
Indented use	Made into juice by mixing with water. An ingredient in yoghurt and smoothies. Added to tea, marinades, or sauces
Packaging	Mini plastic Ziploc bags
Target customer	General population

4.3.2 Verified flow diagram

A flow diagram showing activities from sourcing baobab fruits to the finished product was designed as shown in Figure 4.1. Baobab fruits are sourced from farmers, which are then delivered to the factory and sorted at the reception. The fruits are then stored awaiting production. Pre-cleaning of the baobab fruits is carried out before the start of production. Crushing, scooping, and milling are all part of the manufacturing process. The milling process is followed by sieving, weighing, and packaging.

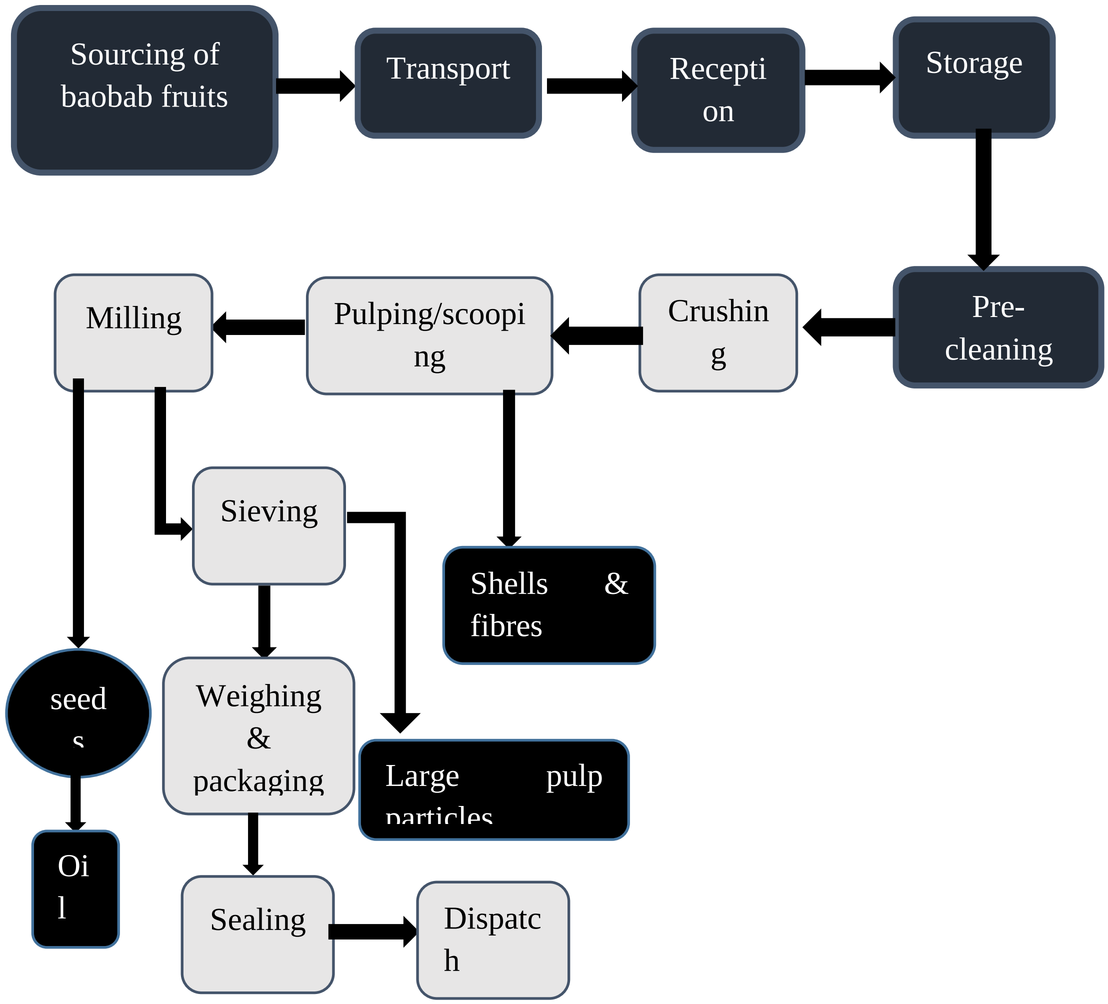


Figure 4.1: Baobab pulp processing flow chart

4.3.3 Hazard identification

Inadequate hazard detection during the development of the HACCP framework has been reported as a major barrier to successful HACCP implementation. The hazards listed in Table 4.6 have been identified and classified, as well as their potential mitigating strategies

Table 4.6: The hazards along each baobab pulp processing line and their possible control measures

Processing step	Physical, biological, and chemical hazards	Source	Control measure
Sourcing baobab fruits	Foreign materials, pesticides, cracked fruits, old fruits	Farm activities, the harvesting process	Sorting of raw materials, inspection at the farm before sourcing.
Transport	Dirt, grease	Farm activities, transport vehicle	Proper inspection of the transport vehicle to ensure its cleanliness and no grease leakages.
Storage	Insects, old fruits, snakes	Environment, farms activities	Fruits inspection and sorting, continual maintenance of the store
Pre-cleaning	Itchy furs, stones, bacteria	Fruits, personnel hands, environment	Sorting, protective clothing, pre-cleaning in a different area than the cracking area
Breaking	Shell, bacteria	Fruits, contact surfaces	Personnel hygiene and facility cleaning,
Scooping	Fibre, insects, dust, bacteria, mold	Fruits, environment, Personnel hands	Personnel hygiene and clean environment, scooping in a clean area protected from any environmental contaminants
Milling	Seeds, fibre, grease, metal pieces, dust, rust, bacteria	Fruits, processing equipment, personnel hands, Environment	Personnel hygiene, providing an outlet for the seeds after processing, regular maintenance of the milling machine, proper cleaning and drying of the milling machine before processing
Sieving	Fibre, shells, dust, bacteria	Fruits, environment, personnel hands, processing equipment	Personnel hygiene, clean sieve of proper size, the processing area should be shielded from any environmental contaminants
Packaging, weighing & labeling	Glue, ink, bacteria, dust	Packaging material, labeling ink, personnel, environment.	Use of food-grade glue and labeling ink, avoiding contact of the glue and ink with the product, protecting the area against environmental contaminants
Storage	Mold	Environment	Maintaining a hygienic environment and proper storage conditions

Table 4.7: Identified CCPS for baobab pulp HACCP plan

CCPs	Process step	Hazard	Critical limits	Monitoring procedure	Frequency	Preventive measure	Corrective action	Records	Responsible person	Verification procedures
CCP No 1	Reception	Total Aflatoxins (AFB1+AFB2+AFG1 +AFG2) µg/kg Aflatoxin B1(AFB1) , µg/kg	10 5	Baobab fruits inspection for compliance for every batch by the QA -laboratory aflatoxin analysis	Every delivery	Withholding of the baobab fruits awaiting inspection and approval	Rejection of the batch if they do not comply with the raw material specification	Raw material specification	QA personnel	Check the raw material verification records and get quarterly reports from accredited labs for aflatoxin tests

Table 4.8: Identified OPRPS for the baobab pulp HACCP plan

		Monitoring						
OPRPs Processing step	**Hazard**	**What**	**When**	**Where**	**Who**	**How**	**Preventive measure**	**Records**
1-Scooping **2-Milling**	Yeast and molds, Escherichia coli, Bacillus cereus, Staphylococcus aureus, Shigella, Salmonella,	Washing and sanitizing	Every 30 mins	Production area	All Production staff	SOP	Regular handwashing and sanitizing with a food-grade alcohol-based sanitizer. Proper production attire (white aprons and hairnets) Production personnel should not be allowed in the production area if; they haven't washed and sanitized hands, sick and have open wounds, have not acquired a medical certificate	Handwashing and sanitizing records Medical certificates

Notes: OPRPs- Operational prerequisite programs, HACCP – hazard analysis critical control point, SOP- standard operating procedure

4.3.4.10 Establishment of the critical control points (CCPs)/ Operational pre-requisite programs (OPRPs), monitoring procedures, and corrective actions

4.3.4.10.1 CCP1 – Processing step 3 (Reception)

The first CPP was identified at the reception with the target hazard detected being aflatoxins. It is a critical step since there is no subsequent step that can eliminate or reduce the levels of aflatoxins. This was based on the company's experience with aflatoxin incidences in finished goods as a result of contamination of the raw materials. Farmers were reported to supply moldy baobab fruits from the previous season, some of which were contaminated aflatoxins. In Kenya, the maximum aflatoxins limit for baobab products are 10 µg/kg for total aflatoxins (AFB1, AFB2, AFG1, AFG2) and 5 µg/kg for AFB1 (EAC, 2016).

4.3.4.10.2 OPRP 1 and OPRP 2- processing steps 8 and 9 (Scooping and milling)

The OPRP 1 and 2 were identified at the scooping and milling steps with bacteria and yeast and molds as the target hazards. The 4W 1H rule (What, Where, Who, when (Frequency), and How) was used to monitor the OPRP (KokkinakisEetal.,2008)

4.3.4 Evaluation of Prerequisite programs –(PRPs)

An assessment of the PRPs was done according to the general principles of the Codex Alimentarius on good manufacturing practices (GMPs) and good hygiene practices (GHPs). The study revealed that the environment and the premise conditions were suitable for the production of baobab pulp, however, there were key areas of concern discussed below.

4.3.4.1 Storage of baobab fruits

The storage site was ideal for storing baobab fruits since it raises the fruits above the ground and provides adequate aeration however, it poses a food safety risk during rainy seasons because rainwater can easily seep into the baobab fruits from the sides of the storage structure.

4.3.4.2 Premise condition

The premise was set up in such a way as to permit good food hygiene practices. It however did not shield the finished product from cross-contamination since the product flow was not mapped out. In addition, the walls were not rodent and insect-proof.

4.3.4.3 Maintenance and cleaning

The facility and equipment were washed regularly. While repairs had not been carried out in a while, the equipment was still fit for processing.

4.3.4.3 Pest control and waste management

A pest control contractor had been hired by Vokenel Enterprises Ltd. There was a pest control schedule and protocol in operation, which had been documented. A regular waste disposal system is operated by the county garbage collection scheme. The wastewater treatment plant of the county council takes liquid waste directly. It was suggested that solid waste should be disposed off daily.

4.3.4.4 Personal hygiene guidelines

Personnel had access to a sanitation (toilet) facility. A sanitary (toilet) facility was available to personnel. The factory did not have any handwashing or foot sanitization stations. In addition, there were no suitable production attires as observed.

4.3.4.5 Traceability

A structured protocol was in place for dealing with consumer concerns. In the event of a hurdle, the traceability system in place was in terms of baobab farm, year of production, the month of harvest, and day of harvest, ensuring that any recall procedures were implemented quickly.

4.3.4.6 Staff training

The training was done for all the staff whose awareness, support, consent, and participation in HACCP are necessary for the full realization of the HACCP benefits. The training schedule was functional and was designed to take into account the baobab production process from reception to dispatch, understanding standards and the procedures required to maintain the integrity of the products and product labeling. The training also helped in achieving dedication from senior management down to operational personnel. For newcomers and those returning to the premises after a long absence, refresher training was recommended.

4.3.4.7 Behavioral changes after HACCP training

The HACCP training had visible effects as presented in Plate 5.2 and plate 5.3. During production, aprons, hairnets and gumboots were among the noticeable changes. There were also handwashing and foot sanitizing stations on the site. Hand sanitation was also introduced during production, with hand sanitizing taking place at intervals of 30 minutes.

4.3.4.8 Microbial quality before and after HACCP training

In this study, the microbial analysis was deemed vital in determining the effectiveness of the prerequisite programs. A significant difference was observed between the microbial analysis from the first set of swabs and the second set Table 4.9. The first set of swab microbiological analysis was done prior to any training, and the second set was obtained during the second visit six weeks after the training. After the training, the *E. coli*, total coliforms, total plate count, yeast and mold loads were significantly (p=0.01, 0.0009, 0.003) lower as shown in Table 4.9.

Table 4.9: Microbial loads for the swabs before and after HACCP training in CFU/g.

	Personnel's hands		Cracking Machete		Storage Buckets		Pulping machine	
Microbe	Before	After	Before	After	Before	After	Before	After
E.coli	5±0.55	0	103±0.72	0	17±0.33	0	39±0.12	0
Total coliforms	55±0.12	3±0.41	87±0.36	5±0.17	75±0.63	0	63±0.71	0
Total plate count	20±0.43	2±0.02	107±0.75	10±0.92	29±0.03	6±0.07	33±0.32	7±0.89

Yeast and molds	13±0.03	0	16±0.39	2±0.04	36±0.05	4±0.09	43±0.35	5±0.43
P-value	0.01		0.0009		0.003		0.0001	

4.3.4.9 Aflatoxin analysis

Aflatoxin analysis showed a significant difference between the aflatoxin (AFG1, AFG2, AFB2) levels in the outer surface of the fruit and the pulp inside (p=0.04, 0.01, 0.009) Table 4.10. Aflatoxin AFB1 was not detected in the inner parts of the baobab fruits. There was no significant difference between aflatoxin B1 levels in the outer and inner surface of baobab fruit.

Table 4.10: Aflatoxin analysis of the inner pulp and the outer shell of baobab fruits

Samples ID		Aflatoxin (μg/kg)			
		AFG2	**AFG1**	**AFB2**	**AFB1**
Inner pulp	18BIN	937±0.1	ND	ND	ND
	18GIN	1211±0.7	533±0.4	ND	ND
	20BIN	3915±0.3	532±0.7	ND	ND
	20GIN	1259±0.5	536±0.1	ND	20±0.3
	20RIN	1358±0.9	ND	ND	11±0.9
	20TIN	1121±0.1	ND	ND	ND
Outer shell	18BO	1976±0.4	533±0.1	ND	9±0.3
	18GO	3677±0.8	557±0.5	63±0.1	85±.8
	20BO	1584±0.6	762±0.8	66±0.5	ND
	20GO	14355±0.5	537±0.3	58±0.9	26±0.2

	20RO	4817±0.7	532±0.1	ND	17±0.3
	20TO	9283±0.6	534±0.2	67±0.8	5±0.3
P-value		0.04	0.01	0.009	0.20

CHAPTER FIVE

DISCUSSION

5.1 Moisture content and water activity of baobab products

Baobab candies had relatively high moisture content and water activity compared to the pulp. The highest moisture content in baobab pulp was 15.60% while that of candies was 23.47% (Table 4.1). The moisture content results were comparable to those of a study on the microbial content of commercial South African high-moisture dried fruits (Witthuhn et al., 2005). In baobab pulp processing, there is no addition of additives or liquids and the moisture content is dependent on the drying processes, transport, and storage conditions (Shimelis et al., 2019). On the other hand, in baobab candies processing water is added to dissolve additives such as food colour and sugar which in turn increases the moisture content (ICRAF, 2018). Poor packing and storage, which exposes the candies to a humid environment, resulting to moisture reabsorption, could be to blame for candies from informal processors having significantly higher moisture than those from formal processors. It could also be due to a lack of knowledge among informal baobab processors regarding the existing drying protocol and standards of processing dry fruits (Victor et al., 2017). The high moisture content in some baobab candies and pulp could cause microbial deterioration, reducing the shelf life of the products (Witthuhn et al., 2005). Water activity is an indicator of free water available in food that supports chemical and biological reactions (Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO), 2014) (United Nations, 2014). Candies from informal processors had a water activity of above 0.6 which falls into the category of intermediate moisture dried foods, where fungi are the most common spoilage microorganism (Murray et al., 2017; Witthuhn et al., 2005).

5.2 Microbial Loads of baobab products

The presence of microbes in food could either imply unfitness for consumption or the hygienic status during the preparation and processing(Olaimat & Holley, 2012a).

Nonetheless, exceeding certain levels such as total aerobic count above $1.0x10^{-4}$ CFU/g, *Enterobacteriaceae* $1.0x10^{-2}$ CFU/g, yeast and molds $1.0x10^{-4}$ CFU/g (KEBS, 2018), AFB1 2ppb, and total aflatoxin 4ppb as permitted for dried fruits can suggest of poor hygiene and food unfit for consumption (Guirguis, 2018). Surpassing the set limits shows a failure to comply with good hygiene practices (GHP) and good manufacturing practices (GMP) as set by KEBS, WHO, and Codex Alimentarius guidelines on dried fruit (Aber et al., 2019).

Enterobacteriaceae is frequently used as an indicator microorganism for the assessment of quality and hygiene conditions in the production while the total aerobic count is used to indicate bacterial populations, therefore, informing on compliance with GMP (Aboagye et al., 2020). The high levels of *Enterobacteriaceae* in 75% of the baobab pulp from informal processors (3.1±0.70 $\log_{10}$ CFU/g) (Table 4.1) could imply poor hygienic and sanitary conditions during processing (Daelman et al., 2013). Baobab candies had relatively low *Enterobacteriaceae* loads compared to the baobab pulp. All the candies from formal processors and 67% of those from informal processors were below the KEBS microbiological limit in terms of total aerobic count. The presence of total aerobic count in levels above $1.0x10^{-4}$ CFU/g in 75% baobab pulp (4.3±0.22) (Table 4.1) and in 33% candies from informal processors (5.00±0.22) show unhygienic handling environment along the baobab value chain. The total aerobic count results were comparable to those obtained in a study on the microbiological quality of selected dried fruits and vegetables (5.92±89) in Maseru, Lesotho (Victor et al., 2017).

Production practices, extrinsic, intrinsic, and processing factors determine the microbial load of food products at the time of consumption (European Commission, 2002). The baobab pulp contamination can be traced back to handling practices along the value chain (Jäckering et al., 2019). Most processors source baobab pulp from farmers or traders who crack the fruits on farms or in aggregation centres and store them in polythene sacks. More often than not, these farmers and traders may not be conversant with the set hygienic guidelines or the standard operating procedures during the cracking and scooping of the baobab fruits (Momanyi et al., 2019). A study on the microbiological quality of selected dried fruits and vegetables in Maseru, Lesotho, revealed a similar trend whereby the informal sector had significantly more microbial load compared to the formal sector (Victor et al., 2017).

Sun drying of baobab fruits might be one of the major contributions to pre-processing contamination. It is a slow and time-consuming process that ends up exposing the cracked fruits to insects, dust, rain, and other animals resulting in contamination (Sim´eon Bourdoux et al., 2016). This contamination is exacerbated by the lack of proper packaging bags and unhygienic packaging processes during storage and transportation to the final processors. A number of ready-to-eat products derived from baobab such as baobab pulp are not subjected to thermal processing and hence the chemical, physical and microbial hazards throughout the value chain find their way into the end product. Hygienic handling and processing are therefore mandatory for the safety of baobab pulp (Olaimat & Holley, 2012b).

During processing, candies undergo thermal treatment where sugar, food colour, and desired ingredients are dissolved in water and heated on while continuously stirring on medium heat. This is then cooled and packaged (ICRAF, 2018). Thermal treatment serves as a critical control point in the production of baobab candies where it significantly lowers the microbial load which explains the lower microbial load in baobab candies from the formal sector. Although candies undergo heat treatment that significantly lower the microorganism present in food, *Enterobacteriaceae* counts were still detected in 66.7% of the candies (1.80±0.56 $\log_{10}$ CFU/g) from the informal processors. Lack of sanitary hand washing facilities in production areas which are mostly in the homesteads may be the likely source of microbial contamination by the production personnel. During post-heating stages such as cooling and packaging microbes could be re-introduced to the finished products (European Commission, 2002).

The highest total aerobic count (TAC) contamination in candies was detected in samples collected from Mombasa County (Table 4.2) whereas the highest *Enterobacteriaceae* contamination was detected in samples collected from Kilifi County. This could be linked to the type of water used during processing. Groundwater supplies 50% of the water demand in the counties of Kilifi and Mombasa (Mwamburi, 2015). Microbiological findings of groundwater in Kilifi County indicated the presence of *E. coli* in shallow wells and boreholes (Jimoh et al., 2019).

5.3 Fungal and mycotoxin contents of baobab products

About 33 % of candies and 25% of pulp from informal processors were above the KEBS recommended limit for yeast and molds. The yeast and molds counts were slightly higher when compared to those obtained in a study on the microbiological quality of selected dried fruits and vegetables in Maseru, Lesotho (Victor et al., 2017). Candies from Mombasa and Kilifi Counties had the highest levels of yeasts and molds which could be due to the high temperature and humidity experienced most of the year in these two regions. The temperatures in Kilifi and Mombasa Counties are as high as 29 and 32 °C respectively, while the average annual humidity in both regions is 74 percent, with the most humid months being 80 percent, which is conducive for mold growth (Raccach & Mellatdoust, 2007). Furthermore, the polythene packages used for baobab candies and the majority of pulp from the informal sector may not be able to provide sufficient protection to prevent moisture-laden air from leaking in and, in addition, they have very little resistance to internal pressure. This renders the baobab candies and the pulp susceptible to moisture absorption which in turn favours the growth of yeast and molds. Safe moisture content and a relative humidity equilibrium have to be attained for the long storage of foodstuffs to suppress the proliferation of fungi (Hell et al., 2009).

All aflatoxin-contaminated baobab samples had concentrations (**Table 4.3**) that were by far higher than the maximum tolerable limits for the East Africa Community (EAC), where 5 µg/kg is used for AFB1, and 10 µg/kg for total aflatoxins whereas for the EU market 2 µg/kg is used for AFB1, and 4 µg/kg total aflatoxins. Temperature, water activity, and humidity play a vital role in fungal growth and mycotoxin production (Mamo et al., 2020). The water activity of samples 1 and 7, which are baobab pulp samples from the formal sector, and 12 and 14, which are candies from the informal sector, was above 0.7, which can easily provide a suitable environment for fungal growth, explaining the correlation between water activity and ergosterol content (Parsi & Górecki, 2006). Baobab trade in areas with elevated humidity and temperatures such as Kilifi and Mombasa can be disadvantageous if the moisture content is not controlled.

The water activity of samples 3 and 5, which are baobab pulp samples from formal sector, and sample 16, which is baobab pulp from informal sector, was less than 0.7, however, they had fungal and mycotoxin contamination which could be the result of direct fungal contamination, in which molds are transmitted from the environment into the product. Along the baobab value chain, some steps predispose baobab fruits to direct fungal contamination. Soil is the principal reservoir for fungal species inclusive of mycotoxin–producing fungi (Mamo et al., 2020). These fungi can invade baobab fruits during cracking and drying since these handling practices are done in the open in the farms. Besides, policies to ensure safe transportation of food products are not enforced, and therefore baobab pulp is transported in any available truck that provides cheap services. This may predispose the baobab pulp to environmental fungal contamination (Aristil et al., 2020).

The positive correlations observed (Table 4.4) between the water activity, ergosterol, and AFB2, AFG1, and AFG2 in contents in baobab samples respectively show that the quantitative measure of ergosterol is a good indicator of aflatoxin infection in food products (Lamper et al., 2000). The results obtained are comparable to the prediction of deoxynivalenol (DON) contamination in fusarium-infected wheat grains based on the determination of the ergosterol content (Lamper et al., 2000).

The majority of baobab products were free of fungal contamination; for instance, 75% of baobab pulp and 100% of baobab candies from the formal sector were free of fungal contamination. In the informal sector, fungal contamination was found in just 5% of the baobab pulp and candies. There could be a long shelf life for baobab goods during marketing, giving time for any fungal cells to proliferate and produce mycotoxins.

Products with such high pricing may have a low turnover rate; for example, the retail price for formal baobab pulp is 3000 KES ($30) for 200 grams. On the contrary, 200 grams of baobab pulp from informal processors retail at 50 KES (~$0.5). This leads to rapid turnover of these products due to the affordability by the majority low income earners. The results from the study show that there is minimal inspection of the on shelf baobab products by the regulatory agencies. There was no significant difference in AFB2 and AFG1 contamination between baobab samples from formal and informal processors, whereas for AFB1 and AFG2 a significant difference was observed. Since there are no standards or contamination monitoring protocols for baobab fruits in the farm areas, fungal contamination occurs most frequently during the earliest stages of handling, such as harvesting and drying (James et al., 2022). The farm supplies both formal and informal processors with already cracked baobab fruits (Kaimba, 2020; Kiprotich et al., 2019). Except for the candies, which are thermally treated, any contamination that has already occurred in the farms is almost impossible to eliminate.

Aflatoxin concentrations were ranging between 12.79±0.02 to $23.15 \pm 0.01 \times 10^3$ μg/kg in the analyzed samples indicating a potential health risk to baobab consumers (Karaca & Nas, 2006). The consumption of baobab candies and pulp is dispersed throughout several age groups. As a result, no population group is immune to the hazards posed by aflatoxin contamination in baobab products. Aflatoxin-contaminated baobab candies may have a long-term influence on children's growth because they are the primary consumers of the candies as snacks (Kiprotich et al., 2019). Another downside of having aflatoxin-contaminated pulp is that baobab products from the country of origin can be quarantined in the export markets with stricter mycotoxin regulatory controls. It is an exporter mandate to supply commodities with mycotoxins levels not exceeding the set maximum limits (European Commission, 2002).

5.4 HACCP Development

5.4.1 Preliminary steps to enable hazards analysis

Step 1: Food safety team

To implement the system's requirements, the company formed a multidisciplinary team of six people. The team formed was comprising of a production manager, production engineer, a food scientist, HACCP consultant, sales manager and the production team. The team received extensive training in the HACCP system and the ISO 22000: 2005 standard.

Steps 2 and 3: Product description and intended use

The food safety team began by thoroughly describing the baobab pulp, noting their composition, chemical, biological, and physical features, how the product is processed, a list of ingredients (if any), preservation methods, primary packaging, storage conditions, shelf life and the intended use of the baobab pulp (Table 4.5).

Steps 4 and 5: Flow diagrams and onsite confirmation

The flow diagram included a thorough list of each step required to produce baobab pulp (Figure 4.1). The flow diagram also showed the processes from the time the product is obtained until it reaches the consumer, in order to identify variables that may potentially affect product safety and which should be taken into consideration (Allata et al., 2017). The food safety team examined the flow diagrams on site.

5.4.2 HACCP principles

5.4.2.1 Principle 1: Hazard Analysis

The first principle entails performing a hazard analysis to evaluate the hazards associated with a product's manufacture. It involved gathering and analyzing information on hazards and the circumstances that led to their occurrence, so as to determine which hazards are important for food safety and should be addressed in the HACCP plan (Quinn & Marriott, 2002). First all the possible biological, chemical, and physical hazards were identified with the baobab pulp value chain (Table 4.6). This was followed by the risk assessment which involved evaluating potential adverse effects resulting from exposure to hazards.

The HACCP team assessed which hazards have been identified as "significant" whereby a significant hazard is one with a high likelihood of occurrence and severity of illness.

5.4.2.2 Principles 2,3,4, and 5: Determining Critical Control Points (CCPs) or Operational prerequisite program (OPRP), Establishing Critical Limits for the CCPs, Monitoring procedures and Corrective actions

CCP 1 – Processing step 3 (fruit reception)

The reception step was identified as the first CPP with the target hazard detected being aflatoxins. No subsequent step would eradicate or lower the levels of aflatoxins if they are not eliminated at this stage of the process. some of the monitoring methods put in place for this step included visual inspection of all fruits to ensure they were of that season, inspecting the fruits for any moldy surfaces, and analyzing each batch for total aflatoxins and aflatoxin B1 in a certified laboratory. This method of control was comparable to that deduced by the African Food Revisited by Research institute (AFTER) when conducting a study on HACCP for plant extracts as functional foods (AFTER, 2011). Farmers were reported to supply moldy baobab fruits from the previous season, some of which were contaminated with aflatoxins. In Kenya, the maximum aflatoxins limit for baobab products are 10 μg/kg for total aflatoxins (AFB1, AFB2, AFG1, AFG2) and 5 μg/kg for AFB1 (EAC, 2016). The baobab fruit suppliers were to be pre-qualified to ensure that only those trained in the handling of baobab are approved and given the responsibility of delivering baobab fruits. To prevent baobab fruits from overstaying at the reception bay during processing, the First In First Out (FIFO) principle was recommended; and finally, the baobab storage structure was to be covered on all sides to prevent rain from seeping into the fruits, which could result in high moisture content in the fruit, allowing yeast, molds, and bacteria to thrive.

5.4.5.2 OPRP 1 and OPRP 2- processing steps 8 & 9 (Scooping and Milling)

The OPRPs 1 and 2 were identified at the scooping and milling steps to control bacteria and yeast and molds Table 4.7. In baobab pulp processing there is a lot of handling in the scooping and milling, and this increases the chances of bacteria, yeast and molds contamination. Salmonella, *Enterobacteriaceae*, and staphylococcus aureus are some of the common bacteria that are handled during production. An effective cleaning and sanitation program, just like in any other food processing industry, is part of the process of eliminating bacteria (Victor et al., 2017).

A standard operating procedure for cleaning was created which included a sequence of washing, sanitizing, and rinsing of work surfaces. The system offered uniform, consistent cleaning while enabling cleaning operations to be traced back as should a standard system (Allata et al., 2017). Handwashing and sanitizing at regular intervals of 30 minutes were also part of the control methods used at this point in the production line. They were also required to wear white aprons and hairnets while processing. Any member of the production team was to be excused from duty in the event of injuries or open wounds on the hands. The pulp contact surfaces and storage buckets were to be cleaned with a food-grade soap and sterilized. The milling machine was to be cleaned before production and allowed to dry adequately, and it was then to be sprayed with ethanol. To avoid dust accumulation, the milling machine was to be covered while waiting for another batch to be processed. It was also proposed that the milling machine be air blown at high pressure and ethanol sprayed before processing. After processing, the pulping or milling machine was to be covered to prevent dust while waiting for another batch to be milled.

5.4.6 Establishing verification procedures, documentation, and record-keeping

Verification is the use of strategies, processes, and tests to ascertain whether a business complies with the HACCP plan and it encompasses all internal daily HACCP processes (Quinn & Marriott, 2002). Every three months, the quality assurance personnel were to conduct internal verification. During the verification, the HACCP manual and other records were to be cross-examined against the real condition in the company and any necessary changes made. A HACCP system certification agency was to conduct the external verification. Records are mandatory in any food industry operation with an effective HACCP system. The goal of record keeping is to demonstrate that the HACCP plan is in accordance with the documented system (Milios et al., 2012). The documentation was conducted as part of the monitoring process. Any remarks about the CCP, OPRP, critical limits, monitoring procedures, corrective action, and remarks about verification were to be properly documented and recorded during the baobab pulp processing. This data was to be used by Vokenel Enterprise Ltd during the implementation process.

5.4.1 Evaluation of Prerequisite programs –(PRPs)

The prerequisite programs serve as the basis for the development, implementation, and continuous maintenance of the HACCP (Milios et al., 2012). The study revealed that the environment and the premise conditions were suitable for the production of baobab pulp, however, there were key areas of concern discussed below.

5.4.1.1 The premises

The premises layout was poorly constructed permitting an easy entry of pests and rodents into the building and making it difficult to adopt the HACCP plan. In addition, the storage facility for the baobab fruits posed a food safety issues, especially during the rainy season. These findings were consistent to that reported by Masaad and Mustafa (Masaad & Mustafa, 2019), who evaluated HACCP prerequisite programs in beef meat exportation slaughterhouse at Khartoum state, Sudan. A well-designed and structured facility should assure the safety of food goods, hygienic conditions, proper cleaning, and pest infestation management. Renovations were proposed to keep insects and rodents out, as well as a shift in product flow to keep finished product away from the raw materials. In collaboration with management, a sanitation protocol for personnel hygiene and cleaning was also created. As for the baobab storage structure, it was suggested that the sides of the storage structure be covered in order to provide a rain barrier (Plate 5.1).

5.4.1.2 Maintenance, cleaning, and personal hygiene guidelines

While repairs had not been carried out in a while, the equipment was still fit for processing. The management was given the task of implementing the drawn maintenance, sanitation, and cleaning procedures. It was noted that there was no designated hand washing sink with an appropriate drying setting in the production area. In the production area, inadequate and insufficient hand sanitizing practices were noticed. These observation were similar to those of Liz Martins & Rocha, 2014 whose study was on Evaluation of prerequisite programs implementation at schools foodservice who came to the conclusion that the inadequate employee hygiene standards were one of the main weak points along the production process. Lack of resources and favorable conditions for proper hand washing practices were the main causes of incorrect personal hygiene habits identified in this study. Personal hygiene execution was advised, as well as the use of head covers, footwear, and aprons for staff handling processing, packaging, and storage of baobab pulp. Production personnel were subjected to a medical examination and issued with a food handler's certificate, with their compliance monitored. Monitoring of the cleanliness and hygiene of the employees was proposed. Visitors and all other contractors who could come into contact with the facility were to be subject to the same rules.

5.4.1.3 Traceability

There was no system in place for traceability. Establishing traceability procedures and programs for baobab fruits was judged crucial for enhancing food safety, inventory management, and trade effectiveness (Charlebois et al., 2014). A traceability index including batch number, incoming date, and output date was recommended, as well as the First in First Out (FIFO) approach to traceability. A structured protocol was in place for dealing with consumer concerns.

5.4.2 Microbial analysis before and after HACCP training

In this study, microbial analysis was deemed vital in determining the effectiveness of the prerequisite programs. The primary goal of the microbial analysis is to ensure that all possible sources of contamination are detected. It has also been used in other studies to assess the likelihood of occurrence of hazards and to establish sanitation standard operating procedures (SSOPs) (Kokkinakis & Fragkiadakis, 2007; Kvenberg & Schwalm, 2000). The significant reduction of the microbial loads in the personnel hands, the cracking machete, storage buckets and the pulping machine could be demonstrating the impact of the implementation of the personal hygiene and sanitary operation prerequisite programmes (Table 4.9). The findings were comparable to those of a study conducted in Greece on the microbiological quality of ice cream following the application of HACCP (Kokkinakis E et al., 2008).

5.4.3 Behavioral changes after HACCP training

There were also handwashing and foot sanitizing stations observed on the site after the HACCP training. Hand sanitation was also introduced during production, with hand sanitizing taking place at intervals of 30 minutes. The trend observed in this study matched that of a study done by (Kussaga et al., 2017) on microbiological performance of HACCP based food safety management systems. The general hygiene of the premises and the surroundings significantly improved (plate 5.3), as demonstrated by the cutting of grass around the compound, the cleaning of floors and work surfaces, and the reduction of microbial loads on the personnel hands, and storage buckets.

5.4.4 Aflatoxin analysis of the outer shell and inner pulp

The exterior surface of baobab fruits, if infected by mold may grow rapidly and more so if the drying process is not effectively carried out. The age of baobab fruits was mentioned as a factor while procuring baobab fruits for baobab pulp manufacturing. Fruits harvested in previous seasons are more likely to be moldy, depending on the method of storage of the fruits. Some storage practices expose baobab to humidity leading to mold growth. The findings of the aflatoxins analysis on the outer and inner surfaces of the baobab fruits, revealed that the shell acts as a protective barrier against the mycotoxins (Table 4.10). Mycotoxins, on the other hand, can easily migrate from the outer surface to the pulp during processing after the cracking of the fruits. To prevent this from happening a conveyer belt was suggested to help transfer the cracked fruits to the scooping station during the production of baobab pulp. This ensures that scooping occurs promptly after each fruit is broken, as opposed to formerly when all cracked fruits were piled together in one bucket to be scooped afterward.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In conclusion, products sourced from the informal processors recorded the highest bacteria contamination with 75% of baobab pulp and 33% of baobab candies from the informal processors exceeding the KEBS limit for both the total aerobic count (1.0×10^4 CFU/g) and *Enterobacteriaceae* (1.0×10^2 CFU/g). This could indicate unhygienic processing conditions and lack of awareness on good hygiene and manufacturing practices.

The majority of baobab products were free of fungal and aflatoxin contamination where, 75% of baobab pulp and 100% of baobab candies from the formal sector were free of fungal contamination. In the informal sector, fungal contamination was found in just 5% of the baobab pulp and candies. The findings of this study point to subpar postharvest handling practices as the source of fungal contamination for the baobab pulp and candies.

The establishment of a HACCP plan was deemed necessary for ensuring the safety of processed baobab products. To deal with the identified hazards, a complete HACCP plan, as well as the required pre-requisite programs were created. HACCP training proved to be the foundation of effective HACCP development. There were significant changes after the training was completed.

6.2 Recommendation

To baobab processors

HACCP development is critical to ensuring the safety of dried baobab fruits and baobab products along the baobab value chain; nevertheless, remedial procedures such as training on good hygiene and good manufacturing practices are required along the baobab value chain. Farmers must be educated on postharvest handling techniques because the first point of contamination occurs during cracking and drying in the fields.

Processors should look into obtaining un-cracked baobab fruits. This would ensure that monitoring procedures are in place throughout the processing system. It would also be simpler to incorporate a quality management system, such as HACCP, within the processing system. Baobab fruits should be dried using either convective air drying or vacuum drying. In the case that solar drying is to be employed, particularly in farms, indirect solar drying or enclosed solar dryers are recommended since they protect the fruits from insects, animals, and dust. Baobab fruits should be packaged in appropriate packaging materials, with primary and secondary packaging technologies, particularly hermetic bag packages, integrated.

Farmers

Farmers have an essential role in ensuring food safety because the value chain starts with them. When they are harvesting, cracking, packaging, and transporting, they should adhere to the established hygienic standards. It would be advantageous to have farmer group organization in order to pool resources and obtain the required training.

Wholesalers

Wholesalers are the main suppliers of baobab fruits to processors in cities. They should store baobab fruits in appropriate conditions which do not favor mold growth. Wholesalers should receive hands-on instruction in how to properly store and handle baobab fruits to ensure.

Kenya Bureau of Standards

The institution needs to collaborate closely with the processors, educating them on baobab handling guidelines and standards. Organized trainings may have an impact on them even as they train the rest of the actors along the baobab value chain. To monitor the safety of the products and inform on industry best practices for processing, they should look into the informal sector and provide some aid with registration while also advising on its importance.

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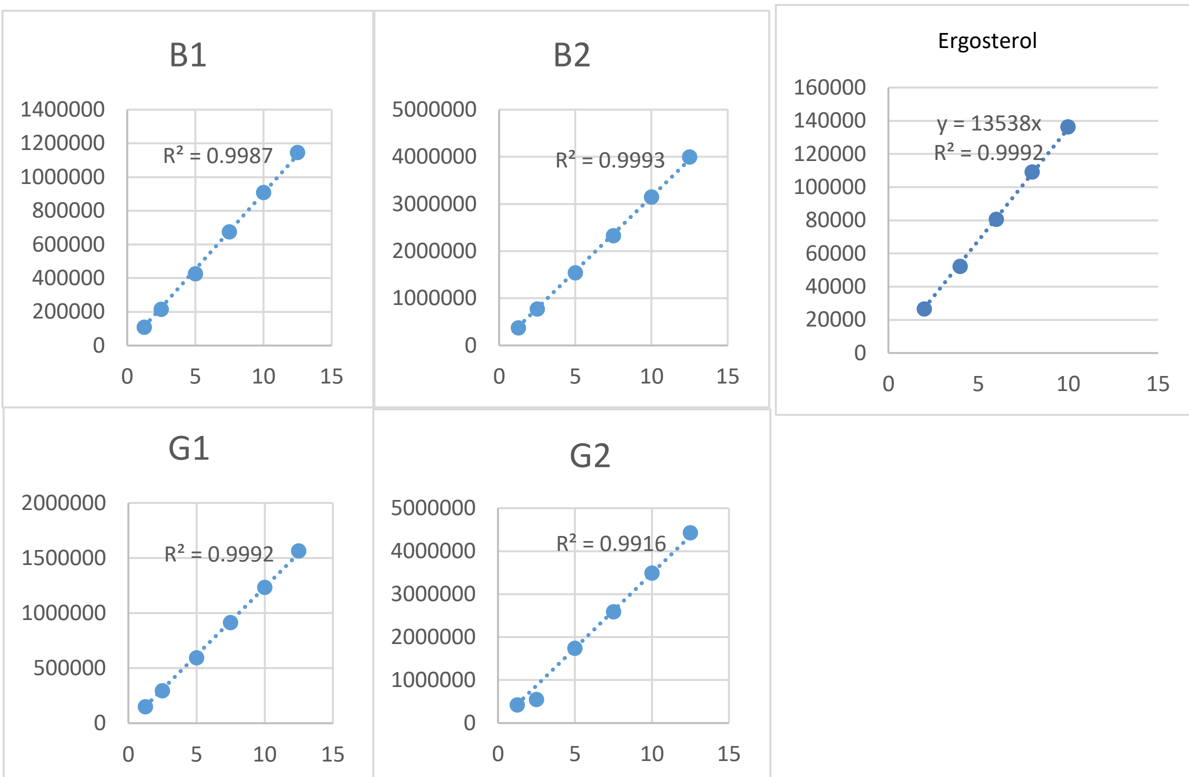
Plate 5.1: Baobab storage structure

Plate 5.2: Cracking and scooping of baobab fruits before HACCP training

plate 5.3: Cracking and scooping station after HACCP training

APPENDICES

Appendix I: Ergosterol and aflatoxin standard curves



Appendix II: Vokenel Enterprises Ltd Food Safety Policy

VOKENEL ENTERPRISES LTD is committed to the processing, packaging, storage and distribution of quality and safe human food products. To achieve this **VOKENEL ENTERPRISES LTD** commits to satisfying the statutory, regulatory and customer requirements and shall ensure adequate communication with all interested parties on food safety matters. **VOKENEL ENTERPRISES LTD** is committed to providing the required resources to meet the food safety objectives and achieve continual improvement.

Signed:

Managing Director

Date:

Appendix III: Pre-Requisite Programme For Facility Pest Control

1.0 Distribution list

- Production Manager
- Supervisor

2.0 Scope

This pre-requisite programme covers all the air and energy supply at Vokenel Ltd.

3.0 Responsibility

The Production Manager is responsible for the implementation of this prerequisite programme.

4.0 Reference documents

HACCP Plan

5.0 Definitions and abbreviations

Nil

FACILITY PEST CONTROL

Common pests in the processing plant

- Flying insects
- Rodents
- Birds pests

Flying insects:

1. Removal and elimination of breeding sites within the factory plant by frequently removing garbage generated from the factory.

2. Dust bins will be emptied regularly and kept away from doors. Compost pits will be designated away from the factory and incinerated on a daily basis.

3. The compound supervisor shall ensure that the cleaning drainages surrounding the factory are done at regular intervals and that the area is free of any stagnant water.

4. Regular inspection of the factory roof and walls will be done to ensure they are water proof. Cracks and crevices will also be checked with a view of eliminating them.

5. The factory has installed electrocution traps in designated areas within the plant to attract and execute flying insects. Dead flies will be removed from the traps regularly.

6. The factory plant will install self-closing doors and curtains to prevent flying insects from entering the processing buildings.

7. The factory will maintain an open well-kept perimeter around the processing plant to discourage rodent activity.

8. The production and compound supervisor will ensure removal of all general clutter from the factory plant and around the factory compound to eliminate possible rodent hiding sites.

9. All structural cracks and vent openings will be inspected and filled to prevent rodent entry.

10. Physical control systems including bait boxes and traps will be placed strategically around and within the processing plant to catch stray rodents.

Birds:

1. An entry barrier/bird proofing will be installed and maintained around the processing plant to blocks birds from entering the facility.

2. The production supervisors will inspect at regular intervals possible nesting and feeding sites on the factory buildings and in the vicinity with a view of eliminating them.

3. The production supervisor shall ensure daily cleaning of storage areas and processing equipment to remove spillages and accumulated dust.

4. Routine inspection of the entire plant to objectively identify possible pest problems

5. In event that a pest problem is noted during the routine inspection the following actions may be taken:

6. Repair or replacement of the ineffective elements of the pest control system

7. Hiring of a Pest Management Provider or expert to offer detailed pest control program.

All storage and production premises shall be managed as below;

i) The design and construction of the premises shall be suitable for the prevention of pest ingress and infestation build up.

ii) Adequate control measures shall be taken on incoming raw materials to prevent pest ingress.

iii) Good stock rotation shall be maintained to avoid pest build up.

iv) Potential entry points for pests shall be controlled e.g. drains, doors, windows, ventilation ducts shall be screened.

v) The site shall be well managed e.g. outside walls kept clear, spillage cleared and appropriate waste management practices implemented.

vi) There shall be an effective cleaning programme, clearly documented, thoroughly implemented and accurately recorded.

vii) Regular monitoring of pest activity shall be undertaken by a registered pest control contractor or suitably trained person and records kept.

In the event that preventative measures are not effective, the following requirements must be met;

(a) Any measures using controlled substances shall prevent direct contact with organic raw materials or product.

(b) All treatments shall be carried out by a suitably qualified person.

(c) Those parts of the site that are not used for organic production or storage, shall be treated, where possible, using only methods permitted within the organic standards. Use of other methods shall ensure the prevention of contamination of organic production or storage by migration, contact, personnel, etc.

(d) Organic fruits, semi-finished or finished products shall not be fumigated.

(e) Records shall be kept of all pest control measures taken.

(f) Substances used for pest control shall be correctly labelled and securely stored when not in use.

(g) Permission to use restricted treatments should be sought in advance from Ecocert. The application should detail reasons for use, substance and details of the procedures to avoid product contamination.

(h) Where an external pest control contractor is used, the contractor must be a registered member of the pest control board of Kenya.

(i) The contractor shall be made aware that the premises are used for storing or processing organic products, by asking the contractor to supply a letter confirming this, and by copying this section of the Standards, both of which are to be filed in the front of the pest control file.

(j) Where pest control is done in house, the person concerned shall be adequately trained.

(k) In all cases there shall be a plan of the baiting site.

Practices like putting physical barriers, sticky boards and use of pheromone traps shall be encouraged.

Factory fabric & environment

1. Preparation establishments shall be hygienic and precautions shall be undertaken to protect food from contamination and or deterioration.

2. The premises, walls, floors, etc., shall be suitable for the storage and processing of food and shall be maintained to prevent the ingress of pests & contaminants.

3. The surroundings shall be maintained in a clean and tidy state.

4. Concrete walls shall be kept clean to prevent the ingress of dirt into the factory environment.

Appendix IV: Pre-Requisite Programme For Equipment And Instruments

1.0 Distribution list

Production Manager

Supervisor

2.0 Scope

This pre-requisite programme covers all the equipment and instruments at Vokenel Enterprises Ltd.

3.0 Responsibility

The Production Manager is responsible for the implementation of this pre-requisite programme.

4.0 Reference documents

HACCP Plan

5.0 Definitions and abbreviations

Nil

6.0 Procedure

6.1 All plant equipment and instruments shall be so designed and of such material and workmanship as to be adequately cleanable, and shall be properly maintained.

6.2 The design, construction, and use of equipment and utensils shall preclude the adulteration of food with lubricants, fuel, metal fragments, contaminated water, or any other contaminants.

6.3 All equipment shall be so installed and maintained as to facilitate the cleaning of the equipment and of all adjacent spaces.

6.4 Food-contact surfaces shall be corrosion-resistant. They shall be made of non-toxic materials and designed to withstand the environment of their intended use and the action, and, if applicable, cleaning compounds and sanitizing agents.

6.5 Food-contact surfaces shall be maintained to protect baobab pulp from being contaminated by any source, including unlawful indirect food additives.

6.6 Equipment that is in the manufacturing or food-handling area and that does not come into contact with food shall be so constructed that it can be kept in a clean condition.

6.7 Holding, conveying, and manufacturing systems, including gravimetric, pneumatic, closed, and automated systems, shall be of a design and construction that enables them to be maintained in an appropriate sanitary condition.

Appendix V: Pre-Requisite Programme For Facility Hygiene

1.0 Distribution list

- Production Manager
- Supervisor

2.0 Scope

This pre-requisite programme covers all the equipment and instruments at Vokenel Enterprises Ltd.

3.0 Responsibility

The Production Manager is responsible for the implementation of this pre-requisite programme.

4.0 Reference documents

HACCP Plan

5.0 Definitions and abbreviations

Nil

FACILITY HYGIENE

1. Cleaning procedure shall describe the cleaning requirements for each store, production area, staff facilities, item or equipment and working surfaces. Cleaning frequency shall be described as daily, weekly or monthly and cleaning materials shall also be included. The procedures shall ensure that contact surfaces are rinsed with potable water before organic products are processed.

2. The cleaning and hygiene measures shall comply with industry standards and best practice to ensure that the products are not contaminated by microbes, chemicals, foreign bodies or residues from non-organic products.

3. Cleaned surfaces of equipment and working areas coming into contact with the organic product shall be rinsed with potable water to remove any trace of hygiene detergents used for cleaning.

4. There shall be verification that the cleaning has been done to the appropriate standard and that the equipment and contact surfaces have been washed with potable water and this shall be recorded in a checklist for each operation and signed by the production in charge.

5. Cleaning detergents shall be clearly labelled and stored safely to ensure that the products cannot be contaminated.

6. Material Safety Data Sheets must be held on file for the cleaning detergents which have been approved by the certification body for use.

7. Factory fabric & environment cleaning;

a. Preparation establishments shall be hygienic and precautions shall be undertaken to protect food from contamination and or deterioration.

b. The premises, walls, floors, etc., must be suitable for the storage and processing of food and shall be maintained to prevent the ingress of contaminants.

c. The surroundings shall be maintained in a clean and tidy state.

d. Concrete walls shall be kept clean to prevent the ingress of dirt into the factory environment.

e. Loading areas adjacent to stores shall be cleaned regularly.

Appendix VI: Pre-Requisite Programme for Plant Design, Construction and Grounds

1.0 Distribution list

- Production Manager
- Supervisor

2.0 Scope

This pre-requisite programme covers all the grounds and plant at Vokenel Enterprises Ltd.

3.0 Responsibility

The Production Manager is responsible for the implementation of this pre-requisite programme.

4.0 Reference documents

HAACP plan

5.0 Definitions and abbreviations

Nil

6.0 Procedure

6.1 The grounds about Vokenel shall be kept in a condition that will protect against the contamination of food. The methods for adequate maintenance of grounds shall include, but are not limited to:

6.1.1 Properly storing equipment, removing litter and waste, and cutting weeds or grass within the immediate vicinity of the plant buildings or structures that may constitute an attractant, breeding place, or harborage for pests.

6.1.2 Maintaining yards, and parking lots so that they do not constitute a source of contamination in areas where the baobab pulp is exposed

6.1.3 Adequately draining areas that may contribute contamination to baobab pulp by foot-borne filth, or providing a breeding place for pests.

6.1.4 Operating systems for waste treatment and disposal in an adequate manner so that they do not constitute a source of contamination in areas where baobab pulp is exposed.

6.2 Since the grounds are bordered by grounds not under the Vokenel control and not maintained in the manner described above, care shall be exercised in the plant by inspection, extermination, or other means to exclude pests, dirt, and filth that may be a source of food contamination.

6.3 Plant buildings and structures shall be suitable in size, construction, and design to facilitate maintenance and sanitary operations for food-manufacturing purposes. The plant and facilities shall:

6.3.1 Provide sufficient space for such placement of equipment and storage of materials as is necessary for the maintenance of sanitary operations and the production of safe Baobab pulp.

6.3.2 Permit the taking of proper precautions to reduce the potential for contamination of baobab pulp, its contact surfaces, or packaging materials with microorganisms, chemicals, filth, or other extraneous material.

6.3.3 Be constructed in such a manner that floors, walls, and ceilings may be adequately cleaned and kept clean and kept in good repair; and that aisles or working spaces are provided between equipment and walls and are adequately unobstructed and of adequate width to permit employees to perform their duties and to protect against contaminating baobab pulp or pulp contact surfaces with clothing or personal contact.

6.3.4 Provide adequate lighting in hand-washing areas, dressing and locker rooms, and toilet rooms and in all areas where baobab pulp is examined, processed, or stored and where equipment or utensils are cleaned; and provide safety-type light bulbs, fixtures, skylights, or other glass suspended over exposed baobab pulp in any step of preparation or otherwise protect against baobab pulp contamination in case of glass breakage.

6.3.5 Provide adequate ventilation and locate and operate fans and other air-blowing equipment in a manner that minimizes the potential for contaminating baobab pulp, pulp-packaging materials, and pulp-contact surfaces.

6.3.6 Provide, where necessary, adequate screening or other protection against pests.

7.0 Records

Waste disposal records

Cleaning records

Appendix VII: Pre-Requisite Programme for Product Processing

Distribution list

- Production Manager
- Supervisor

Scope

This pre-requisite programme covers all the operations at Vokenel Enterprises Ltd.

Responsibility

The Production Manager is responsible for the implementation of this pre-requisite programme.

Procedure

1.1 All operations in the receiving, inspecting, transporting, segregating, preparing, manufacturing, packaging, and storing of baobab pulp shall be conducted in accordance with adequate sanitation principles.

1.2 Appropriate quality control operations shall be employed to ensure that baobab pulp is suitable for human consumption and that the packaging materials are safe and suitable.

1.3 Overall sanitation of the plant shall be under the supervision of one or more competent individuals assigned responsibility for this function. All reasonable precautions shall be taken to ensure that production procedures do not contribute contamination from any source.

1.4 Chemical, microbial, or extraneous-material testing procedures shall be used where necessary to identify sanitation failures or possible baobab pulp contamination.

1.5 All pulp that has become contaminated to the extent that it is adulterated shall be rejected.

1.6 All plant equipment and utensils shall be so designed and of such material and workmanship as to be adequately cleanable, and shall be properly maintained.

1.7 Baobab pulp-contact surfaces shall be maintained to protect pulp from being contaminated by any source.

Additional steps

i) The ladies scrub the greenish, itchy fuzz off of each fruit with brushes so it does not get mixed in with the fruit pulp

ii) During processing, precautionary measures shall be taken to avoid the risk of contamination by dis-allowed synthetic substances or products.

iii) When non-organic products are also prepared or stored in the preparation unit concerned, the following measures shall be put in place;

(a) Ensure that the production of processed organic products is kept separate in time or space from the production of processed non-organic products.

(b) Carry out the operations continuously until the complete run has been dealt with, separated by place or time from similar operations performed on non-organic products.

(c) Inform the control body on annual production plans and keep available an updated register of all operations and quantities of products processed.

(d) Take the necessary measures to ensure identification of lots and to avoid mixtures or exchanges with non-organic products.

(e) Carry out operations on organic products only after suitable cleaning of the production equipment.

Appendix VIII: Pre-Requisite Programme for Sanitary Operations

1. HANDLING INCOMING MATERIALS

1.0 Distribution list

- Production Manager
- Supervisor

2.0 Scope

This pre-requisite programme covers all the incoming packaging materials, ingredients, chemicals and raw materials at Vokenel Ltd.

3.0 Responsibility

The Production Manager is responsible for the implementation of this pre-requisite programme.

4.0 Reference documents

HACCP Plan

5.0 Definitions and abbreviations

Nil

6.0 Procedure

6.1 Packaging materials shall be inspected and segregated or otherwise handled as necessary to ascertain that they are clean and suitable for packing baobab pulp.

6.2 Containers and carriers of raw packaging materials should be inspected on receipt to ensure that their condition has not contributed to the contamination or deterioration of packaging material.

6.3 Packaging materials and other ingredients shall either not contain levels of microorganisms that may produce food poisoning or other disease in humans shall be rejected.

6.4 Packaging materials, other ingredients which shall be held in containers designed and constructed so as to protect against contamination and shall be held at such temperature and relative humidity and in such a manner as to prevent the baobab pulp from becoming adulterated.

6.5 Liquid or dry raw materials and other ingredients received and stored in bulk form shall be held in a manner that protects against contamination

7.0 Records

Incoming materials inspection records

8.0 KPIs

Nil contaminated packaging material on the production floor.

2. STORAGE OF PRODUCTS AND RAW MATERIALS

1.0 Distribution list

- Production Manager

- Supervisor

2.0 Scope

This pre-requisite programme covers all the STORAGE at Vokenel Ltd.

3.0 Responsibility

The Production Manager is responsible for the implementation of this prerequisite programme.

4.0 Reference documents

HACCP Plan

5.0 Definitions and abbreviations

Nil

6.0 Procedure

6.1 Secondary materials for storage are categorized as follows:

a) Chemicals

b) Liquids e.g. paint, battery water, glue, lubricating oils

c) Fragile items

6.2 The storekeeper ensures that the arrangement of the stores facilitates accessibility of items, segregation of unlike items, and practice of material issuance as per the FIFO method.

6.3 The storekeeper also ensures that the store is maintained in a clean state at all times as per the cleaning schedule of the store.

7.0 Records

a) Stores records

b) Cleaning checklist for stores

c) Pest control book for Packing

8.0 KPIs

Nil cross contamination

3. **TRANSPORTATION OF FINISHED PRODUCTS**

1.0 Distribution list

- Production Manager

- Supervisor

2.0 Scope

This pre-requisite programme covers all the transportation at Vokenel Ltd.

3.0 Responsibility

The Production Manager is responsible for the implementation of this prerequisite programme.

4.0 Reference documents

HACCP Plan

5.0 Definitions and abbreviations

Nil

6.0 Procedure

6.1 All vehicles transporting finished products from the factory must be from the authorized transporter and should comply with the requirements stipulated in the transport contract.

6.2 The drivers will be required to wash and dry the interior surfaces of the carrier prior to loading and inspected for cleanliness

6.3 Prior to loading the supervisor will check and document on the dispatch note identification details of the truck and the driver

6.4 Routine inspection of every baobab pulp transport vehicle to check for compliance to baobab pulp transport requirements prior to loading will be done.

6.5 Refrain from loading any vehicle found to be non-compliant to the baobab pulp transport vehicle requirements.

7.0 Records

- Baobab pulp transport inspection checklist
- Baobab pulp transport requisitions Records

8.0 KPIs

Nil cross contamination

Appendix IX: Pre-Requisite Programme for Plant Design, Construction and Grounds

1.0 Distribution list

- Production Manager
- Supervisor

2.0 Scope

This pre-requisite programme covers all the grounds and plant at Vokenel Enterprises Ltd.

3.0 Responsibility

The Production Manager is responsible for the implementation of this pre-requisite program.

4.0 Reference documents

HAACP plan

5.0 Definitions and abbreviations

Nil

6.0 Procedure

6.1 The grounds about Vokenel shall be kept in a condition that will protect against the contamination of food. The methods for adequate maintenance of grounds shall include, but are not limited to:

6.1.1 Properly storing equipment, removing litter and waste, and cutting weeds or grass within the immediate vicinity of the plant buildings or structures that may constitute an attractant, breeding place, or harborage for pests.

6.1.2 Maintaining yards, and parking lots so that they do not constitute a source of contamination in areas where the baobab pulp is exposed

6.1.3 Adequately draining areas that may contribute contamination to baobab pulp by foot-borne filth, or providing a breeding place for pests.

6.1.4 Operating systems for waste treatment and disposal in an adequate manner so that they do not constitute a source of contamination in areas where baobab pulp is exposed.

6.2 Since the grounds are bordered by grounds, not under the Vokenel control, and not maintained in the manner described above, care shall be exercised in the plant by inspection, extermination, or other means to exclude pests, dirt, and filth that may be a source of food contamination.

6.3 Plant buildings and structures shall be suitable in size, construction, and design to facilitate maintenance and sanitary operations for food-manufacturing purposes. The plant and facilities shall:

6.3.1 Provide sufficient space for such placement of equipment and storage of materials as is necessary for the maintenance of sanitary operations and the production of safe Baobab pulp.

6.3.2 Permit the taking of proper precautions to reduce the potential for contamination of baobab pulp, its contact surfaces, or packaging materials with microorganisms, chemicals, filth, or other extraneous material.

6.3.3 Be constructed in such a manner that floors, walls, and ceilings may be adequately cleaned and kept clean and kept in good repair; and that aisles or working spaces are provided between equipment and walls and are adequately unobstructed and of adequate width to permit employees to perform their duties and to protect against contaminating baobab pulp or pulp contact surfaces with clothing or personal contact.

6.3.4 Provide adequate lighting in hand-washing areas, dressing and locker rooms, and toilet rooms and in all areas where baobab pulp is examined, processed, or stored and where equipment or utensils are cleaned; and provide safety-type light bulbs, fixtures, skylights, or other glass suspended over exposed baobab pulp in any step of preparation or otherwise protect against baobab pulp contamination in case of glass breakage.

6.3.5 Provide adequate ventilation and locate and operate fans and other air-blowing equipment in a manner that minimizes the potential for contaminating baobab pulp, pulp-packaging materials, and pulp-contact surfaces.

6.3.6 Provide, where necessary, adequate screening or other protection against pests.

Appendix X: Pre-Requisite Programme for Personnel Hygiene

1.0 Distribution list

- Production Manager
- Supervisor

2.0 Scope

This pre-requisite program covers all the personnel at Vokenel Ltd.

3.0 Responsibility

The Production Manager is responsible for the implementation of this pre-requisite program.

4.0 Reference documents

HACCP Plan

5.0 Definitions and abbreviations

Nil

6.0 Procedure

6.1 The plant management shall take all reasonable measures and precautions to observation is shown to have, or appears to have, an illness, open lesion, including boils, sores, or infected wounds, or any other source of microbial contamination by which there is a reasonable possibility of baobab pulp, pulp contact surfaces, or baobab pulp-packaging materials becoming contaminated, shall be excluded from any operations which may be expected to result in such contamination until the condition is corrected.

6.2 Personnel shall be expected to report any of the above-mentioned health conditions to their supervisors.

6.3 The factory staff undergo medical check-ups every six months and a medical certificate is issued thereof. This is done to check whether any member of staff is a carrier of pathogenic microorganisms.

6.4 Staff members will also be required to report any accidents sustained at the workplace to facilitate immediate attention.

6.5 All persons working in direct contact with baobab pulp, pulp-contact surfaces, and baobab pulp packaging materials shall conform to hygienic practices while on duty to the extent necessary to protect against contamination of baobab pulp. The methods for maintaining cleanliness include, but are not limited to:

6.5.1 Wearing outer garments suitable to the operation in a manner that protects against the contamination of baobab pulp, pulp-contact surfaces, or baobab pulp-packaging materials.

6.5.2 Maintaining adequate personal cleanliness.

6.5.3 Washing and drying hands thoroughly (and sanitizing if necessary to protect against contamination with undesirable microorganisms) in an adequate hand-washing facility before starting work, after each absence from the work station, and at any other time when the hands may have become soiled or contaminated.

6.5.4 Removing all unsecured jewelry and other objects that might fall into, equipment, or containers, and removing hand jewelry that cannot be adequately sanitized during periods in which baobab pulp is handled by hand. If such hand jewelry cannot be removed, it may be covered by material that can be maintained in an intact, clean, and sanitary condition and which effectively protects against the contamination by these objects of the baobab pulp, pulp contact surfaces, or pulp-packaging materials.

6.5.5 Maintaining gloves, if they are used in baobab pulp handling, in an intact, clean, and sanitary condition. The gloves should be of an impermeable material.

6.5.6 Wearing, where appropriate, in an effective manner, hair nets, headbands, caps, beard covers, or other effective hair restraints.

6.5.7 Storing clothing or other personal belongings in areas other than where baobab pulp is exposed or where equipment or utensils are washed.

6.5.8 Confining the following to areas other than where baobab pulp may be exposed or where equipment or utensils are washed: eating food, chewing gum, drinking beverages, or using tobacco.

6.5.9 Taking any other necessary precautions to protect against contamination of baobab pulp, pulp-contact surfaces, or baobab pulp-packaging materials with microorganisms or foreign substances including, but not limited to, perspiration, hair, cosmetics, tobacco, chemicals, and medicines applied to the skin.

6.6 The supervisors responsible for identifying sanitation failures or baobab pulp contamination shall have a background of education or experience, or a combination thereof, to provide a level of competency necessary for the production of clean and safe baobab pulp.

6.7 Food handlers and supervisors shall receive the appropriate training in proper food handling techniques and food protection principles and shall be informed of the danger of poor personal hygiene and unsanitary practices.

6.8 Responsibility for assuring compliance by all personnel with all requirements of this part shall be assigned to the supervisors. During production, supervisors maintain constant vigilance to ensure that workers adhere to the Hygiene Code.

6.9 Management shall ensure that the supervisors comply.

6.10 Visitors - Supervisors must also ensure that no visitor is allowed to the production area without fully complying with the requirements of the Hygiene Code.

7.0 Records

Personnel hygiene inspection records

Personnel education and training records

Personnel health records and analysis report

Personnel Hygiene Code

Appendix XI: Pre-Requisite Programme for Water Quality and Supply

1.0 Distribution list

- Production Manager
- Supervisor

2.0 Scope

This pre-requisite program covers all the water supply and sanitary facilities at Vokenel Ltd.

3.0 Responsibility

The Production Manager is responsible for the implementation of this prerequisite program.

4.0 Reference documents

HACCP Plan

5.0 Definitions and abbreviations

Nil

5.1 The water supply shall be sufficient for the operations intended and shall be derived from an adequate source.

5.2 Any water that contacts baobab pulp-contact surfaces shall be safe and of adequate sanitary quality. Running water at a suitable temperature, and under pressure, as needed, shall be provided in all areas where required for the cleaning of equipment, utensils, and employee sanitary facilities.

5.3 There are two categories of water used at the plant:

a) Raw water – comprises of water used for boilers and fire-fighting systems.

b) Treated water – comprises of water used for processing, quality control purposes, domestic consumption, and for cleaning of plant and equipment. This water must be treated and comply with the KEBs standards for portable water.

5.4 A maintenance program is in place for monthly cleaning of the water storage tanks and water supply line

5.5 Bacteriological and chemical analysis of the treated water is carried out every year.

5.6 If the water fails to comply with the company's standard, the treatment process shall be re-evaluated and corrective action taken accordingly. The water shall then be re-analyzed to verify the effectiveness of the corrective action.

5.7 Plumbing shall be of adequate size and design and adequately installed and maintained to:

5.7.1 Carry sufficient quantities of water to required locations throughout the plant.

5.7.2 Properly convey sewage and liquid disposable waste from the plant.

5.7.3 Avoid constituting a source of contamination to baobab pulp, water supplies, equipment, or utensils or creating an unsanitary condition.

5.7.4 Provide adequate floor drainage in all areas where normal operations release or discharge water or other liquid waste on the floor.

5.7.5 Provide that there is no backflow from, or cross-connection between, piping systems that discharge wastewater or sewage and piping systems that carry water for processing purposes