**KWAME NKRUMAH UNIVERISTY OF SCIENCE AND TECHNOLOGY**

# HAZARD ANALYSIS AND CRITICAL CONTROL POINT (HACCP) PLAN FOR DRIED FRUIT PROCESSING

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of

M.Sc. FOOD QUALITY MANAGEMENT

BY

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## DECLARATION

I hereby declare that this submission is my own work towards the M.Sc. and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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# DEDICATION

This work is dedicated to the memory of my late mother, Agnes Maku Nyumuah aka Yohunor and to my wife, Doreen Aya Nkoah  Nyumuah.

# 1 ACKNOWLEDGEMENT

I am grateful to the God in three persons, Holy Trinity, for the enablement and provision to pursue this programme successfully.

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# 2 ABSTRACT

To process dried pineapples, fresh pineapples are washed, peeled, cured and sliced into rings or chunks. Sliced pineapples are then dipped in 5 ppm $Na_2S_2O_5$ and spread on trays for drying in a forced hot air chamber set at 62°C to 65°C for 24 hours. Dried fruits, usually to a moisture content of 12% to 13%, are cooled, trimmed and packed. In this study, the principles of HACCP were applied to forced air dried fruits processing using pineapple as the reference product. Following a typical batch processing from reception of raw materials to the final product is packed in a secondary carbon carton, each process step was correctly identified and subjected to hazard analysis to identified all potential food safety hazards that could possibly be associated with each step. Each hazard identified was classified based on the three major hazards, (biological, chemical and physical) and subjected to a hazard evaluation matrix to determine the level of significance. Six (6) hazards associated with five (5) processing steps were evaluated to have high level of significance. The steps are peeling, drying, trimming and metal scanning and the hazards are biological except for peeling and drying that also possess significant physical hazard risk from iron fillings from cutting edges and rust within the drying chamber. Subjecting these steps to the CCP Decision Tree, the drying and scanning steps were identified as CCPs to control biological and physical hazards respectively. Drying at 62°C for 24 hours does not only destroy pathogens but also brings the product to moisture content of less than 14%, $a_w$ <.065 and 3.04-4.0 pH. These characteristics also constitute a multi-huddle to prevent survival and growth of most pathogens. A metal detector validated for Ferrous 1.19mm, Non-ferrous 2.0mm and Stainless 2.5mm is also effective CCP for detecting and eliminating products that could be contaminated with iron fillings or flacks of rust. Thus two (2) CCPs were identified and critical limits set for drying at 62°C for 24 hours and scanning with a metal detector with sensitivity of Ferrous 1.19mm, Non-ferrous 2.0mm and Stainless 2.5mm.

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# 6 ABBREVIATION

| | |
|---|---|
| AOAC | Association of Analytical Communities (Voluntary Analytical Methods) |
| BH | Biological hazards |
| BRC | British Retail Consortium (Voluntary Standards) |
| CCP | Critical Control Point |
| CODEX | Codex Alimentarius Commission |
| EU | European Union |
| FDA | Food and Drugs Authority |
| FMEA | Failure Mode Effect Analysis |
| FRI | Food Research Institute |
| GHP | Good Hygiene Practice |
| GIZ | German Agency for International Cooperation |
| GIZ-MOAP | GIZ – Market Oriented Agriculture Program |
| GMP | Good Manufacturing Practice |
| HACCP | Hazard Analysis Critical Control Point |
| IFS | International Featured Standard |
| ISO | International Organization for Standardization |
| MOFA | Ministry of Food and Agriculture |
| MRL | Maximum Residue Level |
| PRP/PrP | Prerequisite Program |
| QA | Quality Assurance |
| QM | Quality Manager |
| QMS | Quality Management System |

| | |
|---|---|
| SME | Small and Medium Enterprises |
| SOP | Standard Operating Procedure |
| SQA | Supplier Quality Assurance |
| USFDA | United States Food and Drug Administration |
| WHO | World Health Organization |

# CHAPTER ONE

# INTRODUCTION

## 1. INTRODUCTION

Food safety is the concept that food will not cause harm to the consumer when it is prepared and/or consumed according to its intended use (Mead *et. al.*, 1999). High standards of hygiene are therefore imperative to prevent food poisoning, food spoilage, pest infestation, as well as loss of business.

Consumers and governments are currently pushing for safer food management systems throughout the entire food supply chain, from primary producers to exporter, feed manufacturers to restaurants (Taylor, 2001). What is more is that consumers want proof of your food safety up-front, in addition to being assured that the company will continue to meet their needs now and in the long-term.

To ensure profitable operations while meeting these demands, managers must implement policies and systems relating to all their activities. One of the most important of these policies is maintaining cost-effective hygiene by way of a food safety management system based on the principles of Hazard Analysis Critical Control Points (HACCP). HACCP systems are designed to prevent and control food safety hazards associated with food from farm to fork (Stevenson, 1990).

HACCP was a brain child of the Pillsbury Company in the US in collaboration with the US army and NASA in their attempt to produce safer food for astronauts (Marques *et. al.*, 2012). The system was fashioned along an engineering management technique called Failure, Mode and Effect Analysis (FMEA). FMEA is characterised by a study of every single step of the process by analysing what can go wrong, the possible causes of the problem and its possible effect (ICMSF, 1998). Thus similar to FMEA, HACCP focuses on food safety hazards and attempts to establish control mechanisms designed to ensure the safety of the product. HACCP is therefore a set of proactive food safety management principles aimed at preventing the occurrence of food safety hazards along the entire value chain in order to assure safer food delivery.

HACCP is not only recommended by Codex and FAO but also the United States Food and Drugs Administration (USFDA), as well as, the European Union (EU) Commission. In some developed countries, the implementation of HACCP is mandatory for selected food industries such as the dairy and egg industry in the US. It is also widely structured into requirements in many global standards such as the British Retail Consortium (BRC), ISO 22000, IFS among others. HACCP focuses on the technology of food safety management and therefore makes it easy for standard bodies such as the ISO to transmit its principles into technical requirements in combination with management principles to achieve full standards. In fact, the ISO 22000 was developed mainly for the EU market to be able to convert the principles of HACCP into auditable requirements (Arvanitoyannis and Kassaveti, 2009).

Food drying is an old technology applied in food preservation. The technology involves the removal of water from food through either evaporation or sublimation (Brennan, 2006). There are three types of drying based on technology and principles. These are sun/solar drying, forces air drying and sub-atmospheric drying. This project will however focus on forces air drying of fruits. This involves burning of fossil fuel to generate heat which is blown over a bed of fruits (slices, chopped, etc.) in a chamber. The drying process employs the principles of evaporation and diffusion to remove water from the surface and from the centre of the fruits respectively.

Drying as business in Ghana was initiated and is heavily supported by the German Agency for International Cooperation, providing technical assistance to the Food Research Institute and private sector enterprises. Dried fruits processing in Ghana targets mainly the European market. It is estimated that only 10% of dried fruits in Europe is consumed directly (ITC, 2015). The remaining is used as additives in breakfast cereals and baby foods. The market is therefore very sensitive requiring high standards for food safety and quality management systems.

## 1.1. DEVELOPMENT OF FRUIT DRYING TECHNOLOGY IN GHANA

For many developing countries and for Ghana in particular, agriculture remains an important driver of economic growth, development, and employment. The challenge to agriculture is not only limited to issues concerning efficient production but heavily affected by post-harvest losses. Ghana‟s post-harvest losses of pineapples have been estimated to be in the ranges of 15% to 25% (GIZ 2016). These huge losses could be attributed to poor infrastructure including access roads to farm gates, storage facilities and the weak agroprocessing infrastructure.

In line with this, the German Development Cooperation (GIZ) in collaboration with Ministry of Food and Agriculture (MOFA) initiated the Market Oriented Agriculture Programme (MOAP) with the main objective of applying the value chain approach to resolving some the challenges bedevilling the agricultural sector of the economy. This project aims at providing extensive technical support to selected value chains through innovation and the adoption of appropriate technology and best practices to improve crop yield, limit postharvest losses and increase market assess to horticultural products from Ghana. One of the major achievements of the project is the introduction of fruit drying technology onto the Ghanaian agro-processing landscape (Swetman et al., 2011).

In partnership with the Food Research Institute (FRI), MOAP has established a fruit drying centre within the premises of FRI to serve both the purpose of research, as well as an incubation centre to promote fruit drying in Ghana. Dryers installed at the drying centre for fruit drying includes:

- Two solar dryers
- Two tunnel dryers (forces air fuelled by LGP)
- An oven dryer (forced air fuelled by electricity)

These dryers, installed in 2011, are the first types of commercial dryers in Ghana (Bashiru, 2015). Over the years, different entrepreneurs have used the facility with three of these incubators currently operating commercially for exports into the EU.

## 1.2. PROBLEM STATEMENT

Today"s consumer has the privilege of enjoying a wide variety of well-balanced food with broad sensory characteristics, longer shelf life effective and attractive packaging and with a greater degree of convenience. Thanks to the fast pace of improvement in food science and technology with its associated commercialization of technology and globalization of businesses. Moreover, issues of nutrition and supply chain management have contributed extensively to this achievement. Despite these achievements, the safety of these foods still remains a major concern (Kaferstein, 2003). Food borne related diseases and organisms such as Bovine Spongiform Encephalopathy (BSE), dioxins, E. c*oli*, *Listeria*, etc have become a very common threat in the last two decades or so (Mead *et. al.*, 1999). As though this is not enough, consumers are now confronted with the possibilities of food terrorism, especially after the 9:11 attack on the United State of America (USA). Nations are therefore going every length to protect the health and safety of their citizenry (Meselson, *et. al.*, 2002).

Issues relating to food safety have, therefore, assumed a major stage in the global food trade. It is common for nations to use food safety as a non-tariff barrier for imported food products. In fact, the issue of food safety assumes not just business dimension but also political (WHO, 2002). The situation is no different in Ghana where the Food and Drugs Authority (FDA) and Ghana Standards Authority make public statements concerning unwholesome food items and close down several food industries due to poor standards and non-existence of a Quality Management System (QMS).

Unfortunately, while the developed countries have instituted measures to assure food safety, same cannot be said of developing countries. Unlike the EU and USA, the national regulator, the FDA of Ghana does not mandate HACCP as a prerequisite for market authorisation. Local food manufacturing companies therefore do not see the need in implementing food safety management systems such a s HACCP when it is neither market nor regulatory driven (Ackah *et al.*, 2014). Our local food industry thus operates on the tenet of Good Manufacturing Practices (GMP), a proposition that does not make them competitive on the international market. HACCP is a basic requirement to enter the international market, especially the EU and North American markets.

Dried fruits, one of the newest entrants into the Ghanaian food industry have a target market in the EU where HACCP is a basic requirement. In fact, the market will not only require HACCP in isolation but more likely in combination with other management systems that may be prescribed in standards such as the BRC, IFS and ISO among others. Any entrepreneur that ventures into this dried fruits industry in Ghana with the intention to sell on the European market must therefore have HACCP as a minimum requirement.

### 1.3. RESEARCH OBJECTIVE

The objective of this study is to apply the concept of Hazard Analysis Critical Control Points (HACCP) system in the fruit drying industry. Specifically, the work seeks to:

i. Determine the critical control points (CCP) in using forced drying methodology in drying sliced fruits such as pineapple ii. Suggest critical limits for the different critical control points based on the recommended international standards such as Codex criteria for limits on hazards that may be identified.

In the end, the study will contribute, not only, to the academic knowledge but will lead to the implementation and adoption of the concept of HACCP to the food industry based on lessons learnt and recommendations.

### 1.4. SIGNIFICANCE OF RESEARCH

This study brings to bear the importance in applying the HACCP concept to a specific industry in the food business and the challenges associated with installation. The design and implementation of HACCP is critical in the food industry and much so in manufacturing for the export market outside Africa. The EU market requires the implementation of the HACCP concept for the food industry. However, the literature at the local level indicates poor appreciation and implementation of Food Safety Management Systems for various reasons including the fact that it has not been demand driven coupled with lack of resources be it technical or financial (Agei-Baffour *et al.*, 2013). This study will thus lay the foundation for the implementation of food safety management system for the fruits and vegetable drying industry in Ghana and beyond.

## 1.5. RESEARCH METHODOLOGY

The first part of the study was a walkthrough of the fruit drying facility located at Food Research Institute (FRI), Accra to identify the processing steps in fruit drying. Notes were taken of the processing steps and technology been applied at the facility.

Interviews were then conducted with a team of technicians and engineers at the facility to gather information that was used for the study. This helped the researcher to better understand the process of drying to identify the main processing steps and the associated principles underlining the steps. Details of methodology is provided in chapter three of this study.

## 1.6. ORGANISATION OF THESIS

The study is organised in six chapters. Chapter one introduces the subject of the study stating the purpose and objectives for which it is to achieve. The second chapter is a review of literature and other related issues expounded by many scholars on the principles of fruit drying technology; the concept of HACCP; how HACCP relates to other international food safety and quality management systems standards and legislations regarding the implementation of HACCP. Chapter three describe in detail, the approach used in the research work. Chapter four presents an in-depth audit findings and observations based on the method employed for the research. It includes results of GAPS assessment on the Prerequisite programmes at the centre. It finally discusses the results of the HACCP study.

Chapter five summarizes and concludes the study. Based on the findings some relevant and valuable recommendations are made for the formation of possible strategies that could lead to the successful implementation of HACCP.

# CHAPTER TWO

# 2. LITERATURE REVIEW

## 2.1. INTRODUCTION

This chapter reviews various works and studies in the area of food drying, food contamination and the application of Hazard Analysis and Critical Control Points (HACCP). It is the section that reveals the thoughts, suggestions and recommendations of various scholarly articles and works on HACCP and its implementation in food processing.

## 2.2. PRINCIPLES OF FRUIT DRYING

Drying is the removal of moisture from a substance (Brennan, 2006). There are three types of drying process: sun/solar drying, forced air drying and sub-atmospheric drying. Each method can be utilized commercially and the selection of the type to adopt is dependent on the raw material characteristic, quality requirement of the finished product and the economic factors.

According to the Codex Code of hygiene practice for dried fruits (CAC/RCP 3-1969), dried fruits refer to:

"…all fruits that have been dried by natural or artificial means or a combination of both. The fruit is dried to the extent that the greater part of the moisture has been removed, and in addition the fruit may be subjected to a safe and appropriate treatment in preparation and packing, to permit marketing in normal trade channels" (CAC/RCP 3-1969).

Fruit drying is one major technology in preserving fruits and extending shelf-life, one of the key prerequisite in international trade. This is so because, dried fruits are easily transported over long distances under ambient temperature without compromising nutritional quality and taste due to the substantial removal of water (Swetman *et. al*., 2011)

The most effective way of drying fruits is to expose them to a current of heated air either by burning different kinds of fuel (forced air drying) or through more environmentally friendly methods such as sun-drying. Sun-drying can be carried out in the open air by spreading the fruits on racks or mesh or via a solar dryer. In the case of the latter, the fruits are placed in a cabinet and the sun used as a source of energy to heat a current of air that passes through the cabinet to dry the fruits. The construction of solar cabinets requires some mechanical engineering in order to improve efficiency and effectiveness.

Forced air dryers are cabinets with a fan that blows pre-heated air through a chamber (Mercer, 2012). Air that is blown in by the fan gets heated as it passes over heating coils or gas flames. The heated air has low humidity due to reduced moisture content hence an increased capacity to absorb more moisture. The heated air is blown into the chamber and over the sliced fruits arranged usually on wire mesh racks. The flow of air current forces the misted air out of the drying chamber to be replaced with fresh dried air. This cycle of flow allows the fruits to dry up in a combination of evaporation and diffusion as explained below.

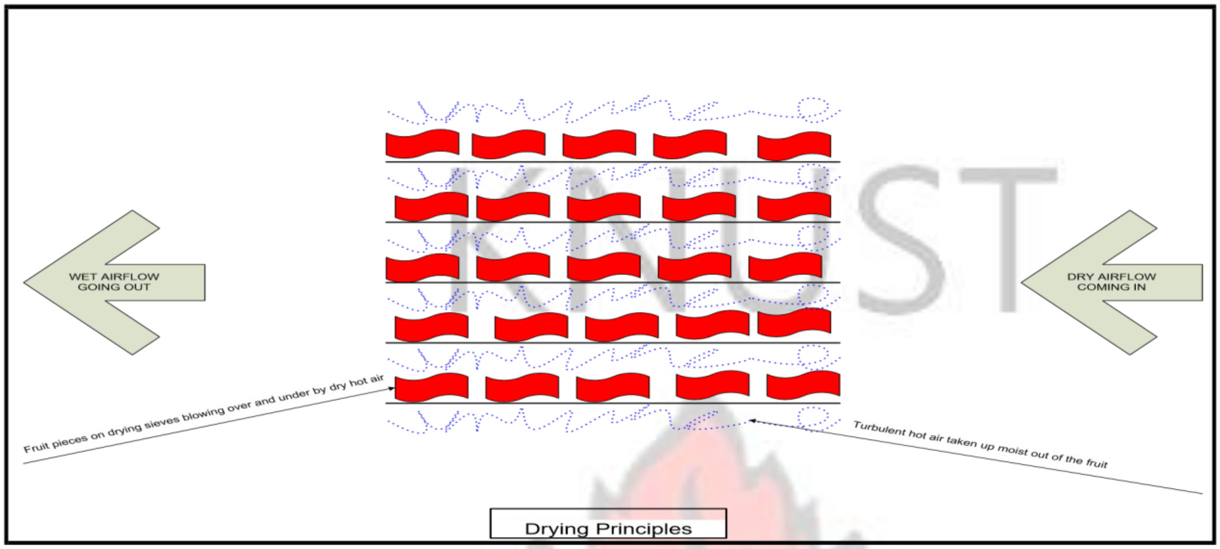


**Figure 1: Airflow in Forced Air Dryer**

Source: Swetman *et al*., 2011)

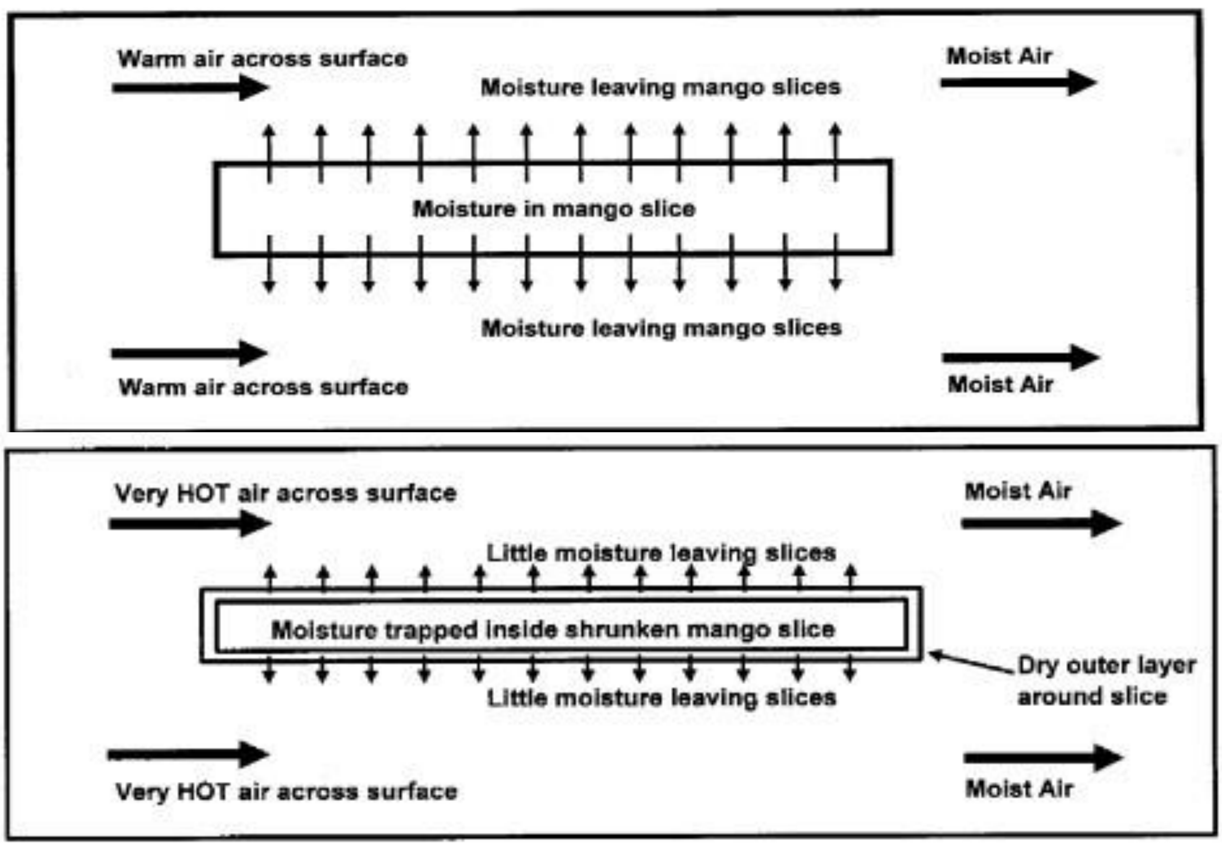


**Figure 2: Moisture removal from sliced fruits during forced air drying**

Source: Mercer, (2012)

According to Brennan, 2006 the rate of moisture loss in the fruits is a function of the thickness of the fruits; the dryness or otherwise of the air (humidity); and the rate of air flow. Usually, fruits to be dried are cut into slices of different shapes and forms depending on market requirement. Sliced pieces of fruits lose moisture from the surface through evaporation as a current of dry air passes over it. It is imperative, therefore, that air for drying should not be humid or saturated with water. Moisture trapped within the sliced pieces is then forced to diffuse to the surface. The diffused moisture will again be evaporated to continue the cycle.

Because the hot air is blown from one direction of the chamber and exits through the opposite direction, the efficiency in drying tends to be higher at the inlet part of the chamber and reduces as the hot air progresses towards the exist end of the chamber. This is because the humidity of the air tends to increase and hence decreases in ability to absorb air at the exist end. In practice, the drying racks are designed such that they can be rotated within the chamber to reduce the tendency of uneven drying (Mercer, 2012). Again, the temperature and velocity of air within the chamber is controlled during the drying process.

Sub-atmospheric drying on the other hand occurs at low air pressure. Typical examples include vacuum drying and freeze drying technology. This type of drying removes moisture from products at temperatures less than boiling point under ambient conditions as with vacuum drying or through sublimation in freeze drying. It is recommended for products that may deteriorate through oxidation or may be have chemical modification under heat drying that are not desirable. Its main advantage lies in the retention of flavour and nutrient, minimal damage to product texture and chemical structure and minimal change in product shape and colour relative to elevated heat drying.

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## 2.3. FACTORS THAT INFLUENCE DRYING

The efficiency and effectiveness of fruit drying according to Swetman *et al.* 2011; Brennan, 2006 is influenced or affected by three basic factors. They are:

i. Temperature of the drying air ii.

Velocity of the drying air iii.

Thickness of fruit slices

The first two factors are dependent on the air and structural design and engineering of the dryer whilst the last has to do with the product.

### *2.3.1. Effect of temperature*

The ideal temperature for fruit drying is between $50^oC$ to $55^oC$ (Mercer, 2012). It is further recommended that drying temperature for fruits should not exceed $60^oC$ for two main reasons; loss of nutrients and case hardening. According to the author, most nutrients within fruits are destroyed at temperatures above 60 $^0C$. It is therefore recommended that in order to preserve the nutrient value of the product, a temperature below 60 $^0C$ is ideal. Again, as drying temperature increases, cells on the surface of sliced fruits collapse, forcing the fruits to shrink on the surface (Mercer *et al.*,2008). This phenomenon is referred to as "case hardening" and has both safety and quality implication for dried fruits. In such instances, the rate of evaporation far exceeds the rate of water diffusion within the fruit slice. Thus even though the fruit may look and feel dried, more than enough moisture is still trapped within the centre of the slice. Water that has been trapped within the fruit eventually diffuses to the surface of the fruits. It condenses within the airspace of the primary packaging, forming water droplets. This reduces the quality of the product and also supports mold growth on the fruit (Mercer, 2012).

### *2.3.2. Effect of air velocity*

A good air current allows replacement of saturated air with unsaturated air on the surface of the product. This allows for continuous evaporation and hence satisfactory drying efficiency. In the absence of air current, an immobile saturated air forms a stagnant boundary layer. In practice therefore, the faster the air current, the better it is to prevent the formation of stagnant boundary layer and hence the better the efficiency of the drying process. An air speed of 0.2 to 0.5m/s is recommended (Swetman, *et al.,* 2011).

### *2.3.3. Effect of thickness of fruit slices*

The thicknesses of the slice of fruits affect the rate of water movement from the core to the surface for evaporation. The thicker the slice, the longer it takes for water diffusion and hence the longer the drying time. It therefore, presumes that thinner fruits are preferred as drying time is the most important factor. However, it is worth noting that the quality of the dried fruits should meet the market expectation. In this regard, too thin slices may result in such unacceptable end products. These may even be blown within the chamber during the drying process (Swetman *et al.*, 2011; Mercer,2012).

Figure 3: Sliced Fresh Pineapple ready to be dried

Figure 4: Dried sliced Pineapple

**MARKET OPPORTUNITIES FOR DRIED FRUIT**

The market for dried fruits in Ghana is heavily untapped. This could be due to the ubiquitous availability of tropical fruits almost throughout the year (Swetman *et al.*, 2011). The EU serves as the major destination for dried fruit products from Ghana. According to the Ghana Export Promotion Authority, the EU has been the traditional export destination of fruit products with dried fruits serving as the larger part of exports (Ghana Exports Promotion Authority 2013). Swetman *et. al*. (2011) reported that the EU imported 2.65 million metric tons of dried fruits and vegetables in 2008 at an estimated value of 3.1 billion Euros. It is estimated that over 47% of these imports came from developing countries. The market for dried fruits and vegetables in the EU is estimated to be increasing at 6.48% per annum (ITC, 2015).

Dried fruits are mainly consumed as snack and ingredient for breakfast cereals, ready-toeat snacks and deserts. They are therefore mostly exported in bulk packaging rather than single use packaging sizes. Unlike fresh horticultural products, dried fruits are easy to transport over longer distance. The huge water loss makes it less bulky to transport. Besides, drying to good moisture content is in itself a preservation treatment, thus allowing for extended shelf-life of the products.

The major fruits that dominate the drying industry in Ghana are pineapple, mango, pawpaw and coconut. HPW Fresh and Dry Limited, a major fresh and processed fruit exporter to the EU argues Ghana is less competitive in dried banana relative to the South American countries (Blaisser, 2014).

## 2.4. QUALITY ASSURANCE

Quality is defined by ISO 9000 series as:

*"the degree to which a set of inherent characteristics fulfils requirements."*

In other words, quality can be regarded as fitness for purpose or conformance to user‟s expectations since the user determines whether a product is of the desired quality. Quality in the food industry therefore, includes food safety, an assurance that a food will not cause harm if consumed according to intended use (Sansawat, 2009).

The quality of goods and services results from many interrelated activities. These activities need to be coordinated through a Quality Management System. As indicated by William Foster, "Quality is never an accident; it is always the result of intelligent effort." (Henson *et al.*, 2005)

In order to survive in today‟s competitive marketplace, an organization has to consistently satisfy its customers‟ needs and anticipate their future needs. This can be achieved by providing customers with the products they want, "getting it right first time," without the need for rework. To satisfy customers, one must go higher along the production chain, right up to the suppliers, not forgetting employee morale and commitment. Suppliers provide the raw materials or products for further processing by employees; if suppliers and employees do what is expected of them, “getting it right first time,” customers will be satisfied.

As defined by the International Organization for Standardization (ISO): "Total Quality Management is a management approach for an organization, centred on quality, based on the participation of all its members and aiming at long-term success through customer satisfaction, and benefits to all members of the organization and to society." (ISO 8402:1994)

A quality management system in the enterprise, based on prevention rather than cure, minimises waste and rework by ensuring that products are made right first time and every time. In adopting a preventive approach by investing in plants and equipment, training staff and purchasing the appropriate raw materials/inputs, an organization can reduce inspection cost and more specifically, the costs of failure and/or delays. These costs arise from rework or discarding non-conforming in-process materials and finished products.

***Quality Assurance (QA) and Quality Management (QM) Models***

The publication of the ISO 9000 series of standards in 1987 heightened awareness of the benefits of QA requirements among Small and Medium sized Enterprises (SMEs), many of which are implemented as ISO 9000 QA models to improve their competitive position as well as to join the ranks of suppliers to large companies. While both the 1987 and 1994 versions of ISO 9001, ISO 9002 and ISO 9003 were based on a QA model, the revised standard (ISO 9001), published in 2000, is based on QM principles (Ghana Standards Board, Export quality management, 2009).

**Table 1: The broad relationships between inspection, quality control, quality assurance and quality management**

| System | Objective | Activities | Applicability | Nature |
|---|---|---|---|---|
| Inspection | Product conformance by screening out conforming products from nonconforming products | Visual checks/ measuring; then testing and reporting the results. | Generally, Production-related activities, such as checking incoming goods, in-process or final product, predispatch, etc | Detection after the event. |
| Quality control | Product Conformance by Eliminating causes of non-conforming products | Inspection followed by appraisal of results and feedback to the process being controlled | As above | Detection and or offline correction. |
| Quality assurance | Generating confidence in product conformance | Comprises all QC activities, plus documented quality systems and quality audits | All functions of the company from design to after-sales service. | Prevention. |
| Quality Management | Continual improvement of product conformance | Continual improvement of processes in addition to all QA activities | As above | Prevention and improvement. |

Source: (Ghana standards board, Export quality management 2009)

## 2.5. FOOD SAFETY QUALITY MANAGEMENT SYSTEM

Food safety is the assurance that a food, when consumed according to intended use will not cause harm to the consumer. In other words, food safety relates to the absence of food borne hazards in food at the point of consumption. Food safety hazards could be introduced into the food at any point of the value chain from farm to fork. In fact, some food safety hazards are inherent in the food itself. Adequate control throughout the food chain is essential in eliminating or reduces the chances of occurrence of these hazards and the severity of the risk associated with them. Thus food safety is ensured through the combined efforts of all the parties participating in the food chain. (Extract From ISO 22000, 2005)

The following are generally recognised key elements to ensure food safety along the food chain from farm to folk:

- Traceability and interactive communication
- System Management
- Prerequisite programmes
- HACCP principles

Communication and traceability along the food chain is essential to ensure that all relevant food safety hazards are identified and adequately controlled at each step within the food chain. This implies both upstream and downstream in the food chain traceability systems. Communication with customers and suppliers about identified hazards and control measures would assist in clarifying customer and supplier requirements e. g., with regards to the feasibility and need for these requirements and their impact on the end product. (ISO 9001 Quality Manual)

Recognition of the organisation‟s role and position within the food chain is essential to ensure effective interactive communication throughout the chain in order to deliver safe food products to the final consumer.

The most effective food safety systems are established, operated and updated within the framework of a structured system and incorporated into the overall management activities of the organization. This provides maximum benefit for the organisation and interested parties. ISO 22000:2005 has been aligned with ISO 9001 in order to enhance the compatibility of the two standards. (Extract From ISO 22000, 2005)

ISO 22000 integrates the principles of the Hazard Analysis and Critical Control Point (HACCP) system and application steps developed by the Codex Alimentarius Commission. By means of auditable requirements, it combines the HACCP plan with prerequisite programmes (PRPs). Hazard analysis is the key to an effective food safety management, since conducting a hazard analysis assists in organising the knowledge required to establish an effective combination of control measures. ISO 22000 requires that all hazards that may be reasonably expected to occur in the food chain, including hazards that may be associated with the type of process and facilities used, are identified and assessed. Thus it provides the means to determine and document why certain identified hazards need to be controlled by a particular organisation

and why others need not. (ISO 22000 Food Safety Management System). HACCP implementation is thus industry and plan specific and is affected by differences such as technology, internal technical knowhow, complexity of the organisation among others, in their the occurrence and significance of a given food safety hazard.

## 2.6. ORIGIN AND DEFINITION OF HAZARD ANALYSIS CRITICAL CONTROL POINTS (HACCP)

HACCP (pronounced “hae-sip”) stands for “Hazard Analysis Critical Control Point”. It is a system that relies on risk identification and control to minimize food safety risks in the food industry. The origin of HACCP was developed in 1960 by the Pillsbury company whiles working for NASA and the US Army laboratories to provide safe food for space expeditions (Goodrich-Schneider *et al.*, 2012). It was difficult testing end products due to various limitations by the company who was trying to provide the safest food possible for use in space. In order to ensure the safety of all products leaving for space, all products must be tested individually which will eventually leave very little product for use. A new approach which will ensure a classification and understanding of all known and associated hazards was needed in ensuring each unit of the product produced was not tested. These efforts gave birth to the practical and proactive approach of HACCP to reduce food safety failures. It is based on an engineering principle called Failure, Mode and Effect Analysis (FMEA) (ICMSF, 1998). According to Wallace (2014), HACCP has been used since the 1970s, and is now internationally recognised as the best system for ensuring food safety. It is ideal to think of HACCP as a preventive food safety system other than a traditional quality control inspection system. HACCP in it totality does not eliminate the risk of hazard getting into the food product or process but strives to decrease the possibility of the occurrence of these hazards to acceptable levels with control measures.

HACCP principles are used as tools to assess hazards and establish control systems that focus on preventing the production of unsafe food, rather than relying on end product testing (Cumpanici, 2006). HACCP can be implemented through the food chain from primary production to final consumption. For this to be fully implemented, the commitment of senior management and staff is crucially needed. It also requires a multidisciplinary approach from field to consumer to successfully realize its implementation and sustainability. The implementation of HACCP produces significant benefits of which some are strengthening of Quality Management Systems, demonstration of due diligent, demonstration of management, commitment to food safety, evidence of regulatory compliance, efficient resource management, preventive approach to food safety management, Promotes international trade and Reduces rework and product recalls among others.

HACCP implementation also increases consumer confidence that the processes involved in producing a particular food are safe and regulated

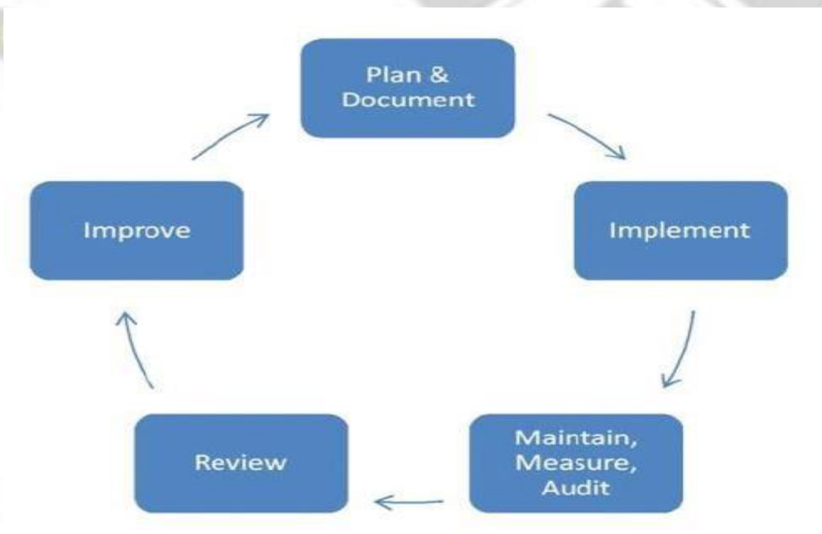


**Figure 3: Food Safety Quality System Process Diagram**

Source: Amoako-Mensah, 2010

## 2.7. OBJECTIVES AND PRINCIPLES OF HACCP

HACCP is meant to assure the production and distribution of safe food by identifying and controlling process steps that are critical in elimination of food safety hazards or reducing the effect of these hazards to safe levels. HACCP applies a systematic approach in the identification, evaluation and determination of appropriate control measure in food manufacturing (NACMCF, 1998). Codex prescribes seven (7) principles in the implementation of HACCP. Thus unlike standards that promulgate requirements, HACCP is based on principles and therefore not prescriptive in its application and implementation. The seven principles are:

### *2.7.1. Hazard analysis*

This involves the identification of all potential hazards at each process step along the production or manufacturing chain and evaluating each hazard on a probability of occurrence and severity of health effect. The hazard identification step also involves classification of each hazard. Codex identifies three main classes of food safety hazards under HACCP. These are Biological, Chemical and Physical hazards. Control measures are also established to either eliminate the presence of the identified hazard or reduce the risk of occurrence to acceptable levels. i.e. level that would not cause harm to the consumer.

### *2.7.2. Identification of Critical Control Points (CCP)*

These are steps in the chain where loss of control over a hazard will result in an unsafe food. That is to say that beyond that step, there is no further step in the manufacturing process that can take care of the hazard in question. Such steps are therefore considered critical in the quest to achieve food safety.

### *2.7.3. Establishment of critical limits*

A control measure must set a limit of control that would ensure that the said hazard is either eliminated or reduced to acceptable level. Such limits become very crucial at the CCP, and it establishes criteria for acceptable and unacceptable products.

### *2.7.4. Establishment of a monitoring procedure*

Monitoring procedures are surveillance systems for observation and monitoring of the control measure at the critical control points. These surveillances are implemented at specified time intervals during food processing. Deviations from the critical limits are noted during monitoring for corrective and preventive actions.

### *2.7.5. Establishment of corrective actions*

These are measures to be taken whenever a deviation is recorded at a CCP during monitoring.

### *2.7.6. Establish a verification procedure*

These are methods to verify that the HACCP system is functioning correctly.

### *2.7.7. Establish a record keeping and documentation system*

Record keeping and documentation in relation to the HACCP system must be developed for effective management.

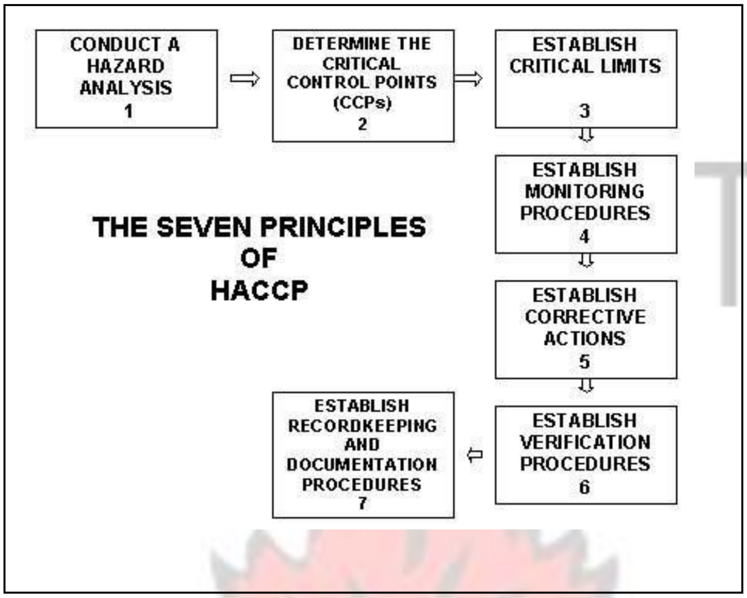


**Figure 4: Principles of HACCP, Adopted from Codex Alimentarius**

Source: Cumpanici, (2006)

**PREREQUISITE PROGRAMS FOR HACCP IMPLEMENTATION**

The prerequisite programs are those foundation programs that any HACCP implementation is built upon. Prerequisite programs are a must if HACCP is to be implemented. According to Codex Alimentarius Commission, cited by Cumpanici, (2006), HACCP should be:

1. Typically applied to each specific production procedure separately
2. Take into consideration the nature and size of the implementing organization or company
3. Dynamic
4. Reviewed timely to accommodate changes in equipment and process step

Considerations must be given to the effects of raw materials, ingredients, production operations, intended end-use of the product, epidemiological evidence and target consumers during the stages of hazard identification, evaluation and the implementation of HACCP.

Without the strong system of the prerequisite programs such as GMPs and Good Hygiene Practices (GHP), HACCP cannot be implemented. GMPs are the minimum sanitary and processing requirements necessary to ensure the production of wholesome food (Cumpanici, 2006). The key areas targeted by GMPS are factory hygiene practices, employee hygiene rules, buildings and facilities, equipment and utensils for processing, production process parameters and control.

Also a very important pre-requisite is raw material specification of control. The management and operational practices to assure quality and safe raw materials for food production is termed Supplier Quality Assurance (SQA). The process of SQA starts with the development of specification and criteria for raw materials. These specifications must be clearly established in unambiguous terms to both the manufacturers and the suppliers. These must cover food safety and quality criteria including packaging and handling conditions as well as traceability systems. Specifications are communicated to suppliers in supplier contracts. SQA would also involve supplier audits which could be done through a third party audit system. A basic criterion for reception of raw material is certificate of analysis for each batch of material received.

Standard Operation Procedures (SOPs) are those documented GMPs necessary to ensure the hygiene and sanitation of the process area and environment are kept in control to meet regulatory requirements. A standard SOP plan should include the sanitary concerns, controls and frequency of controls. The SOP should typically address issues of cross contamination, equipment/utensils maintenance, food contact surfaces, factory cleaning and pet control actions.

Essential procedures to the provision of safe food include product recovery and rework procedure, traceability system and recall procedure. These processes must be accurately documented and authorised in order to comply with relevant specifications and requirements.

Good Laboratory Practices are essential part of the quality management system. A laboratory provides quantitative criteria for product quality and safety. It is therefore imperative that an on-site laboratory implements Good Practices recommended for the food industry. The efficiency of a laboratory involves appropriate premises, facilities and competent staff. Accreditation may be one way of ensuring that a particular laboratory delivers to international standard. Where laboratory activities are outsourced, management systems should be put in place to verify the competence of the laboratory and hence the credibility of results churned out of such laboratories.

Other PRPs includes water quality control plan, cleaning and disinfection plan, training programme for food handlers, preventive maintenance plan and pest control plan. These are critically not part of the HACCP system. However, initial controls of these systems are necessary in order not to jeopardise a HACCP system.

Codex has classified these pre-requisite programmes into six (6) categories to facilitate implementation and audit. These classifications are similar to requirements by other standards such as the BRC, ISO and IFS. The codex classifications put issues in technical and technological perspective as against the requirements of standards that are more managerial focus.

## 2.8. DEVELOPING A HACCP PLAN

A HACCP plan is a protocol with the required information for the implementation of the HACCP management system. It is made up of two main components, the process flow diagram and the HACCP control chart. The format is a schematic and sequential representation of the steps involved in the processing of the food in question, whilst the latter is a table indication the key process steps including the CCPs with detail information on how and when to proceed with the controls and who (Quality Control Manager, process operator, HACCP team member, etc.) should implement the control (Serra *et al.*, 1999). The HACCP plan may also include such information that may be required to reach the objective of the food safety management system.

In order to effectively implement a HACCP Plan, the seven HACCP Principles are applied in twelve steps. The main steps according to the Codex Alimentarius Commission are:

***2.8.1. Assemble a HACCP team***

The first task in developing and implementing a HACCP system is the putting together of the appropriate personnel to see to it that management objectives are meet. A HACCP team should be multidisciplinary in nature is led by a HACCP champion, usually the Quality Assurance Manager. The leader sees to it that the team members receive appropriate training, organising meeting and leasing with management to ensure management commitment in releasing resources for the team (Stevenson, 1990). The team, usually between five and six members are coordinated from specific departments such are production, quality assurance, engineering, procurement, etc. A HACCP team should not be structured according to the company‟s organogram or hierarchy. In some instances, an external expert may be hired to support the activities of the team. HACCP should never be developed and implemented by a single individual or consultant for a company (Marques *et al.,* 2012).

***2.8.2. Description of the product***

This involves the gathering of information about the all the raw materials and ingredients to be used as well as the finished products expected. This information includes intrinsic factors of raw materials and ingredients as they impact on the safety characteristics of the finished product. Factors to be considered include pH, acidity, water activity, preservatives, among others. It therefore requires an elaborate description of the characteristics of the product and its raw materials and comes in the form of a checklist.

#### *2.8.3. Describe the intended use of the product*

This intended use of the product should help know if the product is a raw material, to be further processed by the end user on to be consumed without further processing. This step should also provide information or the consuming population of interest especially with regards to sensitive population such as children, elderly and the immune-compromised population (Marques *et al.*, 2012).

#### *2.8.4. Construct a process flow diagram*

A process flow diagram is a schematic sequential representation of the various process steps that falls under the control of the processing facility. This may start from the reception of raw materials to the table of the consumer. It may however end with the final packaging if the distribution system is not under the control of the company. A flow diagram enhances the understanding of the process as it makes it easy to visualise the relationship that exist in the processes.

#### *2.8.5. On-site verification of the flow diagram*

It is important that the HACCP team confirms the flow diagram by conducting a walk through the processing line. Where necessary, modification should be made to the flow diagram to ensure accuracy and completeness.

### *2.8.6. Conduct a Hazard analysis (principle 1)*

Codex Allimentarius (1997) describes the first principle as "list all potential hazards associated with each step, conduct a hazard analysis, and consider any measure to control identified hazards (Bryan, 1990). The principle thus involves two major activities;

a. That the HACCP team should list all hazards that may be reasonably expected to occur at each process step in as far as the product is under the control for the processor or within the scope of the HACCP team from farm to folk.

b. Each hazard must be analysed at each process step to identify which hazards must be controlled (eliminated or reduced to acceptable levels) in order to assure the production of safe food.

Codex defined a Hazard as a biological, chemical or physical agent in or condition of food with the potential to cause and adverse health effect. Thus three (3) groups of hazards are identified; biological, chemical and physical hazards.

**Biological hazards** could be biological agents or microorganisms that are found in or on food and has the potential to cause harm. These include pathogenic bacterial, viruses, parasites and moulds. They may come with the raw materials, poor cleaning of equipment and food contact surfaces or from food handlers. Biological hazards also includes such agents as beetles, flies, etc. which may carry along with them pathogenic bacterial and contaminate food.

**Chemical hazards** are chemical substances that end up in food either as intrinsic to the raw material, an additive or other chemical use of sanitising and treating plants or machinery. Chemical hazards also include mycotoxins. With the exception of allergy (which is sometimes considered as forth class of hazards – allergens), the adverse health effect of chemical hazards are cumulative and cancerous in nature.  Some major sources of chemical hazards in the food chain are plant protection products and agrochemicals, veterinary drugs, hormones, pesticides, sanitisers, additives such as  preservatives, colorants taste and flavour enhancers. Chemical hazards could also result from the food processing technology employed. For instant, the exposure of meat or carbohydrates to flames could result in the development of known carcinogens such as Poly Aromatic Hydrocarbons (PAH) and Acrylamides (De Meulenear 2006).

**Physical hazards** are largely physical entities or particles that could be present in food and can cause such harm as cuts, broken tooth, chocking among others. They could be foreign to the food such as piece of metal or part of the food that should have been eliminated during processing, e.g. fishbone.

The hazard identification is one very important step in the development and implementation of a HACCP plan. This is because the omission of any hazard during the identification stage would mean that no control measure would be put in place to control such a hazard. Paints must therefore be taken to ensure that all potential hazards are identified at this stage to have a robust HACCP plan. Three techniques are recommended in hazard identification which are best use in combination. These are log of process deviations, what would happen if? and brainstorming (Serra *et al.,* 1999).

Every identified hazard will require a control measure to assure food safety. Control measures are measures adopted to either eliminate or reduce a hazard to acceptable level in order to guarantee food safety. Codex recommends that consideration should be given to what control measures, if any exist, can be applied to each hazard identified. One control measure can be used to control more than one hazard. On the other hand, some hazards may require more than one control measure to be effectively controlled.

With the inventory of hazard completed and control measures established, the HACCP team will have to evaluate the hazards to assess the food safety risk. This evaluation involves an investigation into the chances of occurrence of the hazard and the severity of the public health risk should the hazard occur. Literature prescribes a simple matrix of probability and effect for hazard analysis and evaluation. A sample hazard analysis matrix is shown below:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Severity of health effect | Can cause fatality | 5 | 5 | 10 | 15 | 20 | 25 |
| | Can lead to serious illness | 4 | 4 | 8 | 12 | 14 | 20 |
| | Can cause illness | 3 | 3 | 6 | 9 | 12 | 15 |
| | Can cause inconvenience | 2 | 2 | 4 | 6 | 8 | 10 |
| | Almost of no significance | 1 | 1 | 2 | 3 | 4 | 5 |
| | | | 1 | 2 | 3 | 4 | 5 |
| | | | Unlikely | Rare | Could occur | Likely | Frequent |
| | | | (<1/2 years) | (1 / year) | (1/6 month) | (1 / month) | (1 / week) |
| | | | Likelihood of occurrence | | | | |

**Figure 5: Hazard classification matrix**
Source: Serra *et al.*, (1999)

**Table 1.1: Interpretation of Hazard Matrix**

| Low risk hazards | Medium risk hazards | High risk hazards |
|---|---|---|
| non-significant hazard | significant hazards | |
| will not be subject to decision tree | will be subject to decision tree | |
| usually controlled by PRPs | usually controlled by PRPs or HACCP plan | |

Source Serra *et al*., (1999)

### *2.8.7. Determination of Critical Control Points (CCPs) - Principle 2*

Critical control points are those steps on the processing line where continuous control is necessary to eliminate or reduce a hazard to an acceptable level. Thus loss of control at such points results in a potentially unsafe product with a high public health risk. CCP identification is a complex process and may differ from one plant to another even when they process the same product. A decision tree is a tool used on hazard evaluation to determine CCPs. A decision tree consists of a series of logical question that need to be answered for each hazard at every processing step. The set of sequential questions leads the team to determine whether a step is a CCP or not.

The use of the decision tree encourages teamwork and group participation. It also provides a structured pattern of thinking among the HACCP team (Bryan, 1990). Factors such as competence and personnel, equipment, state of pre-requisite programmes, etc. has adverse effect of the CCPs. A plant that has too many CCPs is an indication that the pre-requisite programmes are not adequate or effective.

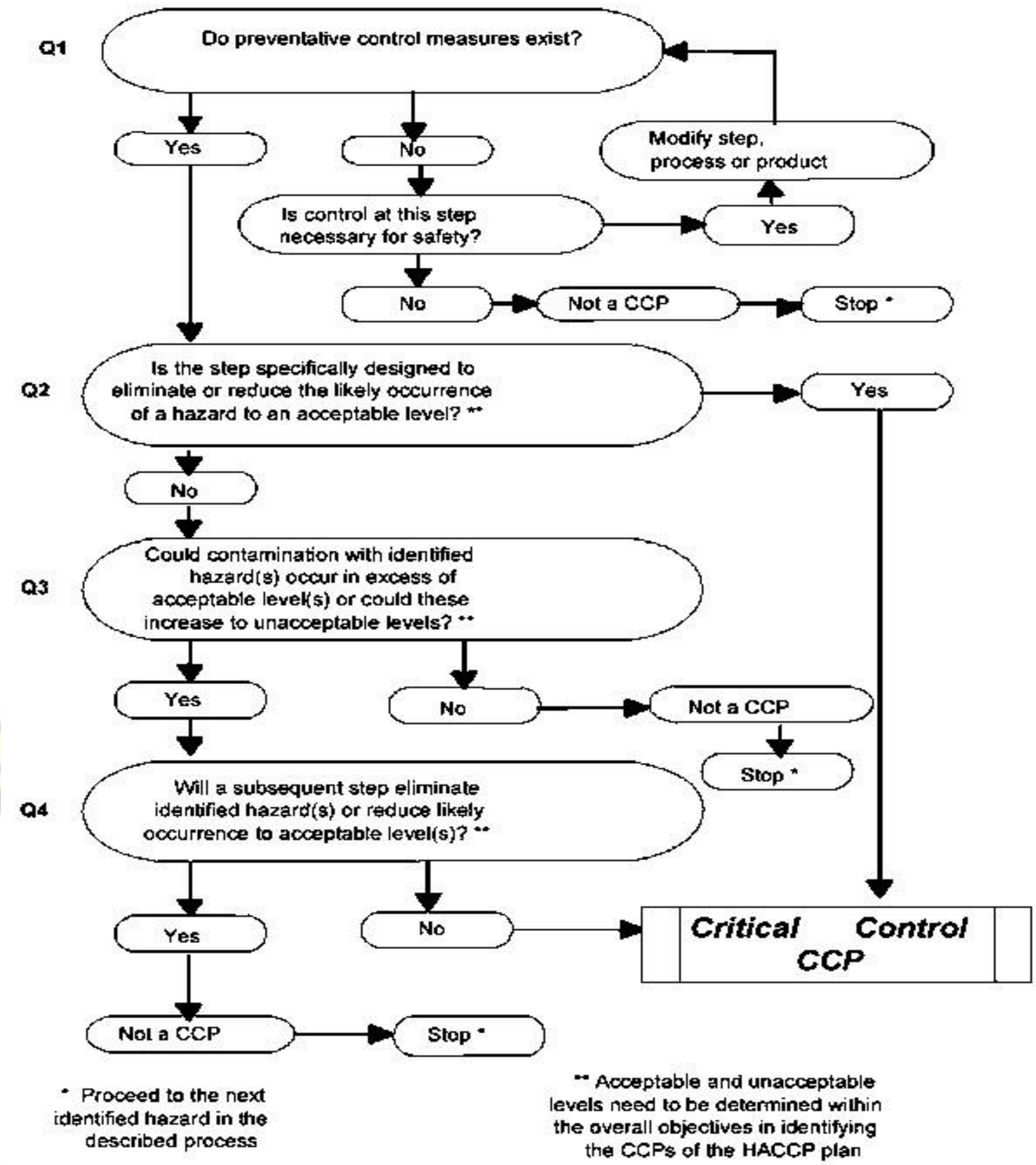


**Figure 6: CCP Decision Tree**

Source: Bryan, (1990)

### *2.8.8. Establishing critical limits for each CCP - (Principle 3)*

Critical limits are the tolerance levels of operation determined scientifically which when deviated from, the food would be considered unsafe. Or a hazard may be considered not to have been eliminated or reduced to acceptable level. Critical limits are therefore used in controlling

CCPs in order to keep the process within safe limits (Bryan, 1990). Critical limits are therefore accurate values that establish the criteria between safe and unsafe. Most critical limits involves an upper and a lower absolute values or criteria, the lower values providing the minimum requirement to guarantee safety whiles the upper limits are usually to preserve the quality values of a product. Critical limits must allow for routine monitoring and must also provide immediate results for decision making. These could be physical such as time/temperature readings, chemical such as acidity to be detected with test strips and biological limits such as absence of salmonella spp. Because critical limits should be easy to measure and provide quick result for decision making, long and elaborate laboratory methods such as culturing of microorganism are not use.

However, simple field test kits and strips could be use in detecting and monitoring critical limits.

### *2.8.9. Establish a monitoring system for each CCP – Principle 4*

Monitoring systems are the surveillance structures put in place to monitor operation to ensure that the process operation at a CCP is achieving established critical limits. Monitoring provides the documented evidence that the system is working effectively. It also indicates when there is a deviation at the CCP so as to implement the necessary corrective actions to bring the process under control. It is therefore imperative that the monitoring criteria selected are able to quickly detect a loss of control at a CCP. Monitoring must therefore be done at regular intervals and recorded appropriately. Equipment used in monitoring should also be calibrated and records kept. While some monitoring procedures are continuous such as a thermograph and may be automated to the operation of equipment, others require manual monitoring within scheduled frequency.

CCP monitoring is a key feature in HACCP implementation. It provides the strategic documentation that the system is being implemented and working according to plan. Establishing the type of monitoring procedure, the how, when and who are crucial in achieving project objectives. The documentation obtained for monitoring will need to be signed or initialled by the person doing the monitoring and properly file for management decision making.

#### *2.8.10. Establish corrective action – Principle 5*

Determination of CCP, establishing critical limits and putting in place a monitoring system does not mean that the system cannot deviate. It only means that we are keeping a close eye on critical areas to avert deviation and also to ensure that deviated products are easily identified and prevented from going to trade without due diligence. Because HACCP is a proactive approach to food safety management, the system makes provision to pre-determine actions to be taken in the event that monitoring reveals deviation. Corrective actions are well documented in the HACCP control chart and usually comes in two fold objectives:

1. To take the necessary action to ensure that the CCP is back under control, this is referred to in the ISO standard as „Correction". The correction also means quarantining affected product for management to take a decision of their fate.
2. The second objective of corrective action is for the implementation team to conduct a "root cause analysis" on the failure and determine what revisions may be necessary within the monitoring process to prevent the re-occurrence of such failures.  This is sometimes referred to as „preventive action"

### *2.8.11. Establishing Verification procedure – Principle 6*

Verification is a set of activities to establish that the HACCP system is working according to plan. It can only be done after the system has been installed. Verification is however not a single activity but should be carried out periodically on the system. Scheduled verification of the system is necessary as the HACCP is affected by issues and activities such as change in recipe, ingredient, technology, new scientific information, local or market legislations as well as change in personnel or knowledge base of personnel.

HACCP is meant to put in place a robust system that will assure continuous food safety without the regimental end product testing of every batch as with traditional Quality Control. Validation is therefore a system assurance practice that will provide evidence that the system is achieving desired results.

The result of verification could be either a ratification of the system of modification to adopt required changed that are necessary to assure food safety. The result could either be that the system is still effective and efficient or that there is the need for a change based on either system omission or inadequacy in adopted criteria (Escriche, *et al.*, 2006).

### *2.8.12. Establish a documentation and record keeping system – Principle 7*

Development and filling of appropriate and accurate documentation and records are the only evidence to demonstrate that a HACCP system has been duly implemented and is working. The document development and registration system to be adopted should be a recommendation of the HACCP team. The length to which documents should be filed, however depends on local legislation of company policy on document retention. Like all management system documentation, records and documents should be simple, legible, easily identifiable and retrievable. Some specific documents may include:

a. HACCP team members, job description, responsibilities on the team

b. Unities of meetings including those held prior to the development and implementation of the system as well as those held during the implementation process. Such proceedings provide vital information for system verification.
c. Product description and intended use form/
d. The process flow diagram
e. Hazard control chart
f. Proceedings followed in the hazard identification process, establishment and validation of the control measures were arrived at, how CCPs were decided, critical limits identification, and identification of monitoring procedures, preventive and corrective actions among others.
g. Verification records and log of modification done if any.
h. Results of periodic laboratory analysis on raw materials and end products
i. Records of verification, validation and audits for both internal and external audits.

These records could be kept in hard and or soft copies. Backups are necessary for such records and documentations. Records should be endorsed appropriately.

## 2.9. FOOD SAFETY HAZARDS ASSOCIATED WITH FRUITS AND FRUIT PROCESSING

Food safety hazard may be classified into four major groups. There are Physical hazards, Chemical Hazards, Biological Hazards and Allergens. The major food safety hazards of major concern in the fruit industry are chemical residues and biological contaminants. There have been a number of reported cases of human disease outbreaks linked with the consumption of fresh fruits (Buck. *et al.*, 2003). The rise in human infection comes in the wake of healthy eating and the higher consumption of fresh fruits for maximum nutritional value, as well as, the global sourcing of fruits with its attendant increased human handling and storage challenged (Buck *et al.*, 2003). Given the widespread use of human and animal faecal waste in agricultural practice it is not surprising that enteric pathogens can contaminate agricultural produce and cause outbreaks of illness following consumption. Spores of *Clostridium botulinum*, *Clostridium perfringens*, and *Bacillus cereus* can also be isolated from soil free from faecal contamination and *Listeria monocytogenes* can be found in decaying vegetables (Kaferstein, 2003).

### *2.9.1. Pre-harvest contamination*

Fresh fruits such as mango and pineapples should potentially not come with any physical hazards. However, sand particles and pieces of wood can be found on fruits when they are not properly handled at the farm gate during harvesting, collating and transport from the farm gate.

Except for organic produce, fruits are usually more likely to be contaminated with agrochemicals such as pesticides, fungicides, fertilizers among others that are used as part of the farm practice. The residue of these agrochemicals in fruits could present a major source of chemical contamination to consumers. It is impossible to have a chemical free fruits for nonorganic products. However, regulators at national levels as well as international food safety oriented institutions such as Codex usually have approved list of chemicals for specific fruits. Again, these Maximum Residue Levels (MRL) are prescribed for the active ingredients of these agrochemicals. MRLs are set based on risk assessment on the population and therefore are scientifically generated values.

Fruits are generally protected from pathogenic microorganisms due to two major reasons: 1) fresh fruits have a natural protective skin that prevents the entry of microbes and 2) fruits are generally acidic and therefore usual pathogens are unable to survive and multiply. This notwithstanding, fruits are noted to carry high loads of microorganism, usually non-pathogenic, diverse depending on the cultivation practice and type of commodity (Leff and Fierer, 2013).Yeast, molds and aciduric bacteria are the major source of microbial spoilage for fruits. This is attributed to the low pH of fruits of most fruits that make it difficult for other microbes to survive and multiply (Buck *et al*., 2003). Mould such as *penicillium*, *aspergillums*, *Alternaria*, *tricothecium* among others have been linked with rots in fruits. Yeast from the genera *Aaccharomyces*, *candida*, *torulopis* and *Hansenula* have been associated with fruit fermentation whilst lactic acid and acetic acid bacteria have been associated with soring of some fruits (Raybaudi-Massilia, 2009). *Byssochlamys spp* and *Neosartorya fischeri* have been noted as often present in raw fruits (BCN Research Laboratories Inc.).

Even though the pH of most fruits would not support the survival and growth of pathogenic bacteria, some fresh fruits have been linked with human infestation. Fresh fruits can be contaminated through human animal and pest activities. The use of contaminated water for irrigation and application of agrochemicals could result in the contamination of fruits with waterborne microorganisms. Pest, wild bush animals and farm attendants (human beings) could also contaminate fruits with microorganisms (Buck *et al.*, 2003).

#### *2.9.2. Post-harvest contamination*

Post-harvest contamination of fruits could be during transportation, storage of processing. Fruits are exposed to contact during transportation by the food contact surfaces and humans. Food contact surfaces such as crates could be major source of biological contamination. Again, human beings are major carriers of most pathogens such as *Staphylococcus spp*, E. *coli*, *Listeria monocytogems* among other. These could be transfered onto fruits during post-harvest handling.

### *2.9.3. Contamination during processing*

Fruits could be contaminated at this stage of the value chain by all the four main hazards discussed earlier. Contamination is mainly from either processing personnel, processing equipment of from food treatment agents such as blanching solutions. Fruit processing may typically include washing, peeling/cutting, processing (drying) and packing. Major source of physical contamination includes equipment parts such as rust, or iron fillings from cutting knives/edges, strands of hair from the food personnel and dust from either food contact surfaces or the environment.

Chemical contaminants in food processing include residue of cleaning agents such as detergents and sanitizers, excess bactericidal chemicals in washing water such as chlorine, hydrogen peroxide, etc. and pesticides/fumigants applied during pest control operations.

Fruit contamination with microorganisms during processing and storage could come from the food handler and processing equipment.

Once fruits are exposed through cutting or bruise, they become susceptible to microbial contamination. Four factors account for the rate at which a given fruit could be colonised by microbes. These are

1) Intrinsic factors of the fruits such are water activity, pH, nutritional composition, redox potential and antimicrobial composition;
2) Technological treatment of the fruit that could impact on or modify the initial

microbacta;

3) Extrinsic factors or environmental conditions of the medium such as temperature, relative humidity, and atmosphere;

4) Implicit factors, which depend on the developing micro biota and the handling of both the raw material and the product during processing and storage (Anderson *et al.*, 2011).

Food processing plant and machinery has also been wildly studied to contribute to the contamination of fruits. *Geotrichum candidum* has been termed "machinery mold" because it accumulates on fruit processing equipment. So are some acid tolerant bacteria like *Acetobacter*, *Gluconobacter* and *Zymomonas* that have been isolated from processing lines (Brackett and Splittstoesser, 2001). The presence of contaminants such as coliform bacteria and enterococci are common with processing lines. Their presence, however, does not necessarily indicate faecal contamination unlike E. coli which rarely occurs but is a strong indication of faecal contamination on the line (Brackett and Splittstoesser, 2001).

### *2.9.4. Contaminants in Dried fruits*

Even though dried fruits are of a very low moisture food, they did appear to harbour bacteria and other microorganisms. *Coliforms* were found in several of the dried fruits tested and even *E. coli* in organic raisin samples. Aspergillus type moulds were cultured from mango and raisin samples. Anderson (2011) reported the occurrence of *Pichia spp*. in dried fruits. Dried fruits have been associated with metal contamination from rusted processing equipment (Blassier, 2014).

Drying as a food processing aid could also be a major source of chemical contamination in the fruits. Studies have shown that heat processing of foods including drying could result in the formation of Polyaromatic hydrocarbons (PAH) as a result of pyrolysis of organic compounds (de Meulenear, 2006). PAHs are associated with carcinogenesis even though not all compounds exhibits the same level of toxicity. Again, acrylamides could be produced from maillard related reactions in foods or during heat treatments such that it induces surface dehydration of food (de Meulenear, 2006). In the process where cut fruits are treated with antibrowning chemicals such as the sulphides, excess of such chemicals could lead to Maximum Residual Levels higher than permitted in the food and hence poses a health risk to consumers, especially those with high levels of sensitivity to sulphur.

The process of drying poses very limited physical contaminant health risk to consumers. According to Blaisser (2014), the only major source of physical contamination in the dried fruits industry are iron fillings from cutting knives and rust that could be coming from either drying trays or from the oven. It is therefore important that only stainless materials are used in cutting of fruits. Again all working surfaces should be made from stainless materials to avoid chippings. Rust is rather difficult to control because of the material used in the manufacture of most ovens in addition to the use of chemicals such as acids that could pre-dispose these ovens to rust.

## 2.10. HACCP AND FOOD REGULATION

Globalization of production and food sourcing especially for the developed countries has been accompanied by increasingly rigid product quality and safety regulations. These regulations are particularly stringent in the food and beverage sectors and put enormous strain on producers from developing nations (Luning *et at.*, 2006). According to Anderson *et al.*, (2008), a review of documentation between 1990 and 2004 indicates that the mandatory requirements for HACCP has a positive effect for developed countries but negative effect for developing countries that export seafood into the United States of America. This led to the question of whether the use of food safety standards as market entry requirement is an issue of trade barrier or catalyst as smaller suppliers are always disadvantaged.

The Codex Alimentirious Commission recognises HACCP as the single most effective food safety and hygiene management tool for preventing the occurrence of food safety hazard in the food industry.

Implementation of HACCP is not a requirement for food service operators and food processing firms in Ghana. The national regulatory body in Ghana, the Food and Drugs Authority (FDA) does not require any food processor to implement HACCP as part of the market authorisation process. The FDA requires that all firms implement good Manufacturing Practices (GMPs) and GHP as the basic requirement for licensing. Implementation of HACCP is an added value. Ackah *et.al.,* (2014) reported that there is no policy or regulation for the mandatory implementation of HACCP in Ghana. Indeed, the Public Health Act, ACT 815 of 2012 has no reference to the implementation of HACCP or requiring food processing companies to implement food safety management system based on the principles of HACCP. Internal guidelines applied by the Food and Drugs Authority in Ghana demands prerequisite programs such as Good Manufacturing Practices (GMPs), Good Hygiene Practices (GHPs), Raw material control programs, Standard Operating procedure (SOPs) and traceability procedure as bases for acquiring market authorisation.  A lot more awareness has however been created for HACCP in recent days. The Food and Drugs Authority, the Ghana Standards Authority and the National Board for Small Scale Industries have on several platforms created some level of awareness and also supported some local small and medium scale industries to apply the principles of HACCP in their operations.

Some of these supports are however driven by politically driven trade collaboration between Ghana and the developed countries such as the USA and the EU. These trade blocks, as part of the trade agreement with Ghana instituted project that aimed at supporting local food processing forms to compete fairly on their market. For instance, the EU through its‟ trade assisted quality improvement programme supported a number of local food processing firms targeting the EU market through the NBSSI between 2014 and 2015 to implement ISO 22000.

The destination markets for dried fruits in Ghana mostly require HACCP as a minimum quality system to accept products from Ghana. It is reported by the USFDA and Danyluk *et.al*, 2012 that the USFDA used HACCP based principles in the development of low acid food canning regulations in the 1970s. Also, the 2010 Food modernization Act (FSMA) incorporated the mandatory use of preventative food safety programs such as HACCP in many areas of the food production chain. The HACCP implementation system has also found wide implementation in Europe, Canada, Australia and New Zealand (Goodrich *et. at.* 2012). Article 5 of Regulation (EC) No 852/2004 of the European Parliament and of the Council on the hygiene of foodstuffs requires food business operators to put in place, implement and maintain a permanent procedure based on Hazard Analysis and Critical Control Point (HACCP) principles. Trading with any of the EU countries will require certification to trade standards such as the BRC, IFS and ISO 22000, all of which has HACCP as a mandatory Food Safety Management tool.

It is therefore imperative that companies in Ghana looking forward to export their products to the European Union (EU) and other developed markets implement HACCP to be competitive and for overall acceptance of their products. According to the Ghana Export

Promotion Authority‟s market brief for Dried Fruits, HACCP is one of the most important food safety systems that the EU market require to be able to buy products from Ghana.

# CHAPTER THREE

# 3. MATERIALS AND METHODS

## 3.1. INTRODUCTION

This chapter presents the research design, method and approach in developing a HACCP plan for dried fruits at the Food Research Institute processing facility. It includes a description of the facility that was selected, prerequisite programs that should be in place before the setup of HACCP system as well as, record keeping forms of a well-functioning system.

## 3.2. SUBJECT SELECTION AND DESCRIPTION

GIZ-MOAP and FRI have collaborated to set up a fruit processing facility at the premises of FRI to commercially dry fruits – pineapple, mango and papaya suitable for direct consumption or as raw material for other food processing industries. The centre also serves as an incubation centre for commercial businesses wishing to dry their products for export. The study is anchored on this hypothesis that, having a HACCP system in place at the centre will build on any existing prerequisite system already in place to improve the quality and safety standards of the products coming from its production lines and open the centre for export of its produce.

The drying facility has a manager who supervises six other workers at the facility and report together with the laboratory services staff and plant engineer to the managing director of the institute as shown in Figure 10 below

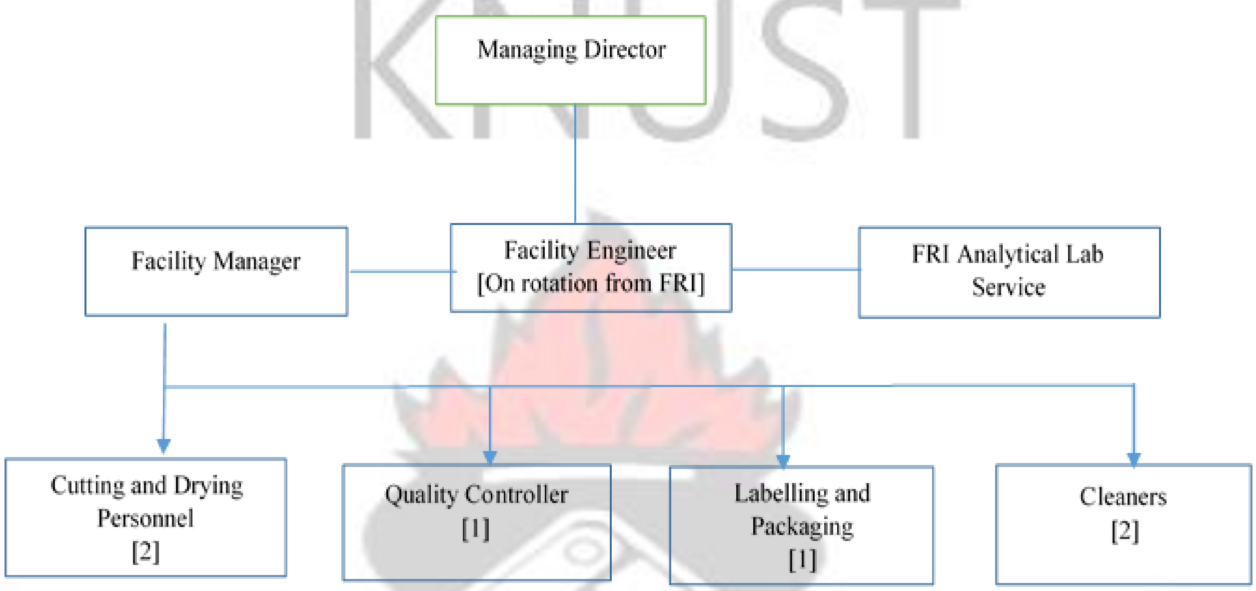


**Figure 7: HACCP Team**

### 3.3. RESEARCH METHOD

The FRI currently does not have safety and quality related data of quantitative value to aid in the research. Therefore, this study employed a qualitative method with an objective of designing a HACCP model. The qualitative approach was appropriate for this study also because it provides profundity and careful inquiry of the program situations, events, employee communications and observed behaviour. It also gives elaborate details of occurrences that are difficult to convey with quantitative methods. The exploratory nature of qualitative research is an added advantage to this study.

### 3.4. RESEARCH APPROACH

This research is moored on two key variables: i). the independent variables and ii). the dependent variables. Once these factors were considered, the researcher designed a sequence of activities encompassing the approach in implementing a master HACCP plan. The approach covered the following topics:

1. Prerequisite program
2. Product description
3. List of product ingredient and incoming materials
4. Process flow diagram
5. Hazard analysis
6. Critical control points determination
7. HACCP Control Chart

Systems audits, expert interviews and observation formed the main tool in information gathering, analyses and in drawing conclusions. To be able to understand how the system works and to develop the required food safety intervention, the research adopted a case study based on a typical batch production, noting the processes involved and the technicalities at each processing step.

#### *3.4.1. Independent Variables*

The main independent variables for this study are the Codex recommended Principles of HACCP and the ISO 22000:2007 Standard. This Standard converts the Codex Principles of HACCP into auditable requirements and thus provides basis to ascertain adherence to the principles of HACCP in a food industry. ISO 22000:2007 is an internationally accepted benchmarking standard for food safety. Unlike the codex principles of HACCP, ISO 22000 is prescriptive in presentation and comes with a checklist for certification of adherence to the principles and concept of HACCP.

### *3.4.2. Dependent Variables*

The state of infrastructure and technology available for the food processing centre at the Food Research Institute is classified under the confines of dependent variable. The foundational stone for a successful implementation of HACCP is the PRPs which focus on the state of the food processing facility (environment, infrastructure and equipment), the human resource, management systems and other concerns such as pest control, waste management among others.

The prerequisite programs of the facility is based on the dependent variable.

## 3.5. PREREQUISITE PROGRAM

The first step when pineapples are produced, dried and packaged is to ensure that the prerequisite programmes are in place. The main PRPs that were assessed in this study included:

- Staff training/education
- Good Hygiene Practices
- Good Manufacturing Practices
- Good Production and Packaging Practices
- Good Storage and Transport Practices
- Product traceability and recall

## 3.6. PRODUCT DESCRIPTION

The final consumer is supposed to have a clear, unambiguous understanding of the form of the final product, its intended uses and other characteristics of it that affects say, its storage. In setting up a HACCP plan, clear criteria is set to amply describe the final product with the consumer in focus. Product description also helps the researcher to make the right decision in the sense that it provides information on possible hazards that could affect the quality and safety of the product.

### *3.6.1. List of product ingredients and incoming materials*

As Zhao (2003) aptly puts it, hazards are rarely created by themselves in processing. This is because most of the hazards come from the ingredients and incoming materials. For example any pest or disease associated with raw fruits may go on to contaminate the end product. Table 3 describes the information collected on incoming ingredients and materials for dried pineapple and mango.

## 3.7. PROCESS FLOW DIAGRAM

The flow diagram describes the sequence of activities in the processing and packaging of dried fruit from the reception of the raw materials until it is shipped out of the factory. It is best kept simple but should capture the salient activities which are associated with potential hazards.

The process flow diagram at FRI facility was done with the assistance of the resident engineer. The team walked through the facility to note each process step. The engineer then explained the significance of each of the step in relation to product realization. Critical attention was given to the technical operations and how the in-process products are either exposed to contamination risk or have impact on reducing/eliminating the risk of potential hazards.

## 3.8. HAZARD ANALYSIS

The process of hazard analysis was divided into two major components, hazard identification and hazard evaluation or risk assessment.

### *3.8.1. Hazard identification and classification*

This phase was mainly a brainstorming activity using expert knowledge and literature. The team identified all possible food safety hazards that could potentially be associated with each process step using a Risk matrix (Table 4b appendix 1). Each potential hazard identified was then classified as either physical, chemical and biological hazards based on ISO 22000 definition of what these classes of hazards are.

### *3.8.2. Hazard evaluation or assessment*

The significance of each identified hazard was determined using a hazard assessment matrix (Table 7). The process lead to establishment of the significant levels of each hazard. The significance of the hazards were determined by considering whether or not their elimination of reduction to acceptable levels was necessary in achieving food safety.

### *3.8.3. CCPs determination*

In accordance with codex recommendation, the CCP decision tree was used as the main tool in determining if a particular processing step that has been identified to have a hazard(s) with significant risk should be a CCP or not. The choice of CCP was also guided by the criteria of being

- Measureable
- Rapid to detect deviation

A HACCP chart was subsequently constructed using the framework recommended by codex. Verification was done using literature as well as expert knowledge from industry leaders and HACCP experts.

### *3.8.4. Validation of CCP*

CCP1: Drying

The EU laws regulating the determination of the moisture content for dried fruit was used as the reference point. The AOAC 1996 system of measurement is used in setting standard for moisture content. The moisture content loss is expressed as percentage by mass (grams per 100 grams). The AOAC determines moisture content of a test portion by drying in an oven for 6 hour at 70 +/- 1$^{o}$C under pressure less or equal 100 mm Hg. The objective at CCP was to attain a moisture content of between 10% - 13% and pH of 3.4 to 4.0.

The moisture content was analysed using a AOAC 1999 moisture balance.  Three samples were prepared from different varieties of pineapples namely sugar loaf, smooth cayenne and MD2. Each sample was prepared in duplicate and analysed using the method described above after drying at 65$^{o}$C for 24 hours.

Water activity was determined using a Novasina water activity meter.

CCP2: Metal detection

Samples of defect products (tainted with minute rust) were scanned using and hand-held metal detector at the FRI facility. Same samples were also scanned at the drying facility of HPW Fruits and Dry Limited.

### *3.8.5. HACCP Control Chart*

Based on the CCPs identified in processing, the HACCP control chart was contracted (Table 4). For each CCP, the identified and preventative measures were listed having assessed and appraised the hazard. Additionally, the critical limits, monitoring, corrective action and responsibility were summarized. It is based on the chart and all other information gathered in the process that a HACCP plan is produced.

**Table 2: HACCP Control Chart**

| Process Step | Class of Hazard | Description of hazard | Source of hazard | Hazard Evaluation/Assessment | Control measure | Responsibility | Record |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

# CHAPTER FOUR

# 4. RESULTS

## 4.1. PRE-REQUISITE PROGRAMS (PRPS)

The location is designed to eliminate the potential for food safety hazards from the environment. The centre, however has not documented environmental risk assessment report. Neither was there any policy or strategic plan on the environment.

Facility layout was linear, from raw material reception to finished product dispatch. High risk areas were well-separated from low risk areas with a good distance between raw material handling areas which involve sorting and de-crowning from all other areas. Washed area is also physically separated from peeling and cutting areas. Peeling, cutting and spreading on drying trays are however, done in the same room. Provision has been made for conditioning before packing of dried products. This room is equipped with a fan to aid the conditioning process. Staff changing facilities have been provided. This includes cloak rooms, toilets and hand-washing facilities.

The facility has a planned maintenance program for the dryer. The responsibility for ensuring this is with the residence engineer who works with a team of mechanical and electrical technicians. There was however no sanitation and pest control program in place.

## 4.2. THE HACCP PLAN

The researcher proceeded to develop a HACCP plan for the facility as detailed below:

For the purposes of the study, the HACCP team was restricted to three persons. These were:

- The Facility Engineer

- GIZ-MOAP Technical Advisor
- The Researcher

### 4.3. PRODUCT DESCRIPTION

For the purpose of this study, the researcher worked with the drying of pineapple for bulk packaging as pertains with companies drying fruits for export from Ghana. Clients are usually either bakeries or breakfast manufacturing companies in the EU. Table 5 provides full description of dried pineapples for export.

**Table 2: Product Description for Oven-dried Sliced Pineapples**

| | Product description form |
|---|---|
| Product name | FRITECH Dried Pineapple |
| Important product characteristics | Golden coloured ring shaped dried pineapples with 12% to 13% moisture; water activity of less than 0.60 and pH of between 3.4 and 4.0 |
| How is it to be used? | Raw material for baking, ingredient for breakfast cereal. Could be eaten directly as snacks |
| Packaging | 5kg packed in polyethylene bags |
| Shelf life | 6 months |
| Where will it be sold? | Other processing companies; retail stores |
| Labeling instructions | Keep refrigerated; could contain sulphur |
| Special distribution control | Stored and transport under normal temperature |

## 4.4. PROCESS FLOW DIAGRAM

The process flow diagram was constructed by a combination of consultation with industry experts. It‟s therefore a generic process flow that can be applied in the fruit drying industry depending on the level of technology and equipment. For instance, the drying facility at FRI does not have a metal detector installed on the line, other processing facilities visited during the research had a metal detector as part of the process flow. This thesis, therefore, included the metal detected as it is essential, based on evidence gathered from industry players in Ghana.

### *4.4.1. Detail of Processing Steps*

The details presented below was based on the observations by the researcher and some explanation provided by the residence engineer:

**Step 1: Raw Material**

Healthy and ripe pineapples of good quality (brix and colour) is used for processing dried pineapple chunks. Raw pineapple must be of MD2 or Queen Variety with a deep yellow colour and brix of 12° or more and not showing signs of translucency.

**Step 2: Cleaning and Sorting**

Cleaning and sorting of the raw pineapple is carried out to remove those that do not meet raw material quality criteria or containing foreign matter. This includes pest infested fruits, fruits with evidence of deterioration.

**Step 3: De-crowning**

De-crowning raw pineapples is done by breaking off the crown. De-crowning is carefully done in order not to cause any physical injury to the fruit.

**Step 4: Washing**

The de-crowned fruits are then washed by fully immersing them, for five minutes (5 Minutes), in a 100 ppm chlorine solution. This solution is changed after processing each batched or twice daily for an 8-hour straight operation. Washing is effectively done in order to destroy vegetative cells of microorganisms of public health significance and reduce the loads of other undesirable microorganism.

**Step 5: Peeling**

A sharp stainless steel knife is used to peel the pineapple. Peeling is carefully and properly done in a way that would not squash the fruit but remove all the eyes. Staff doing the peeling are made to wear the appropriate Personnel Protection Equipment (PPEs).

**Step 6: Coring**

The core of the fruit is gently removed using a pineapple core.

**Step 7: Slicing**

A sharp stainless steel knife or a slicer is used to cut the cored pineapple into rings or chunks (as the case may be) of uniform sizes. The uniformity of rings/chunks is essential in facilitating drying.

**Step 8: Steeping in Sodium Methbisulphate Solution**

Pineapple rings/chunks are placed into a stainless steel sieve/colander which is then immersed into a 0.05 % solution of sodium Methabisulphate for 10 seconds. Fruits are removed after this and adhering solution allowed to drip from the fruits.

**Step 9: Spreading**

Pineapple rings/chunks are spread out thinly on stainless steel drying racks or mesh before loading the racks into a pre-heated dryer. Care is taken to spread fruits thinly and evenly for uniform and rapid drying.

**Step 10: Drying**

Drying process is initiated by inserting fruit trays into the oven at between $60^{o}C$ to $70^{o}C$ for 18 hours.

**Step 11: Cooling**

Dried rings/chunks are removed from dryer and held on racks in the packaging room for cooling. It is of utmost importance that fruits are cooled before packaging to avoid the condensation of moisture within the package after packaging.

**Step 12: Sorting, Trimming and Cutting**

Sub-standard products (under dried, over brown, burnt) are removed. Some are trimmed to required shape and with the edges cut off to make the product look desirable and of uniform colour.

**Step 13: Packaging**

Dried pineapple rings/chunks packed into polyethylene bags or cans and sealed airtight. Packed fruits are stored away from light in a cool, dry area.

**Reception of fresh fruits**

⇩

**Cleaning and Sorting**

⇩

**De-crowning**

⇩

**Washing (200 ppm Chlorine)**

⇩

**Peeling, curing, and slicing**

⇩

**Dipping in 5 ppm $Na_2S_2O_5$**

⇩

**Spreading on Deying Trays**

⇩

**Drying**

⇩

**Cooling**

⇩

**Cutting/Streaming**

⇩

**Primary Packing**

⇩

**Scanning**

⇩

**Secondary packaging**

**Figure 8: Process Flow Diagram for Dried Pineapple**

## 4.5. HAZARD IDENTIFICATION

Table 6 presents the results of the hazard analysis process. It includes the possible hazards identified at each process step and evaluation of the food safety risk associated with each identified hazard. The result indicates that four process steps had hazards with significant levels of risk. These were

a. Peeling, coring and slicing
b. Drying
c. Sorting, cutting and trimming
d. Packing

The potential hazards at these steps were all biological except for the last step that had a physical hazard with significant level of risk.

## 4.6. HAZARD ANALYSIS

Table 6, shows the results of the hazards analysis for each step of the flow diagram. The researcher was unable to specifically identify which microorganisms were of hazardous importance. Instead he identified a mix of microorganisms. Again, the chemical hazards were grouped e.g. agrochemicals or detergents. No hazard was identified to be associated with the cooling step after drying. It was the only process step that was free from any hazard.

Control measures were also prescribed for each hazard identified. These are actions or activities that can be used to prevent, eliminate or reduce the occurrence of a given hazard to acceptable levels. Identified controlled measures are associated with Good Agricultural Practices (GAPs), Good Manufacturing Practices (GMPs) which includes the use of appropriate machinery and equipment and maintenance of high level of personal hygiene and operational sanitation.

**Table 3: Hazard Analysis Chart**

| | Class of Hazard | Description of hazard | Source of hazard | Hazard n/Assessm Likelihood | Severity | Risk | Sig. | Justification | Control measure | Responsibility | Record |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fresh fruit reception | P | Foreign matter | From farm and truck | 2 | 2 | 4 | No | Fruits are sourced from Approved farms | GAP | Supplier | |
| | C | Agrochemical residue | Inherent in fruit from the farms | 2 | 4 | 8 | No | Source fruits from only approved farms | SQA | Agronomist | Supplier list |
| | B | Microbes (sal, E.coli, Staph, etc) | Inherent in fruit | 1 | 3 | 3 | No | Source fruits from only approved farms | SQA | Procurement | Supplier list |
| | | | Personnel | 2 | 3 | 6 | No | Implement GHP | GHP | Supervisor | Supplier list |
| Sorting and decrowing | P | Foreign matter | Farm | 2 | 1 | 2 | No | trained staff & supervision | Training | Supervisor | |
| | B | Microbes (sal, E.coli, Staph, etc) | Food handler | 2 | 3 | 6 | No | Ensure GHP | Training | Supervisor | |
| Washing | C | Excess Cl | Chlorinated water | 1 | 1 | 1 | No | GMP | GMP | QA | |
| | B | E. Coli | Water | 1 | 3 | 3 | No | Water is chlorinated | Cl Conc | QA | |
| | | Staph, E. Coli, etc | Food handler | 2 | 3 | 6 | No | Ensure GHP | GHP | Supervisor | |

| | Class of Hazard | Description of hazard | Source of hazard | azard n/Assessm | | | | | Control measure | Responsibility | Record |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Likelihood | Severity | Risk | Sig. | Justification | | | |
| Peeling, coring & slicing | B | Microbes (sal, E.coli, Staph, etc) | Food handler | 4 | 3 | 12 | Yes | Personnel are in direct contact with exposed fruits when knives and fruits are not well washed and sanitised | GMP | Supervisor | |
| | | | Knives | 4 | 3 | 12 | No | | Uuse only approved knives | Supervisor | |
| steping in Citric Acid | C | Excess Citric acid | Citric acid Solution | 2 | 2 | 4 | No | Follow SOP for preparing solution | GMP | Technician | |
| Spreading | B | Microbes(sal, E.coli, Staph, etc) | Food handler | 4 | 3 | 6 | No | personnel are in direct contact with exposed fruits | Supervision | Supervisor | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | Contamination with metal | Rust from drying chamber | 4 | 4 | 9 | Yes | dryers are susceptible to rusting due to use of acid | 1. Coating of dryers. 2. Install metal detector | QA | |
| Drying | B | Microbes (sal, E.coli, Staph, etc) | inherent in fruits | 3 | 4 | 12 | Yes | Survival of microbes with drying temp/time and moisture content are not achieved | Time/Temp control | Operator | Time/Temp Record, lab analysis of moisture |
| Cooling | None | | | | | | | | | | |

| | Class of Hazard | Description of hazard | Source of hazard | Hazard n/Assessm<br>Likelihood | Severity | Risk | Sig. | Justification | Control measure | Responsibility | Record |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sorting, trimming and cutting | B | Microbes (sal, E.coli, Staph, etc) | Personnel | 4 | 3 | 12 | Yes | 1. GHP 2. When fruits are not well dried | sampling and testing moisture content | QA | Lab records |
| Packing | B | Microbes (sal, E.coli, Staph, etc) | Personnel | 4 | 3 | 12 | Yes | 1. GHP 2. When fruits are not well dried | GHP | Supervisor | |
| Scanning | P | Presence of metal pieces | Drying chamber | 3 | 4 | 12 | Yes | Chamber is susceptible to rust due the use of acid | screening products | Operator | |

### 4.7. DETERMINATION OF CCPS

The hazards that were identified to show high levels of significant and thus posing food safety risk were subject to the decision tree. Table 7 describes the outcome of the exercise. Two (2) process steps were identified as CCPs for pineapple drying. These were **moisture content/pH** at drying and **metal detection** after primary packaging.

**Table 4: Results of the CCP Determination Using the Decision Tree**

**Q1a:** Do control preventive measure (s) exist at this step? **YES:** Go to Q2. **NO:** Go to Q1b
**Q1b:** Is control at this step necessary for safety?

**Q2:** Is this step specifically designed to eliminate or reduce the likely occurrence of the hazard to an acceptable level?

**Q3:** Could contamination with identified hazard (s) occur in excess of acceptable level (s) or could these increases to unacceptable levels?

**Q4:** Will a subsequent step eliminate identified hazard (s) or reduce likelihood of occurrence to an acceptable level?

| Process Step | Activity | Class of hazard | Hazard description | Q1a | Q1b | Q2 | Q3 | Q4 | CCP/PRP/OPRP | Control Measure |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | Peeling, coring and slicing | B | Contamination with micro-organism by personnel and equipment | Yes | | No | Yes | Yes | OPRP | Enforce personal hygiene and sanitation regime for personnel and equipment |
| 7 | Drying | P | Contamination with rust from the drying chamber | Yes | | No | Yes | Yes | PRP (Supplies) | 1. Periodic inspection of chamber. 2. install a metal detector down stream |
| | | B | Survival of Microbes | Yes | | Yes | | | CCP 1 | 1. Enforce time/temp control. 2. Check moisture content before packing. 3. Train staff to detect poorly dried fruits |
| 9 | Sorting, cutting and trimming | B | Re-contamination with microbes | Yes | | No | No | | OPRP | 1. Enforce GHP. 2. pack only well dried fruits |
| 10 | Packing | B | Re-contamination with microbes | Yes | | No | No | | PRP (Pest control) | 1. Enforce GHP. 2. Pack only well dried fruits. 3. Ensure the fruits cool down to conditioning temperature before packing |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 11 | Scanning | P | Presence of metal pieces in product | Yes | Yes | CCP 2 | Monitoring of metal detector using test samples |



#### *4.7.1. CCP monitoring plan*

Table 8 below shows details of the CCP and the monitoring strategy recommended by the researcher. CCP 1 has to do with a time/temperature monitoring during the drying stage. The hazard is a biological hazard, survival of microorganisms if moisture content is favourable. CCP 2 is a physical hazard monitoring step with pieces of rust as the hazard.

**Table 5: CCP Monitoring Plan**

| CCP N° | Activity | Hazard description | Monitoring Parameters | Target | Critical Limits | Monitoring | | Corrective actions | Responsibility | Records | **Verification** (details in Verification Plan) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Procedure | Frequency | | | | |
| CCP 1 | Drying | survival of microbes | Time and temperature | 60 to 65 for 18 hours | 65 for 18 hours | reading on the monitor | Hourly | Re-adjust settings<br>Inform HACCP team leader if deviation persists | operator | Time/temp record sheet | checking of moisture content of products before they are taken from the dryer |
| CCP 2 | Scanning | Presence of rust | Detection of test metals | Ferrous 1.19mm, Non-ferrous 2.0mm and Stainless 2.5mm | | pass product through metal detector | Hourly | Isolate lot<br>Re-scan through metal detector<br>Troubleshoot process line to identify source of metal and address | Supervisor | Metal detection record book | Screening of test samples |

### *4.7.2. Validation of CCPs*

Results of the CCP validation is presented below:

CCP 1: Drying

The objective here is to attain a moisture content of less than 16% and pH of less than 4.3.

**Table 6: Moisture content, water activity and pH in dried fruits**

| Sample | Moisture Content (%) | Water Activity ($a_w$) | pH |
|---|---|---|---|
| Sample 1 | 11.2% | 5.5 | 3.82 |
| Sample 2 | 12.8% | 5.4 | 3.81 |
| Sample 3 | 10.9% | 5.7 | 3.74 |

**Table 7: Test for Metals in Fruits**

| Sample | Hand-held metal Scanner | Industrial Metal Scanner |
|---|---|---|
| Sample 1 | Detected | Detected |
| Sample 2 | Detected | Detected |
| Sample 3 | Detected | Detected |

# CHAPTER FIVE

# 5. DISCUSSION

## 5.1. STATE OF PRE-REQUISITE PROGRAMMES AT THE PROCESSING

**CENTRE**

## 5.2. STATE OF INFRASTRUCTURE

The results of the PRP audit revealed that the basic infrastructures are well-located. There were no issues relating to possible contamination from ether the immediate environment or the fabric itself. The immediate surrounding is partly paved and gravelled. This allows for easy runoff of rain water, as well as, eliminating the possibility of dust contamination.

The building is constructed of concrete block with smooth finishing. Some parts had oil paint while the high risk areas such as the processing room have the walls tiled. This makes it easier for cleaning. The floor is smooth and impervious. Drainage systems are well defined and drain ends covered to prevent the entry of vermin. Overhead fittings such as fans and electrical bulbs are cleaned and well maintained. Bulbs are also well shaded. Electrical wires are well trunked. Plumbing pipes are also well trunked and marked where necessary. Doors and windows are netted against the ingress of pest and rodents.

The process flow from low risk (raw material entry) to high risk (finished product handling) is linear. This eliminates risk of cross contamination during processing. It also helps control human movement within the entire operational area. Colour coding system should however be applied with the dress codes for people working in the low and high risk areas to help enforce restriction of personnel movement.

## 5.3. THE HACCP STUDY

The developed HACCP plan considered three main hazards. These are physical, chemical and biological hazards. The study was based on processing of pineapple. Each process step in the fruit preparation and drying were subjected to hazard analysis based on the Codex Alimentarius guidelines for the implementation of the HACCP system. All food safety hazards, that may reasonably be expected to occur, were identified by the process and fully evaluated and controlled so that products do not represent a direct or indirect risk to the consumer.

## 5.4. CONTROL OF HAZARDS

Hazards are controlled by instituting actions and activities at each processing step to eliminate a hazard or reduces their occurrence and hence risk to acceptable levels. Control measures are mostly defined within existing work instruction except for CCPs.

### *5.4.1. Managing Chemical Hazards*

The Hazard Analysis Chart identified three major potential sources of chemical hazards. These source are

1. agrochemical applied at the farm
2. sanitizers and cleaning agents used in the factory
3. use of pesticides and other vermin control agents within the factory

Agrochemicals are always controlled using Maximum Residue Levels (MRL) recommended by national standards. These can only be controlled at the farm level as the processing steps during fruit drying is unable to reduce or eliminate agrochemical residue. This means that the fruits must be acquired from approved source. A manufacturing unit must therefore implement a Supplier Quality Assurance (SQA) for the supplier of fruits. The farmer must guarantee that the fruits are safe from agrochemicals. A critical means of assuring such safety is through farm (supplier) audit or buying from certified farms. The supplier may be requested to add Certificate of Analysis (CoA) to suppliers as proof of safety.

Contamination from cleaning agent and pest control within the facility could be controlled by conforming to GMP. Using food grade sanitizers and applying at recommended concentration and conditions will ensure that contamination risk is eliminated. Fruits that are washed using sanitizers such as chlorinated water should be rinsed in clean/portable water to remove all traces of the sanitizer from the fruit before processing. Again, sanitized equipment should be rinsed if harsh chemicals such as caustic soda are used.

Pest control using pesticides and fumigants will have to be done by professionals or staff who has received appropriate training.

***5.4.2. Control of Physical hazards*** Codex defined physical hazards as:

*"Potential physical hazards associated with fruit drying are metal usually from processing equipment and foreign materials from the environment"*

Control of physical hazards in dried fruits is very basic GMP issue. It may require

1. Good supervision and training of staff to be vigilant
2. Using stainless steel equipment such as knives and having an inspection regime for cutting tools or metals that come into contact with food.
3. Implementing other policies such as hygiene and glass policy
4. Avoiding the use of small metals such as staple pins in the processing area
5. Metal scanning of finished products

Product lots that are identified to be contaminated with foreign bodies should be isolated and quarantined. The problem will have to be investigated and the appropriate corrective and preventive actions taken. Metal detectors are the most recommended for identification and elimination of dried fruits with metal contamination.

***5.4.3. Control of Biological Hazards***

The first line of control for biological hazards is to ensure that safe raw fruits are used. Avoiding the use of fruits that are rotten and by ensuring that all fruits are washed and sanitized are important in this respect. This study uses chlorine solution at 100 ppm to wash all fruits before processing. Chlorine is a known disinfectant against protozoa, bacterial and viruses except for cysts, eggs of protozoa and hermits which are generally considered to be resistant except at very high concentration and prolong contact. The USFDA Code of Federal Regulation, 21 CFR part 173 recommend 200 ppm of chlorine for distinction of produce and processing equipment. The processing step ensures that the fruits are rinsed after washing to eliminate excess chlorine on fruits while equipment are allowed to drain after washing.

The second source of biological contamination is from staff and equipment. These sources are mostly controlled through the implementation of Good Manufacturing Practices and personal hygiene.

The hazard analysis chart recognises the drying step as the only step where any surviving microorganism can be eliminated from the product. Achieving this requires application of heat at a minimum of 65$^{o}$C for 18 hours. The design of the drying step of 65$^{o}$C for 18 hours is enough to destroy any pathogenic microorganism except for cyst bacterial. This process was considered a CCP after subjecting it to the decision tree because it is also critical for maintaining product integrity after drying. Subsequent steps after drying involves manual handling of the fruits, a practice that could potentially expose processed fruits to re-contamination. Assuring safety during these post-drying steps requires:

i. strict implementation of sanitation and personal hygiene rules.

ii. that dried product has the required characteristics to prevent or minimise the potential for survival and growth of pathogenic microorganisms. Target characteristics are moisture content, water activity and acidity/pH of the dried fruits.

## 5.5. DETERMINATION AND CONTROL OF SIGNIFICANT HAZARDS

Four processing steps were identified with hazards considered to pose high food safety risk to consumers based on their evaluation using the hazard evaluation matrix. The results are presented in Table 11.

**Table 8: Hazard Identification**

| Process step | Hazard |
|---|---|
| 1 Peeling, coring and slicing | BH: microbial contamination from the food handlers and working equipment |
| 2. Drying | PH: Rust from drying shelves and oven |
| | BH: Survival of microbes that may be coming with the fruits |
| 3. Sorting, trimming and cutting | PH: Fillings from cutting knives and scissors |
| | BH: Re-contamination from food handlers and equipment |
| 4. Packaging | BH: Recontamination by the food handlers and equipment |

Two classes of hazards were identified; these are physical and biological hazards. The sources of these hazards were from the food handlers and the processing equipment. This is in line with literature which suggests that the major route for biological contamination if the food industry are the raw materials, processing equipment and food handlers.

With reference to the physical hazards, implementation of Good Manufacturing Practices such as the use of stainless steel cutting material will help eliminate the risk of occurrence. The issue related with rust is however a little complicated as the dryers are already fabricated and replacements may not be easy to implement. Rust could therefore, persist should it find its way into a food product.

The presence of moisture within the drying chamber over a period could aid corrosion on the metal surfaces that can lead to flaky crust. Again, considering that the fresh cut fruits are treated with sulphur based chemicals such as Soduim Metabisulphate, the sulphur could induce more corrosion effect on the metals. Sulphur dioxide in water creates sulphuric acid, with the potential of etching iron into solution and subsequently oxidising to form rust. Blaiser (2015) confirmed that rust contamination has been a course of product rejection by clients. These were traced to the drying chamber. Thus even though iron fillings were identified as hazards with significant risk, the probability of occurrence could be significantly reduce through the use of appropriate equipment. The risk associated with rust is however considered high and significant because simple GMP on the existing facility would not be enough to eliminate the hazard.

### 5.6. CCP DETERMINATION AND SETTING OF CRITICAL LIMITS

The study identified two processing steps as CCPs for the drying of pineapples. These are the drying step for the control of microorganisms and metal scanning of packed products for the presence of rust or iron fillings from processing equipment.

Generally, most pathogenic microorganisms are destroyed at temperatures above 60$^{o}$C. It implies that drying at 62$^{o}$C for 24 hours is enough to destroy any potential microorganism that may be present on the fruits. The real risk, however, is on survival and growth of pathogens. The target time/temperature index is thus to ensure that the product attain water activity/acidity mix that huddles to prevent microbial growth should any potential contamination occur during post drying handling. The result in Table 9 indicates water activity of between 0.54 and 0.57. These are well below the target of 0.60. According to Fontana (1998), water activity of 0.90 limits growth of most pathogenic bacteria, 0.70 for spoilage molds with a critical limit of 0.60 for osmophilic yeast. Water activity is also noted to huddle well with other preservative factors such as pH in controlling microbial activity in food. Therefore, in the control of growth of microbes in dried pineapples, water activity and the low pH huddles to preserve dried pineapples against microbial growth. In addition, „Case Hardening" as observe with the final products seals potential inoculation sites on the product.

The setting of critical limits for metals is based on industrial practice and expert view as solicited from industrial experts in Ghana.

**Table 9: CCPs and Critical Limits**

| Process step | CCP No. | Control Measure | Critical Limit |
|---|---|---|---|
| Drying | CCP 1 | Monitoring of water activity hourly after drying for 18 hours | 0.60$a_w$ |
| Metal Scanning | CCP 2 | scanning of test samples per shift or batch | 1. Ferrous 1.19mm<br>2. Non-ferrous 2.0mm<br>3. Stainless 2.5mm |

### 5.7. CONCLUSION

Two (2) CCPs were identified in the HACCP study. These are CCP1 at drying and CCP2 for metal detection. CCP 1 could be monitored using either moisture content or water activity but preferably with water activity. The critical limits are of 11% to 14% moisture content or a water activity of below .060 and CCP2 at metal detection process step with Ferrous 1.19mm, Nonferrous 2.0 mm and Stainless 2.5 mm. Because it is not economical to open the oven periodically and take samples for analysis, it is recommended that the time/temperature monitoring should be validated for every operation to ensure that the final products reach the set limits.

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# 7 APPENDIX 1

**Table 10: Product Description Form**

| No. | Parameters | Characteristics/conditions |
|---|---|---|
| 1. | Product name | |
| 2. | Important product characteristics | |
| 3. | How is it to be used? | |
| 4. | Packaging | |
| 5. | Shelf life | |
| 6. | Where it will be sold | |
| 7. | Labeling instruction | |
| 8. | Distribution condition | |

Adapted from Canadian Food Inspection Agency (2001)

**Table 11: Raw Material and Potential Hazards Table**

| Main ingredient | Other ingredient | Incoming material | Packaging |
|---|---|---|---|
| | | | |

Adapted from Canadian Food inspection Agency (2001)



**Table 4b: Hazard Risk Assessment Chat**

| Process Step | Potential Hazards | Justification | Hazards to be address in plan (Y/N) |
|---|---|---|---|
| | | | |