UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

THE PROCESSING, PACKAGING, AND ACCEPTABILITY OF YAM STRIPS FOR USE AS CONVENIENT FOOD

ERIC MENSAH CHRIST

DECEMBER, 2014

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DECEMBER, 2014

DECLARATION

STUDENT'S DECLARATION

I, **Eric Mensah Christ,** declare that this Dissertation, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original research work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE……………………………………

DATE…………………………….……………

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this research work was supervised in accordance with the guidelines for supervision of Dissertation as laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: MRS. DEDO-ADI DOREEN

SIGNATURE…………………………………….

DATE……………………..……………………

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DEDICATION

This work is dedicated to my lovely wife Margaret Selorm Akorsihu, my dearest son Klenam, and my siblings and also to my late mother.

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ABSTRACT

Yam is one of the most important food commodities cultivated in Ghana. Nevertheless, majority of those yams go waste due to interrelated factors such as post-harvest losses, deterioration, and weight loss in stored yams. The aim of the study was to process and package yam into strips to enhance its use and marketability to non-producing countries just like Irish potato. Two cultivars of white yam (*Discorea rotundata)*, were used for the study. They were processed into strips and packaged in a 1.5kg polyethylene bag which was designed and labelled for the purpose. The packaged product was frozen using an Ocean freezer at a temperature of -18^{o}C for storage studies over a period of four weeks. The frozen yam strips were fried and presented to respondents on a weekly basis for four weeks to assess them in order of preference with respect to their sensory attributes (size, colour, aroma, taste, moistness, hardness, crispiness, sogginess and overall acceptability). Chemical analysis was also conducted on the frozen yam samples every one week for four weeks to determine the level of moisture, sugars (sucrose, reducing sugars, and total sugars) and free fatty acids. The result of the sensory evaluation showed that fried yam strips were found to be acceptable as most of the participants indicated that they were satisfied. On the other hand, the results of the chemical analysis obtained had no significant change from the first week to the fourth week of analyses. Hence, the yam samples after storage in the freezer for a month (4 weeks) had no chemical change and could therefore be further preserved. It was recommended that the yam strips should be thawed before frying, for this gives a uniform texture as compared to direct frying from the frozen state.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Yam is one of the most important starchy crops grown in the form of large tubers produced by annual and perennial vines and it is the common name given to a plant species in the genus *Discorea* which belong to the family known as *Discoreacea* (IITA, 2012; Lopez-Montes *et al.,* 2012). There are over 600 species of yam in existence but only about six are grown for consumption namely: white yam (*D. rotundata*), water yam (*D. alata*), yellow yam (*D. cayenensis)*, aerial yam (*D. bulbifera*), trifoliate yam (*D. dumetorum*), and chinese yam (*D. esculenta*) (Purseglove, 1972; Orkwor *et al*., 1999; Asadu & Dixon 2013). According to Hahn (1995) cited in Asadu and Dixon (2013) the six species represent over 90% of yam cultivated throughout the tropics. A study by IITA (2012) revealed that among the many species of yam available, about 10 of them are widely cultivated around the world. However, only *D. rotundata, D. alata* and *D. cayenensis* are predominantly cultivated species in West Africa.

The origin of yam, according to Global Crop Diversity Trust (2013), can be traced to each of the three tropical continents: Africa, Asia and America. In Africa, yam cultivation is said to have begun some 11000 years ago (IITA, 2012). Almost all worldwide yam production takes place in developing countries with Africa being the largest producer. Based on the report of International Institute of Tropical Agriculture (IITA) worldwide yam production in 2007 was to the tune of 52 million tons, of which Africa produced 96%. The report further indicated that most of the world's yam production comes from West Africa depicting 94%, with Nigeria alone producing 71%, reaching more than 37 million tons.

About 48.1 million tons of yam are produced annually in West Africa's "Yam Belt" which extends from Ivory Coast to Nigeria, representing over 90% of global production (IITA, 2012; Lopez-Montes *et al.,* 2015). Yam is a primary agricultural commodity and major staple crop in Africa. In West Africa yam is a major source of income and has high cultural value: Yam is used in fertility and marriage ceremonies, and a festival is held annually to celebrate its harvest. Consumer demand for yam is generally very high in this sub-region and cultivation is very profitable despite high production costs. Ghana is the second largest producer of yams after Nigeria with nearly 6.3 million tons of yams produced in 2011(MoFA, 2013; Lopez-Montes *et al*., 2015). According to MOFA statistics, in 2012 yam production reached 6,639 million tons.

Ghana export yam in large quantities making it the market leader in yam exportation in the whole world, even though it is placed second in the production of yam after Nigeria. The total yam exported by Ghana in the year 2008 amounted to 20,841 metric tons. Per capita intake of yam among Ghanaian run high by 12 percent between 1997 and 2007. On an average, the daily intake of yam is close to 300kcal per capita and it is regarded as the most valuable means of energy accounting for 20 percent of the total caloric intake. Yam production during the period of 2005 to 2010 accounted for about 24 percent of total roots and tubers production in Ghana (Anaadumba, 2013).

The study conducted by Anaadumba (2013) further identified that districts which produces yam on large scale are mainly found in the Central and Northern parts of Ghana. The majority of yam comes from the Brong Ahafo, Northern and Easten

Regions, representing 39, 25 and 12 percent of total yam production, respectively. Yam production within the three regions amounted to 76 percent whereas the rest 24 percent of production is distributed among the Upper West, Ashanti, Volta and Western Regions.

In Ghana, smallholder farmers form the majority of people who are actively engaged in yam plantation using basic hand tools. This phenomenon tends to be labour intensive, mostly in terms of land preparation and accessing seed yams. Fundamentally, yam is grown in Ghana through the shifting cultivation system whereby a small scale farmer tills a piece of land until it is no more productive and then shifts to another piece of land rendering the former plot of land unproductive for one or more growing seasons. Usually, planting occurs between February and April whereas the main harvesting season occurs from August to December and a lean crop season occurs from May to July (MCC, 2015; Anaadumba, 2013).

There are many varieties of yam produced in Ghana including Pona, Laribakor, Dente, Asana and Serwa. Mankrong and Kukurapa are the newest varieties introduced by Ghana's Crop Research Institute (CRI). Among the different kinds of yam produced in the country, white yam continues to be the most desired variety in both the domestic and export markets (MCC, 2015; Anaadumba, 2013).

"Laribakor" and "Pona" are regarded as the tastiest yams among the many varieties grown in Ghana and have similar characteristics. In this study "Laribakor" and "Dente" were chosen since they differ in many ways by character. "Laribakor" is said to be tastier than "Dente" due to its sugary characteristic; it has less water content and therefore fry faster than "Dente"; it is also said to have less starch and a lot of fragrance as compared to Dente. On the other hand, "Dente" is branded by being having a flat taste which may be due to its water content. It has high water content than "Laribakor" and hence takes a longer time to fry; it has more starch and less fragrance. However, when the storage time for "Dente" prolongs and dehydration takes place, it becomes tasty but not to the degree of "Laribakor".

Yams are cultivated for direct human intake and are sold as fresh produce in all the growing communities. Generally, yams are prepared by boiling, frying and baking. Boiled yam could be eaten with cocoyam leaf stew or pounded and eaten with light soup. Fried yams are often eaten with fresh pepper sauce and shitor. They are also used for many industrial purposes such as starch, poultry and livestock feed, and production of yam flour. The peels are often dried and used for a popular local dish known as 'wasawasa' which is heavily patronized in the Northern Region of Ghana. The peels are also used as animal feed in many rural areas.

1.2 Problem Statement

Processing and packaging of agriculture produce in Africa are among the greatest basic challenges facing the continent. Although developing countries in Africa are blessed with abundant raw materials such as fertile lands, diverse staple commodities, cheap labour and so on, it is noteworthy that all of these things in themselves alone cannot support the continent to become competitive in today's world.

The paper presented by Byanyima (2004) stated that in modern age where technological advancement reduces distance between countries, it is impossible to rely solely on natural resources to create competitiveness. She said one of the most critical challenges faced by the agriculture sector in developing countries is orienting production and marketing to the consumer in both internal and external market. She further noted that the introduction of variety of goods through food processing, new product development, improved quality and safety supported by market studies is one of the means by which to create new products and expand market opportunities.

In Ghana, the capability of the local people to process pretty good quality food products is still lacking and the country still imports processed foods in large quantities. This phenomenon shows that there is enormous internal market that can be exploited by local food business owners. As a matter of fact, the food processing sector still remains to a large extent unexploited and virgin which is an opportunity in itself for the local people.

Yam is one of the commonest staple commodities cultivated in Ghana. Unfortunately, majority of those yams go waste due to interrelated factors such as post-harvest losses, deterioration, sprouting, respiration and weight loss in stored yams. Nevertheless, almost every household in Ghana include yam dish on their daily menu which is eaten boiled or fried, baked or pounded. Even though Ghana is said to have been the largest exporter of yam in the world, it only does so without any or little value addition to the commodity. As a result, yam is often sold or traded unprocessed.

However, in an era where consumer demand for minimally processed food is high and the need for reduced preparation and cooking time of food, it is becoming unattractive to sell whole yam tubers to the working class since the yam could be minimally processed and used as a convenient food. Fried yam, which is a delicacy for both the elite and the uneducated people in Ghana, is mostly sold by street vending which is quite patronized. But this cannot be compared to the patronage of potato fries which has been attractively packaged and sold on the market.

This research work sort to process yam into strips for use as a convenient food item so as to make maximum use of the crop to increase production throughout the country.

1.3 Main Objective

The main objective of this study was to process and package yam strips from two cultivars of white yam (*D.rotundata*) namely: "Laribakor" and "Dente" for use as convenient food.

1.3.1 Specific Objectives

The specific objectives were to:

1. determine consumer acceptability of packaged yam strips.
2. determine physico chemical properties and storage stability of packaged yam strips.

1.4 Delimitation

The study was intended to cover the following delimitations:

- The study is centered on only two varieties of yam namely: "Laribakor" and "Dente" which are all varieties of white yam (*D. rotundata*) and did not include other types of yams.
- The study focuses on the processing and packaging of yam into strips for use as convenient food.
- The study also attempts to assess commercial viability of packaged yam strips.

1.5 Significance of the Study

In this era of globalization where tourism is on the increase, foreigners would be interested in patronizing local foods. However, this can only be achieved when the local foods are processed and attractively packaged to meet their standard. This will help increase the consumption of locally processed food products in both the domestic and international market. The primary purpose of food processing in developing countries like Ghana should be to encourage effective substitution of imported food items by adding value to local staple commodities so as to increase return on farmers' produce. This will help in expanding the market opportunities for local foods and improve their shelf life to defeat perishability and seasonality. Other important contributions of this study are outlined below:

- Hotels, restaurants and takeaway food operators will benefit a lot since the yam is minimally processed and require no preparation before frying. It will save time and labour.
- Development of yam into convenient food product and high quality packaging will contribute immensely by adding value to the crop thereby increasing yam availability in all seasons.
- Successful completion of this research work may result in building small scale yam processing plants which can help translate into increased yam production and improve farm incomes.
- Local food processing enterprises would benefit from the project as this would help them generate off farm employment in rural areas and therefore decrease over dependence on agriculture.
- Yam exporters would also benefit from the project as they can export yam in its processed form. This would help increase their earnings on export because of the value added to yam.

1.6 The Layout of the Research Report

The research report is presented in five chapters as shown in the outline given below:

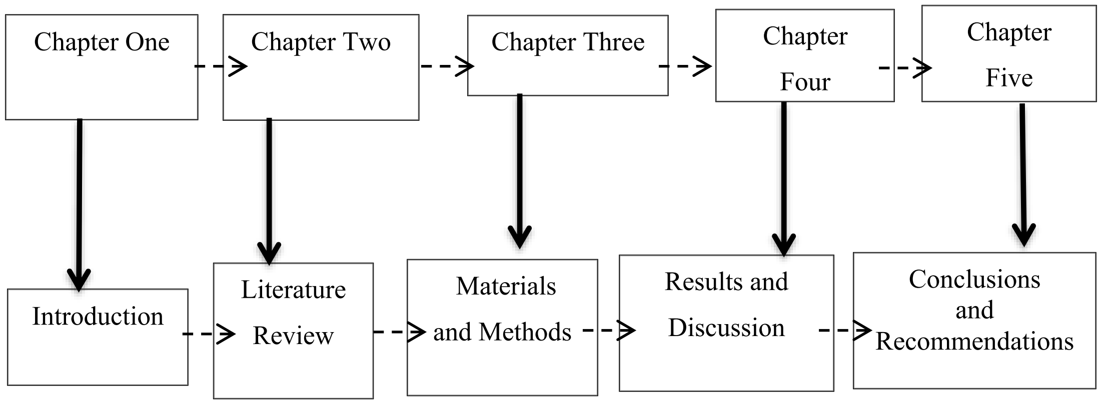

Figure 1.1: An outline of the study

Chapter One: Introduction

The introduction aspect of the study provides the general conceptual framework for the research work. It covers the background and general concepts; problem statement; objective of the study; delimitations, significance of the study; and the general outline of the research report.

Chapter Two: Literature Review

This chapter critically reviews related literature on food processing, packaging and yam. It establishes the premise or the theoretical framework for processing and packaging of yam.

Chapter Three: Materials and Methods

This part of the research report provides an overview of the methods used in processing and packaging of yam strips. It recounts the plan by which the research was conducted.

Chapter Four: Results and Discussion

This chapter presents the results of the study and the objectives of the study are discussed in relation to the findings gathered from the information provided by the research respondents.

Chapter Five: Conclusions and Recommendations

This chapter focuses on the conclusions and recommendations. It draws conclusions from the findings and makes possible recommendations regarding the best ways to use the yam strips and also future research works on yam.

CHAPTER TWO

LITERATURE REVIEW

Introduction

Chapter two focuses on related literature regarding the topic under study. In order to conduct effective literature review, the chapter is presented in three parts. It begins by looking at food processing and packaging; then proceeds to review previous researches conducted on yam and the third part review the chemical analysis conducted on the Dente and 'Laribakor' samples.

2.1 Food Processing

Food processing is defined by Helman *et al.,* (1997) as the practices used by food and beverage industries to transform raw plant and animal materials, such as grains, produce, meat and dairy, into products for consumers. It refers to as any procedure undergone by food commodities after they have left the primary producer, and before they reach the consumer, who may themselves further cook or process the food. The objectives of food processing are manifold, and include the prolongation of shelf-life, ensuring safety, improving palatability, increasing variety, improving nutritional value and increasing convenience (Welch & Mitchell, 2000).

Nearly all foods are processed in some way. Examples include freezing vegetables, milling wheat into flour and frying potato chips. Slaughtering animals for meat is also sometimes considered a form of food processing. Not all foods undergo the same degree of processing. Processed foods are classified in three categories even though there is no universally accepted method of categorizing processed foods. This includes: minimally processed food, processed food ingredients and highly processed food (Helman & Hartel, 1997; Truswell & Brand, 1985; Monteiro & Levy, 2010; Monteiro, 2009). Each of these categories of processed food is briefly explained below.

2.1.1 Minimally processed food

Fruit, vegetables, legumes, nuts, meat and milk are often sold in minimally processed forms. Foods sold as such are not substantially changed from their raw, unprocessed form and retain most of their nutritional properties. Minimal forms of processing include washing, peeling, slicing, juicing and removing inedible parts. Some nutritionists also characterize freezing, drying and fermenting as minimal forms of processing. To prolong shelf life and inhibit the growth of pathogens, perishable foods may have preservatives added to them, or they may be sealed in sterile packaging. Some minimally processed foods and beverages may be exposed to controlled amounts of heat, or in some cases radiation, to inactivate pathogens. Milk, for example, is commonly heat pasteurized. After purchase, consumers may cook these foods and mix them with other ingredients as part of their preparation (Monteiro & Levy, 2010; Monteiro, 2009; Ohlsson *et al*., 2002; Maroulis & Saravacos, 2003; Wiley, 1994; Alzamora, 2000).

2.1.2 Processed food ingredients

In view of Monteiro & Levy (2010), this category includes flours, oils, fats, sugars, sweeteners, starches and other ingredients. High fructose corn syrup, margarine and vegetable oil are common examples. Processed food ingredients are rarely eaten alone; they are typically used in cooking or in the manufacture of highly processed foods. To create these ingredients, starting materials such as grains and oil seeds may be milled, refined, crushed or exposed to chemicals. Unlike minimal forms of processing, these techniques radically change the nature of the original raw materials. Processed food ingredients tend to be nutrient-poor, meaning they are high in calories relative to the amount of vitamins, minerals and other key dietary nutrients.

2.1.3 Highly processed foods

Highly processed foods are made from combinations of unprocessed food, minimally processed food and processed food ingredients which are designed with consumer convenience in mind. They are often portable, can be eaten anywhere (while driving, working at the office and watching TV, for example) and require little or no preparation. Highly processed foods include snacks and desserts, such as cereal bars, biscuits, chips, cakes and pastries, ice cream and soft drinks; as well as breads, pasta, breakfast cereals and infant formula. Highly processed animal products include smoked, canned, salted and cured meats and products made from extruded remnants of meat, such as nuggets, hot dogs and some sausages and burgers. Many vegetarian alternatives to meat are also highly processed. Highly processed foods are made using techniques like mixing, baking, frying, curing, smoking and the addition of vitamins and minerals. (Monteiro & Levy, 2010; Monteiro, 2009; Slimani *et al*., 2009).

2.2 Packaging

According to Fellows (2000), packaging is an important part of all food processing operations and it is integral to the operation itself. There have been substantial developments in both materials and packaging systems over the last ten years, which have been instrumental in both reducing packaging costs and the development of novel and minimally processed foods. He noted that packaging may be defined in terms of its protective role as in 'packaging is a means of achieving safe delivery of products in sound condition to the final user at a minimum cost' or it can be defined in business terms as 'a techno-economic function for optimising the costs of delivering goods whilst maximising sales and profits'.

Packaging plays several functions in food processing which are briefly explained under the following points:

- containment – to hold the contents and keep them secure until they are used
- protection – against mechanical and environmental hazards encountered during distribution and use
- communication – to identify the contents and assist in selling the product. Shipping containers should also inform the carrier about the destination and any special handling or storage instructions. Some packages inform the user about method of opening and/or using the contents
- machinability – to have good performance on production lines for high speed filling, closing and collating (1000 packs per min or more), without too many stoppages.
- convenience – throughout the production, storage and distribution system, including easy opening, dispensing and/or after-use retail containers for consumers (Paine, 1991).

2.2.1 The Use of Plastics in Food Packaging

The most recent EU Directive relating to 'plastic materials and articles intended to come into contact with foodstuffs' (reference 2001/62/EC) defines *plastics* as being: 'organic macromolecular compounds obtained by polymerisation, polycondensation, polyaddition or any similar process from molecules with a lower molecular weight or by chemical alteration of natural macromolecular compounds'. Plastics are used in the packaging of food because they offer a wide range of appearance and performance properties which are derived from the inherent features of the individual plastic aterial and how it is processed and used. Plastics are resistant to many types of compound – they are not very reactive with inorganic chemicals, including acids, alkalis and organic solvents, thus making them suitable, i.e. inert, for food packaging. Plastics do not support the growth of microorganisms. Some plastics may absorb some food constituents, such as oils and fats, and hence it is important that a thorough testing is conducted to check all food applications for absorption and migration. Gases such as oxygen, carbon dioxide and nitrogen together with water vapour and organic solvents permeate through plastics (Kirwan & Strawbridge, 2003). The main reasons why plastics are used in food packaging are that they protect food from spoilage, can be integrated with food processing technology, do not interact with food, are relatively light in weight, are not prone to breakage, do not result in splintering and are available in a wide range of packaging structures, shapes and designs which present food products cost effectively, conveniently and attractively. Plastics can be coloured, printed, decorated or labelled in several ways, depending on the type of packaging concerned. Alternatively, some plastics are glass clear, others have various levels of transparency, and their surfaces can be glossy or matte. Plastics are also used to store and distribute food in bulk, in the form of drums, intermediate bulk containers (IBCs), crates, tote bins, fresh produce trays and plastic sacks, and are used for returnable pallets, as an alternative to wood (Kirwan & Strawbridge, 2003).

2.2.2 Types of Plastics Used in Food Packaging

The following are the types of plastics used in food-packaging

- polyethylene (PE)
- polypropylene (PP)
- polyesters (PET, PEN, PC) (note: PET is referred to as PETE in some markets)
- ionomers
- ethylene vinyl acetate (EVA)
- polyamides (PA)
- polyvinyl chloride (PVC)
- polyvinylidene chloride (PVdC)
- polystyrene (PS)
- styrene butadiene (SB)
- acrylonitrile butadiene styrene (ABS)
- ethylene vinyl alcohol (EVOH)
- polymethyl pentene (TPX)
- high nitrile polymers (HNP)
- fluoropolymers (PCTFE/PTFE)
- cellulose-based materials
- polyvinyl acetate (PVA).

2.3 Botanical and Agronomic Characteristics of Yams

According to O'Sullivan (2010), the term 'yam' refers to all members of the genus *Dioscorea*, which is made up of over 600 species. Nearly 10 species are commonly grown for food, while a number of others are harvested from the wild during scarcity of food (for example Bhandari et al. 2003). In view of Coursey (1967) many wild yam species contain toxic or bioactive chemicals, and some of these are cultivated for pharmaceutical purposes.

All yams, even though highly variable in appearance both between and within species, share a mutual growth habit of thin, twining vines and a shallow, widely radiating root system, both of which die and are renewed each year. All economically important species are tuberous, producing one or more underground tubers, which are starch storage organs derived from stem tissue. The tubers provide a means of vegetative propagation from one season to the next. In most cases the tubers are annual—they wane at the start of the new growing season and are replaced by new tubers. Nevertheless, some genotypes of several species produce perennial tubers, which may continue to grow over several years. Many species produce aerial tubers, or bulbils, as a means of vegetative dispersal (O'Sullivan, 2010).

O'Sullivan (2010) further said that the most common way of yam plantation is by vegetative propagation than propagation by true seed, even among wildest yam species. Cultivated yams are almost exclusively vegetative propagated. As a result, cultivars are clones of an ancestral plant, but spontaneous somatic mutations may have contributed to the diversity and productivity of modern cultivars.

Yams are dioecious, with male and female flowers borne on separate plants. Cultivars may be male, female or sterile. Female plants tend to produce fewer tubers and therefore are relatively rare among cultivated yams. Breeding is inhibited not just because there are few suitable females and the fact that many of the plants with the most desirable features do not flower at all, but also due to the existence of multiple ploidy levels (chromosome numbers) in most species (Hahn 1995) and the flowering of different genotypes at different times. Fertile seeds are produced only when males and females of similar ploidy level flower simultaneously. Nevertheless, promising breeding programs are underway for the most important species, with the exception of *Dioscorea esculenta*, of which no female plants have been found (O'Sullivan 2010).

2.3.1 Origin and current distribution of major food yam species

In the book of Coursey (1967) Dioscorea is a pantropical genus and different species have been independently domesticated on each continent. *Dioscorea alata*(greater yam or water yam) is the most widespread species. It was thought to originate in southern Asia, but recent genetic studies have identified Melanesia as its centre of origin, and this region remains its centre of diversity (Lebot 1999). Evidence exists of its domestication in New Guinea at least 10,000 years ago, and its existence in northern Australia is believed to be due to human introduction before the continent was separated from New Guinea by sea level rise 10,000 years ago. It is believed to have been among several Asian crops introduced to Madagascar by Austronesians some 2,000 years ago, and from there spread into mainland East Africa (Lebot 2009). It is not clear whether *D. alata* was established in West Africa before European contact, but it has since come to rival African species both there and in the Caribbean. In West Africa, *D. cayenensis* (yellow Guinea yam) and *D. rotundata* (white Guinea yam) are endemic, and the main species cultivated. The distinction between these species is unclear, and some researchers prefer to refer to them as the *D. cayenensis–rotundata* species complex (Hahn 1995), while others argue that they should be recognised as separate taxa (Mignouna *et al.* 2005). Among non-geneticists, the distinction is usually retained for practical morphological reasons. The species status of West African yams is poorly defined in any case, as cultivars of both yellow yam and white yam may have arisen through independent hybridisation of wild or feral parents, including *D. abyssinica* and *D. praehensilis*, with little genetic exchange occurring naturally among members of either group (Chair *et al*. 2005). Cultivation of these species in Africa is believed to have started at least 7,000 years ago (possibly much earlier), and domestication of wild types continues today (Lebot 2009).

In Central America, *D. trifida* was domesticated by Amerindians. It has since been widely dispersed in Asia and the Pacific region, but remains a minor crop in all areas in which it is grown. The origin of *D. esculenta* (lesser yam, mami) has not been established, but may be either in South-East Asia or Melanesia. In Papua New Guinea, *D. esculenta* is the dominant staple food species grown by yam dependent communities, although *D. alata* retains its status for cultural and ceremonial purposes. This suggests that the domestication or introduction of *D. esculenta* occurred later, but may only reflect the greater potential tuber size and taste preference for *D. alata*. Melanesia was also the centre of origin of *D. nummularia* (spiny yam, wild yam), from where it has been dispersed through the Pacific region and is locally important (O'Sullivan, 2010).

Dioscorea opposite (also known as *D. batatas* and *D. japonica*) is the only species grown in temperate regions, and is widely cultivated in China and Japan, and more recently in France. Today, West African nations produce approximately 94% of all yams. Across that region, yams are the second most important crop on the basis of production volume, only exceeded by cassava. The rest of Africa accounts for half the remainder. The remaining 3% is grown in the Americas (particularly the Caribbean, having been introduced there with West African slaves), the Pacific region and Asia. On a per capita basis, the Melanesian nations follow the West Africans in yam consumption. Production in Polynesia is patchy, as not all islands have appropriate soils, but on those that do (e.g. Niue and Tonga), yams are highly prized and consumed at higher rates than in most of Melanesia. Consumption in Caribbean nations is similar to that in Central and East Africa. Among Asian nations, Japan, China and southern India are significant producers, but per capita consumption is low (O'Sullivan, 2010).

Regional statistics belie the local importance of yams for particular communities and cultures. Yams are particularly important in areas that experience seasonal drought, as they are the only tropical root crop that can be stored satisfactorily for extended periods after harvest. This capacity for postharvest storage facilitated the dispersal of yams along human migration and trade routes. They were particularly important in the colonisation of the Pacific islands, hence their esteemed status in Polynesian culture (O'Sullivan, 2010).

The tuber characteristics of each species differ in terms of dry matter content, starch quality, texture and flavour, which affect their suitability for different preparation and cooking techniques. These characteristics influence the local selection of species and cultivars. Local environmental factors also affect the selection of species. Compared with *D. esculenta* or the African yams, *D. alata* has a shorter growing season and is more tolerant of wet soils and cold temperatures. It consequently has a larger range in terms of both altitude and latitude. However, its greater susceptibility to foliar diseases, particularly the yam anthracnose caused by the fungus *Colletotrichum gloeosporioides*, limits its use in some warm, humid areas. In general, greatest production is achieved with genotypes that can fully use the available growing season. Consequently, long-season crops such as *D. esculenta* or *D. nummularia* can outperform *D. alata* in areas with only a short or mild dry season (O'Sullivan, 2010).

2.3.2 Aeroponics system of growing seed yam

According to the press release by the International Institute of Tropical Agriculture (IITA, 2013) researchers have successfully grown seed yams in the air using aeroponics technology, creating a lot of alternatives for the propagation of virus- and disease-free planting materials.

The report described Aeroponics System as the process of growing plants in an air or mist environment without the use of soil or an aggregate medium. The technology is said to have been widely used by commercial potato seed producers in parts of eastern and southern Africa but successfully growing yam on aeroponics is a novelty for rapidly multiplying the much needed clean seed yam tubers in large quantities.

In conducting the aeroponics trial, a special structure was built in an existing screen house with Dixon shelf frames using perforated styrofoam box, as support for plant vines, while the developing roots of the plants in the air were enclosed in conditions of total darkness to simulate the situation of soil to the roots. For the plant and tuber to develop, an automated power house system was established for atomizing periodically nutrient enriched water solution in the form of mist to feed the plants.

Preliminary results showed that vine rooting in Aeroponics System had at least 95% success rate compared to vine rooting in carbonized rice husk with a maximum rate of 70%. Rooting time was much shorter in aeroponics. Traditionally, seed yam production is expensive and inefficient. Farmers save about 25 to 30% of their harvest for planting the same area in the following season, meaning less money in their pockets. Moreover, these saved seeds are often infested with pathogens that significantly reduce farmers' yield year after year.

Nevertheless, with an established Aeroponics System for seed yam propagation at the premises of an interested private investor, seed company or humanitarian non-governmental organization; yam producers can have access to clean seed yams. The soilless yam propagation system was formulated to increase the productivity of seed and ware yam and effectively reduce diseases and pest's incidence and severity meaning no soil borne or vector-transmitted pests and diseases during the vegetative phase (IITA, 2013).

2.3.3 Nutritional value of yam

According to Wanasundera and Ravindran (1994), yam is considered to be the most nutritious of the tropical root crops. It contains approximately four times as much protein as cassava, and is the only major root crop that exceeds rice in protein content in proportion to digestible energy (Bradbury and Holloway 1988). The amino acid composition of yam protein is suboptimal in sulfur-containing amino acids (cysteine and methionine), but the overall rating for essential amino acids is high and superior to sweet potato (Splittstoesser *et al*. 1973; Bhandari *et al*. 2003).

Yam is also a good source of vitamins A and C, and of fibre and minerals. Its relatively low calcium content is related to low concentrations of calcium oxalate, an antinutritional factor (Bradbury and Holloway, 1988). It is also low in the antinutrients phytate (Wanasundera and Ravindran, 1994) and trypsin inhibitor (Bradbury and Holloway, 1988). A number of authors (Bradbury and Holloway, 1988; Wanasundera and Ravindran, 1994; AgborEgbe and Treche, 1995) have commented on the variability in protein content within yam species, indicating potential for selection for high protein content. However, some of this variability would be due to varying degrees of nitrogen deficiency in the tubers sampled

(Bradbury and Holloway, 1988). Improving nitrogen nutrition of yams will increase protein production. However, the relative contribution of nitrogen nutrition and genotype to the observed range of protein content has not been determined.

A study done by Opara (2003) indicated that yams have high contents of moisture, dry matter, starch, potassium, and low vitamin A. They contain about 5-10 mg.100 g-1 vitamin C, and the limiting essential amino acids are isoleucine and those containing sulphur. He explained that yams also contain a steroid sapogenin compound called diosgenin, which can be extracted and used as base for drugs such as cortisone and hormonal drugs. Some species contain alkaloids (e.g. dioscorine C13H19O2N) and steroid derivatives. Table 2.1 provides a summary of the nutritional values of yams while Table 2.2 provides that data for individual yam species. It should be noted that the method of preparation affects the final nutritional status of yam-based foods. These data are useful in designing new product formulations as well as efficient food process operations.

Table 2.1: Range of Nutritional Values of Yam (nutrients in 100-g edible portion).

Nutrient	Tuber	Bulbils
Calories	71.00 - 135.00	78.0
Moisture (%)	81.00 - 65.00	79.4
Protein (g)	1.40 - 3.50	1.4
Fat (g)	0.40 - 0.20	0.2
Carbohydrate (g)	16.40 - 31.80	18
Fibre (g)	0.40 - 10.00	1.2
Ash (g)	0.60 - 1.70	1.0
Calcium (mg)	12.00 - 69.00	40.0
Phosphorous (mg)	17.00 - 61.00	58.0
Iron (mg)	0.70 - 5.20	2.0
Sodium (mg)	8.00 - 12.00	
Potassium (mg)	294.00 - 397.00	
b -Carotene eq. (mg)	0.00 - 10.00	
Thiamin (mg)	0.01 - 0.11	
Riboflavin (mg)	0.01 - 0.04	
Niacin (mg)	0.30 - 0.80	
Ascorbic acid (mg)	4.00 - 18.00	

Source: (Opara, 2003).

Table 2.2: Nutrient Content of Yam Species (Dioscorea Spp.) Per 100-G Edible Tuber Portions.

	D. spp.	*D. Alata Water yam*	*D. Bulbifera Potato yam*	*D. Cayenensis Yellow yam*	*D. Dumentorum Bitter yam*	*D. esculenta Lesser yam*	*D. rotundata White yam*	*D. trifida Cushcush yam*
Water (ml)	69	65 76†	71 (79)‡	80	67	70 74†	80	80.7
Calories	119	135 87	112 (78)	71	124	112 102	71	
Protein (g)	1.9	2.3 1.9	1.5 (1.4)	1.5	3.2	3.5 1.5	1.5	2.54
Fat (g)	0.2	0.1 0.2	0.1 (0.2)	0.1	0.1	0.1 0.2	0.1	0.44
Carbohydrate (g)	27.8	31 20	26 (18)	16	28	25 24	16	38
Fibre (g)	0.8	1.5 0.6	0.9 (1.2)	0.6	0.8	0.5 0.6	0.6	
Calcium (mg)	52	28 38	69 (40)	36	52	62 12	36	8
Phosphorous (mg)	61	52 28	29 (58)	17	45	53 35	17	38
Iron (mg)	0.8	1.6 1.1		5.2		0.8	5.2	0.52
Vitamins								
β-carotene equiv. (µg)	10	10 5						
Thiamine (mg)	0.11	0.05 0.10				0.10		
Riboflavin (mg)	0.02	0.03 0.04				0.01		
Niacin (mg)	0.3	0.5 0.5				0.8		
Ascorbic acid (mg)	6	12 6				15		

†Two values reported; ‡Bulbil or aerial tuber.

Source: (Opara, 2003).

2.3.4 Economic and Social Importance of Yams

As stated by Opara (2003) yam comes after cassava as the most important tropical root crop and is consumed in many parts of Africa and Southeast Asia as a staple crop. In the South Pacific, the yam is a significant food crop, accounting for over 20%, 8.1%, and 4.6% of the total dietary calorie intake in the Kingdom of Tonga, Solomon Islands, and Papua New Guinea, respectively. Apart from being an important food source, yams also play a significant role in the socio-cultural lives of some producing regions like the celebrated New Yam Festival in West Africa, a practice that has also extended to overseas where there is a significant population of the tribes that observe it. In some parts of Southeastern Nigeria, the meals offered to gods and ancestors consist principally of mashed yam.

Yams store relatively longer in comparison with other tropical fresh produce, and therefore stored yam represents stored wealth which can be sold all-year-round by the farmer or marketer. In parts of Igboland in Southeastern Nigeria, it is customary for the parents of a bride to offer her yams for planting as a resource to assist them in raising a family (Opara, 2003).

In West Africa, yam (*Dioscorea* spp.) plays a very important role as a source of income, food security, and livelihood systems for at least 60 million people. The crop also makes a substantial contribution to protein in the diet, ranking as the third most important source. Farmers engage in yam cultivation for cash income and household food supply. Yam traditionally plays a significant role in societal rituals such as marriage ceremonies and annual festivals, making the crop a measure of wealth. Yams therefore have significance over and above other crops in the region. At the regional level, yam seems to be a superior economic good in all countries. As incomes increase, consumers shift from cassava to yam. This is related in part to regional cultural values and consumer preferences, which is mainly due to the relative ease in consumer food preparation (Maroya *et al*., 2015).

2.3.5 Worldwide Yam Production and Trading

The largest world production of yam is from Africa (about 96%) with Nigeria alone accounting for nearly 75% of the total world production. According to FAO/STAT, world annual production was estimated to be 25 million Mt in 1974 and 24 million Mt in 1992. The report indicated that during the past 5 years, total world production has increased from 32.7 million Mt in 1995 to 37.5 million Mt in 2000.

Also during this period, export quantity declined slightly while export income remained fairly steady. During the period 1975-90, total yam cultivated area increased by about 38.8% globally, while the total production increased by 45.8%. However, the importance of yam in the economy of the main producing areas appears to be declining due partly to competition with other crops like cassava in Nigeria, and taro in the South Pacific (Opara, 1999). The major producing areas have also continued to experience high population growth rates. During the last four decades, the annual growth rate (%) of per capita production in the major yam zones in Africa has declined (Dorosh, 1988).

2.3.6 Primary and derived product

According to Opara (2003) yams are primarily cultivated for direct human consumption and are marketed as fresh produce in all the growing regions. The commonness ways of preparation include boiling, baking or frying. Boiled and baked yam can be eaten with vegetable sauce or palm oil. Boiled yam can also be pounded or mashed in mortar and eaten as “fufu” or “utara”. Commercially food processing equipment for boiling and mashing of yam into fufu at the press of a button are now available in the market. Yam cultivars, which contain toxic substances such as dioscorene, are first sliced and soaked in salt water for several hours before further processing for consumption.

He further said that yam tubers are also processed into several food products such as the yam flour, which are enjoyed in many parts of the tropics. Industrial processing and utilisation of yam includes starch, poultry and livestock feed, and production of yam flour.

2.3.7 Consumer Choice of Yam

There are considerable consumer preferences for the different yam varieties among the growing regions. White-fleshed yams which have firm texture (mainly *D. rotundata*) are the most popular in West Africa, while in the South Pacific, *D. alata* cultivars (water yam, white purplish with loose watery texture) are most common (Opara, 1999). Consumer preferences might account for some of the predominance of certain cultivars in some region, in addition to agro-climatological impacts on the growing attributes of the species. In parts of West Africa, yams, which have loose texture, are often mixed with gari and pounded to prepare fufu of 'soft' texture.

2.3.8 Harvesting

Harvesting is done by hand using sticks, spades or diggers. Sticks and spades made of wood are preferred to metallic tools as they are less likely to damage the fragile tubers; however, tools need regular replacement. Yam harvesting is a labour-intensive operation that involves standing, bending, squatting, and sometimes sitting on the ground depending on the size of mound, size of tuber or depth of tuber penetration. In rainforest areas, tubers growing into areas where there are roots of trees can pose a problem during harvesting and often receive considerable physical damage. Many also get deformed during growth as a result of the obstacles they encounter. These tubers are usually downgraded. Aerial tubers or bulbils are harvested by manual plucking from the vine (Opara, 2003).

Nystrom *et al* (1983) observed that although some success in mechanical yam harvesting has been reported, especially for *D. composita* tubers for pharmaceutical uses, these machines are still limited to research and demonstration purposes. The use of a potato spinner has been suggested for harvesting species which produce a number of small tubers (Onwueme, 1977). Current crop production practices and species used pose considerable hurdles to successful mechanisation of yam production, particularly for small-scale rural farmers. Extensive changes in current traditional cultivation practices, including staking and mixed cropping, and possibly tuber architecture and physical properties will be required.

Yams can be harvested once (single harvesting) or twice (double harvesting) during the season to obtain a first (early) and second (late) harvest. The first harvest has also been referred to by the terms “topping”, “beheading”, and “milking”, all of which have been considered inadequate and obsolete. In single harvesting, each plant is harvested once and this occurs at the end of the season when crop is mature. The harvesting processes involve digging around the tuber to loosen it from the soil, lifting it, and cutting from the vine with the corm attached to the tuber. The time of harvest is critical in terms of tuber maturity, yield and postharvest quality. Depending on the cultivar, the period from planting or emergence to maturity varies from about 6-7 months or even 6-10 months (Opara, 2003).

Periods of 8-10 months and 4-5 months from planting or emergence to maturity have been recommended for double-harvesting (Martin, 1984; Onwueme, 1977); harvest first at 5-6 months after planting and then 3-4 months later has also been reported (Bencini, 1991). First harvest is carried out by removing the soil around the tuber carefully and cutting the lower portion, leaving the upper part of the tuber or the “head” to heal and continue to grow. The soil is returned and the plant is left to grow to the end of the season for the second harvest.

Some yam cultivars produce several small tubers in the second growth following the early harvest. Double harvesting is most applicable to short-term varieties such as D. rotundata, and to lesser extents D. Cayenensis and D. alata.

Similar yields have been reported for single and double harvesting; however, single-harvested tubers had better eating quality than the double-harvested tubers (Onwueme and Charles, 1994).

2.3.9 Transportation and Packaging of Yam

After harvest, yam tubers are traditionally placed into woven baskets made from parts of the palm tree or coconut fronds. These are ideal for transporting small quantity of tubers over short walking distances. The basket is carried on the head, shoulder, or tied to a bicycle and transported to the market or storage facility. Compression damage is reduced since the basket is able to bend and thereby reduce the amount of force acting on individual tubers. However, when large quantities of tuber are harvested, these baskets are not suitable because of their limited size. Packaging tubers in full telescopic fibreboard cartons with paper wrapping or excelsior reduces bruising and enables large quantity of tuber to be transported over long distances. Tubers can be contained in loose packs, or units of 11 kg and 23 kg (McGregor, 1987). The cartons are hand-loaded or unitised on pallets.

Thompson *et al*. (1977) identified that storing yams in modified atmosphere packaging (MAP) has beneficial effects, particularly using appropriate packaging material with suitable size and number of holes for gas permeation. Sealing yam tubers in polyethylene film bags reduced storage losses due to weight loss and development of necrotic tissue. Coating tubers with Epolene E10 (a commercial vegetable wax improved the appearance quality but there was no effect on levels of fungal infection. The effect of this treatment on weight loss of tuber was inconsistent.

2.3.10 Storage of Yam

According to Opara (2003), three main conditions are necessary for successful yam storage: aeration, reduction of temperature, and regular inspection of produce. Ventilation prevents moisture condensation on the tuber surface and assists in removing the heat of respiration. Low temperature is necessary to reduce losses from respiration, sprouting and rotting; however, cold storage must be maintained around 12-15°C below which physiological deterioration such as chilling injury occurs. Regular inspection of tubers is important to remove sprouts, rotted tubers, and to monitor the presence of rodents and other pests. In general, tubers should be protected from high temperatures and provided with good ventilation during storage. The storage environment must also inhibit the onset of sprouting (breakage of dormancy) which increases the rate of loss of dry matter and subsequent shrivel and rotting of tuber. Both ware yam and seed yam have similar storage requirements.

Notwithstanding cultivar differences, fresh yam tuber can be successfully stored in ambient and refrigerated conditions (Table 2.3). The recommended storage temperature is in the range 12°-16°C. Optimum conditions of 15°C or 16°C at 70-80% rh or 70% rh have been recommended for cured tubers (Martin, 1984; McGregor, 1987). Transit and storage life of 6- 7 months can be achieved under these conditions. The onset of sprouting is enhanced at ambient conditions, especially if ventilation is inadequate. For example, during storage at ambient conditions (20°-29°C, 46-62% rh), D. trifida began to sprout within 3 weeks (Thompson, 1996). Yam tuber decay occurs at higher humidity, and like most tropical crops, they are susceptible to chilling injury (CI) at low storage temperatures. To avoid tuber damage, minimum storage temperatures of 10°C, 12°C and 13°C (Martin, 1984; McGregor, 1987) at or below which CI occurs have therefore been recommended. Storage of D.

rotundata tubers at 12.5C resulted in CI (Coursey, 1968), and storage of D. alata at either 3°C or 12°C resulted in total physiological breakdown within 3-4 weeks (Czyhrinciw and Jaffe, 1951). Storage of D. alata at 5°C for 6 weeks gave good results but CI symptoms developed rapidly when tubers were subsequently put in ambient (25°C) conditions (Coursey, 1961). There is no reliable data on beneficial effects on CA technology on the commercial storage of yam cultivars.

Table 2.3: Recommended Storage Conditions for Yams (Dioscorea spp.)

Cultivar	**Temperature (°C)**	**Relative humidity (%)**	**Length of storage**
D. trifida	3	-	1 month
Elephant yam	10	-	several months
D. alata	12.5	-	8 weeks
D. cayenensis	13	95	< 4 months
D. alata, cured	15-17	70	180
D. alata, non-cured	15-17	70	150
White yam, Guinea yam	16	80	several months
Yellow yam, Twelve month yam	16	80	60 days
Cush cush, Indian yam	16-18	60-65	several months
Lesser yam, Chinese yam	25	-	60 days
Water yam, Greater yam	30	60	several months
	13.3	85-90	50-115 days
	16	65	4 months
	16	70-80	6-7 months

Source: (Opara, 1999).

There are several traditional storage structures used for yam storage including: (a) leaving the tubers in the ground until required, (b) the yam barn, and (c) Underground structures (Opara, 1999). Leaving the tubers in the ground until required is the simplest storage technique practised by rural small-scale farmers. When carried out on-farm, this type of storage prevents the use of the farmland for further cropping. Harvested yams can also be put in ashes and covered with soil, with or without grass mulch until required.

Yams are also stored in underground structures such as pits, ditches and clamps. These are suitable for limited storage periods, especially the early varieties that are often harvested before the end of the rainy season.

Plate 2.1: Typical yam barn in West Africa

2.3.11 Yam Processing

Industrial uses of yam include starch, poultry and livestock feed, and production of yam flour. Residues from sifting and peels are used as animal feed in many rural areas. One of the major disadvantages of industrial processing of yam for food is that nutrient losses in these products can be high, particularly minerals and vitamins. In products obtained from secondary processing such as biscuits and fufu, the amount of loss depends principally on the amount of edible surface exposed during processing operations (Opara, 1999).

Primary unit operations such as milling affect the thiamine and riboflavin contents of *D. rotundata*, with average losses of 22% and 37%, respectively. Sun drying results in high losses of B vitamins with little change in mineral content. Pounding yam flour in a traditional wooden mortar or grinding in an electric mixer had similar effects (Opara, 1999).

2.4 Moisture

Moisture assays can be one of the most important analysis performed on food products and yet one of the most difficult from which to obtain accurate and precise data. Various methods for moisture analysis exist with their principles, procedures, applications, cautions, advantages and disadvantages.

Water activity measurement of total moisture, as an important quality factor with an understanding of techniques described, one can apply appropriate moisture analysis to a wide variety of food products (Nielsen, 2010).

2.4.1 Importance of Moisture Assay

One of the most fundamental and important analytical procedure that can be performed on food product is an assay for the amount of moisture. The dry matter that remains after the moisture removal is commonly referred to as total solids. The analytical value is of great economic importance to a food manufacturer because water is inexpensive filler. The following listing gives some examples which moisture content is important to the food processor (Nielsen, 2010).

1. Moisture is a quality factor in preservation of some products and affect stability in:

   Dehydrated vegetables and fruits

   Dried milks

   Powdered eggs

   Dehydrated potatoes

   Spice and herbs

2. Moisture is used as a quality factor for:

   Jams and jellies, to prevent sugar crystallization

Sugar syrups

Prepared cereal-conventional 4%-8%, puffed, 7%-8%

3. Reduced moisture is used for convenience in packaging or shipping of:

   Concentrated milks

   Liquid cane sugar (67% solids) and liquid corn sweetener (80% solids).

   Dehydrated products (these are difficult to package if too high in moisture)

   Concentrated food juices

4. Moisture (or solids) content is often specified in compositional standards (i.e. standards of identity)

   Cheddar cheese must be ≤ 39% moisture

   Pineapple juice must have soluble solids of ≥ 70%

   The percentage of added water in processed meats is commonly specified.

5. Computation of nutritional values of foods requires that you know the moisture content.

6. Moisture data are used to express results of other analytical determinations on a uniform basis. (i.e. Dry weight basis)

2.4.2 Forms of Water in Food

The ease of water removal from foods depends on how it exists in the food product. The three states of water in food products are;

1. Free water: this water retains its physical properties and thus as the dispersing agent for colloidal and the solvent for salts.
2. Absorbed water: this water is held tightly or is occluded in the cell walls or protoplasm and is held tightly to proteins.

3. Water of hydration: this water bond chemically, for example, lactose monohydrate, also some salts such as $Na_2SO_4.10H_2O$.

Depending on the form of the water present in a food, the method used for determining moisture may measure more or less of the water present (Nielsen, 2010).

2.5 Sugars

Sugars are the generalized name for sweet, short chain, soluble carbohydrates, many of which are used in food. They are carbohydrates composed of carbon, hydrogen and oxygen. There are various forms of sugar derived from different sources. Simple sugars called monosaccharide include glucose (also known as dextrose), fructose, arabinose and galactose. The table or granulated sugar most customarily used as food is sucrose, a disaccharide (Kirk and Sawyer, 1991).

2.5.1 Arabinose

It is a pentose that is widely distributed in plants and occurs to some extent in animal tissues, usually in the form of its anhydrides which yield arabinose on hydrolysis. When distilled with dilute hydrochloric acid, it yields furfural which gives characteristic color reactions with resorcinol or phloroglucinol (Kirk and Sawyer, 1991).

2.5.2 Dextrose

Dextrose or glucose occurs in a variety of animal and vegetable foodstuffs. D-Glucose exists in the anhydrous state and in the hydrated form, which contains one molecule of water. It is produced by the hydrolysis of starch and disaccharides such as sucrose and is therefore, frequently present in food stuffs which contains sugar. Dextrose readily reduces Fehling's (Kirk and Sawyer, 1991).

2.5.3 Fructose

Fructose, laevulose or fruit sugar is commonly present in fruits and is levorotary. It exists in considerable quantities in honey and invert sugar and can be produced enzymatically from glucose syrup (Kirk and Sawyer, 1991).

2.5.4 Galactose

It occurs in a polymerized form in gums. Commercially, it is a product of the hydrolysis of Lactose. It readily crystalizes with one molecule of water in the form of a white powder having an m.p. of 120^{o} (anhydrous form 167^{o}C). It exhibits mutarotation and a high temperature coefficient. The importance of the sugars determination is to ascertain whether the starch has been converted into sugars. This is because, when yam is stored or preserved on the shelf for a long period of time, the starch is converted into sugars by enzymatic activities giving it a sweeter taste or deteriorates during sprouting (Kirk and Sawyer, 1991).

2.6 Free Fatty Acids

The acidity of oils/fats is normally a measure of the extent to which hydrolysis has liberated the fatty acid from their ester linkage with their parent glyceride molecule. This is the reason why acidity is reported as percentage free fatty acids (%FFA). This quality parameter is given as an indication of the care and control exercised during processing; i.e. indication of fresh oil/fat quality and of the amount of hydrolysis that has taken place. Since an amount of oil has been introduced to the slice yam during the blanching, it is then important to assess the quality of oil content during the shelf-life studies.

Free fatty acids (FFA) are the results of the reaction of water and fats at frying temperatures. Very high levels of FFA (about 3-4%) can result in excessive smoking of the oil and unsatisfactory flavors of the product. It is one of the parameters adopted to indicate the quality of fatty acids. The sample is first dissolved in a suitable solvent (neutralized ethanol) before titrating it with a standard alkali (standardized Sodium Hydroxide) in the presence of Phenolphthalein as an indicator until a permanent pink color is obtained. High FFA value indicates low molecular mass of fatty acids. The FFA of the fatty acids decreases with an increasing number of carbon atoms (James, 1995).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials and Equipment

Deep fat fryer (Delonghi Rotofry F28311),

Colander,

Perforated spoon,

Tablespoon,

Teaspoon,

Scale,

Strainer,

Plastic bowl,

Plate,

Stainless Steel Knife,

Chopping board,

Kettle,

Table top burner,

Cooking pot,

Plastic Film sealer,

Ruler,

Deep freezer.

3.2 Sources of Raw Materials

Two cultivars of white yam (*Discorea rotundata*) viz., "Laribakor" and "Dente" were selected for this study due to their relatively higher preference by consumers. Samples were obtained from the Aboabo yam market in Tamale, the Northern Region of Ghana as shown in plate 2.

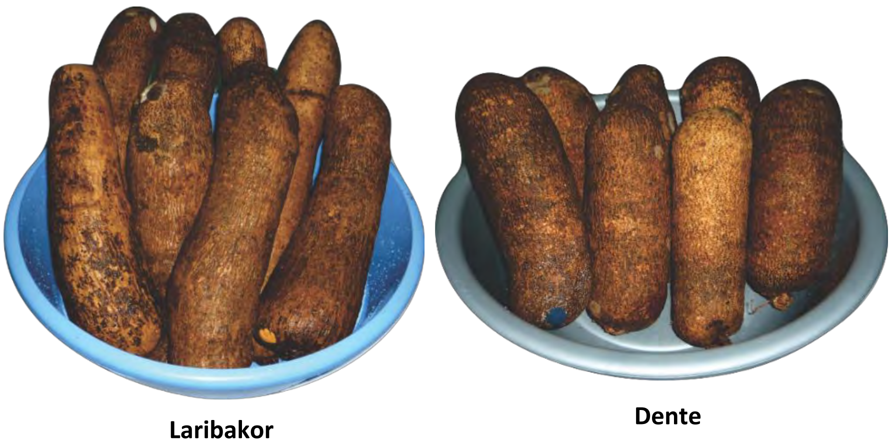

Plate 3.1 Yam samples

3.3 Preparation of yam samples

Yam tubers were washed and cut into 7cm lengths using a stainless steel knife. The cuts were peeled and sliced into 1cm slashes. The slashes were cut into 1cm strips and placed into a bowl of water to prevent enzymatic browning. The sequence for the processing of yam strips is outlined in figure 2.

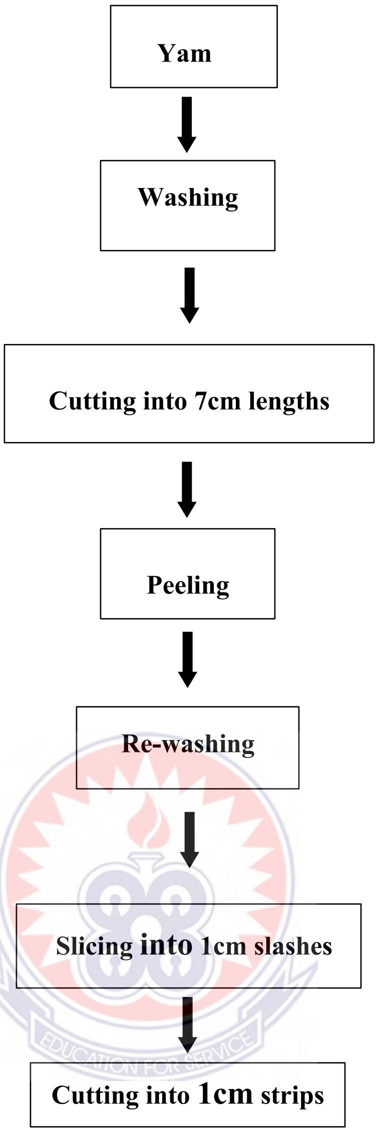

Figure 3.1: Flow Chart for the Preparation of Yam Strips

3.4 Packaging and Freezing of Yam Strips

Yam strips were washed, drained and weighed. Two (2) liters of water was poured into *Moulinex* kettle and 1tablespoon frytol cooking oil added and boiled to 100°c. The boiled water was poured onto 1.5kg yam strips in a sauce pan which was covered with a tight lid (flash-blanched) for 1 minute and drained using a colander. The yam strips were allowed to cool for 25 minutes and packaged into polyethylene bag which was designed and labeled for the purpose. The bagged yam strips were sealed with Plastic Film sealer (TYPE: FR 400A, Impulse) and frozen at a temperature of -18°C.

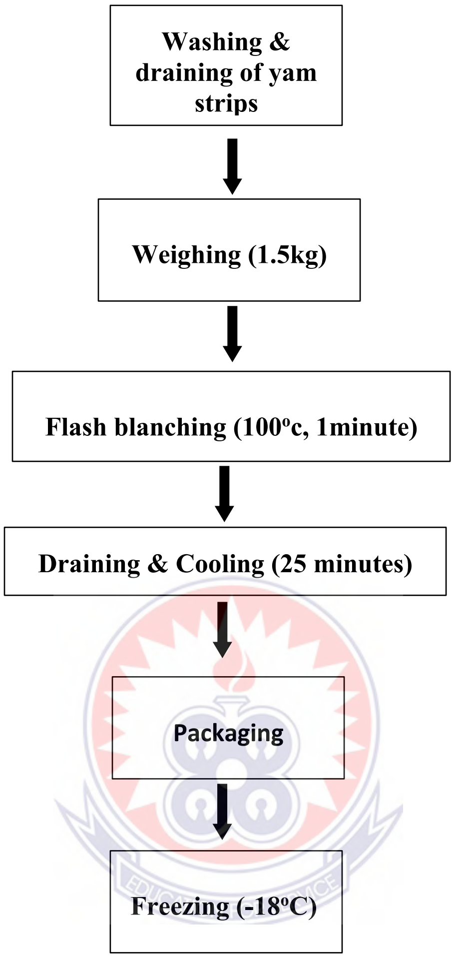

Figure 3.2: Flow chart for packaging and freezing of yam strips

Plate 3.2: Sample Packaged Yam Strips

3.5 Storage Studies of the Frozen Yam Strips

Storage studies of the flash-blanched yam strips were carried out over the period of 4 weeks through random selection of samples for assessment over the storage period. The frozen yam strips were fried and assessed through sensory evaluation by participants. The assessment was done in one week intervals for 4 weeks. Chemical analysis was also conducted on the frozen 'Laribakor' and 'Dente' samples to determine the level of moisture, Sugars (sucrose, reducing sugar, and total sugar) and Free Fatty Acids. These analyses were also carried out once a week for four weeks.

3.6 Frying of Yam Strips for Sensory Evaluation

In conducting the sensory evaluation test for the product, the yam strips, both "Laribakor" and "Dente" were thawed separately. Half ($^1/_2$) teaspoon of salt was dissolved in 5 tablespoon of water and 400kg of yam strips added and tossed for 2 minutes and drained before frying using an electric fat fryer (Delonghi Rotofry F28311). Two (2) litres of frytol cooking oil was used and 400kg of yam strips were fried at a temperature of 190^{o}C for 6-8 minutes and 8-10 minutes for "Laribakor" and "Dente" respectively. The frying times differed because of the higher water content in "Dente". In addition, time intervals were given for frying both yams as consumers have different preference in terms of colour and crispiness.

3.7 Sensory Evaluation of Fried Yam Strips

Fried yam strips were assessed using a 5 – point hedonic scale to ascertain the level of consumer acceptability. Five evaluations were carried out on the two varieties of yam, Laribakor and Dente separately. During the first week, the freshly flash-blanched yam strips were fried and assessed by participants followed by an evaluation of the frozen fried yam strips on weekly basis for four (4) weeks. Fifty (50) participants consisting of staff and students from Tamale Polytechnic were used at each stage of the sensory evaluation. 'Shitor' and 'Hayat Tomato Ketchup' were served with the fried yam strips as an accompaniment to enhance the taste. The two varieties of yam were fried at different times and evaluators were required to rinse their mouth thoroughly after tasting the first sample before assessing the second variety. The assessors ranked each trait of the yam strips as extremely not satisfied, not satisfied, not sure, satisfied and extremely satisfied.

Table 3.1: Interpretation of Sensory Evaluation Form

	Scale				
	Extremely Not Satisfied	Not Satisfied	Not sure	Satisfied	Extremely satisfied
	1	2	3	4	5
Traits					
Size, Colour, Aroma, Taste, Moistness, Hardness, Crispiness, Sogginess, Overall Acceptability					

3.8 Physico Chemical analysis of Laribakor and Dente Strips

The laboratory analysis was carried out at the chemistry laboratory of the CSIR- Food Research Institute. The chemical analysis conducted on the 'Dente' and 'Laribakor' samples were; Moisture, Sugars (sucrose, reducing sugars, total sugars) and Free Fatty Acids. These analyses were done once a week for four weeks. The Moisture content was determined to measure the amount of free water since moisture affects sample upon storage. Sugars were determined to measure the levels of reducing sugars, sucrose and total sugars and also Free Fatty Acids (Oleic Acid) was determined to measure rancidity of the oil introduced to the sample during sample preparation. All the analyses were carried out in duplicates to ensure precision and accuracy. The average of the duplicates was calculated.

3.8.1 Determination of Sugars

The determination of reducing sugars by titration with Fehling's solution is an empirical method and therefore standardized experimental conditions and procedures must be rigidly adhered to in order to obtain satisfactory results. The classical procedure uses a table indicating the amount of invert sugar, dextrose, fructose, and maltose or lactose equivalent to the volumes of reduced Fehling's solutions (Lane & Eynon, 1923).

Percent invert sugar in the sample = $\frac{\textbf{titration x m}}{\textbf{1000}}$

Where **m** is the amount of sample contained in volume.

3.8.2 Sucrose Determination

Sucrose was determined in the absence of reducing sugars by inverting a portion of the test solution with acid followed by neutralization with alkaline and titration by the Lane and Eynon method using standard invert sugar solution for calibration (Lane & Eynon, 1923).

% Sucrose = % Invert sugars × 0.95

3.8.3 Procedures for Determination of Sugars

Before Inversion (Reducing Sugars)

A reasonable amount of the test sample was weighed into a 250ml volumetric flask; 5.0ml of Zinc acetate and 5.0ml of Potassium ferrocyanide (clearing agents) solutions were added. This was followed by the addition of distilled water to the mark and allowed for clearing to take place for 10 minutes. The solution was then filtered and titrated against 10ml of Fehling's solution until brick red.

After Inversion (Total Reducing Sugars)

An aliquot of the filtrate was pipetted into a 100ml volumetric flask and 10ml of Hydrochloric acid (HCl) added and allowed to stay in a water bath for 10 minutes at a temperature of 68-70ºC for complete inversion to take place to reducing sugars.

The solution was neutralized with Sodium hydroxide and titrated against 10ml of Fehling's solution. Reducing sugars was calculated as:

$$\frac{\textbf{titration x m}}{\textbf{1000}}$$

Sucrose = [After Inversion – Before Inversion] × 0.95

3.9 Moisture

Moisture content of the samples was determined using the Air-Oven method (AOAC, 1990). Moisture dishes were dried in the moisture oven and allowed to cool to room temperature in a desiccator. These were weighed soon after reaching room temperature. About 3.0g of a well-mixed test sample was weighed using an analytical balance in the pre-weighed moisture dishes. The dishes with content were dried for 4 hours and the moisture oven maintained at 103 ± 2ºC. The dishes with the content were transferred to the desiccator to cool. The weights were taken soon after reaching room temperature. The loss in weight was reported as moisture.

$$\%moisture = \frac{weight\ of\ water\ in\ sample}{weight\ of\ wet\ sample} * 100$$

FFA Method

An appreciable amount of the yam was dried at a temperature of 40ºC for a period of 24 hours. The dried yam pieces were then milled into fine flour. An amount of petroleum ether was added and stirred and allowed to settle. The ether was then filtered and evaporated. The extracted oil is then analyzed for the free fatty acids. The determination was according to Nielson (1998). The determination was carried out as described below:

1g of oil was weighed into a conical flask; followed by addition of 25ml of neutralized 95% Ethanol; the content was heated till boiling began and titrated with 0.1N NaOH (Sodium hydroxide). The Free Fatty Acid was calculated using the formula below:

$$FFA = \frac{\text{Titre x Factor (282) as oleic acid x Normality of NaOH}}{\text{Weight of extracted oil x 10}}$$

Where **282** is the Molar mass of Oleic acid.

3.10 Data Analysis

The analysis and graphical representations of data collected were done using IBM Statistical Package for Social Sciences (SPSS) version 23.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

Introduction

In this chapter, the results of the study on the acceptability of both fresh and frozen fried Laribakor and Dente strips as assessed by taste panelists as well as the results of the chemical analysis conducted on the shelf life of both yam varieties were presented and discussed.

4.1 Acceptability Rating of Fried Freshly-Blanched Laribakor Strips

The bar chart in figure 4.1 indicates the average distribution of respondents' rating of fried freshly-blanched Laribakor. Most of the respondents forty-two (42) out of fifty (50) were satisfied with all the sensory attributes of the fried yam strips. Two (2) were extremely satisfied whereas six (6) were not sure whether they were either satisfied or not satisfied. On the average none of the respondents rated the sensory attributes of the yam strips as not satisfied and extremely not satisfied.

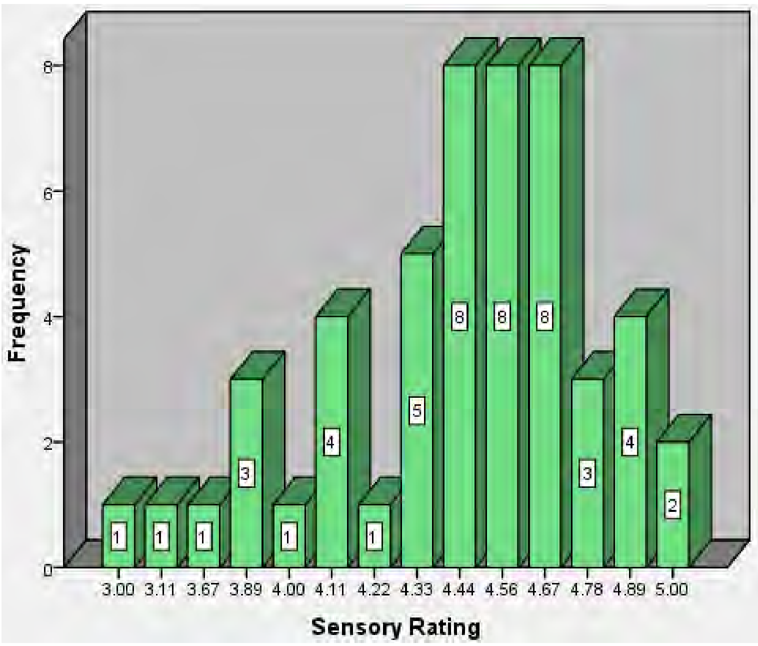

Figure 4.1: Average Acceptability of Fried Freshly-Blanched Laribakor Strips

4.2 Acceptability Rating of One Week Frozen Fried Laribakor Strips

In figure 4.2, the majority of assessors forty-two (42) ranked the one week frozen fried Laribakor strips as satisfied and two (2) of them indicated that they were extremely satisfied while six (6) of them were neither satisfied nor dissatisfied.

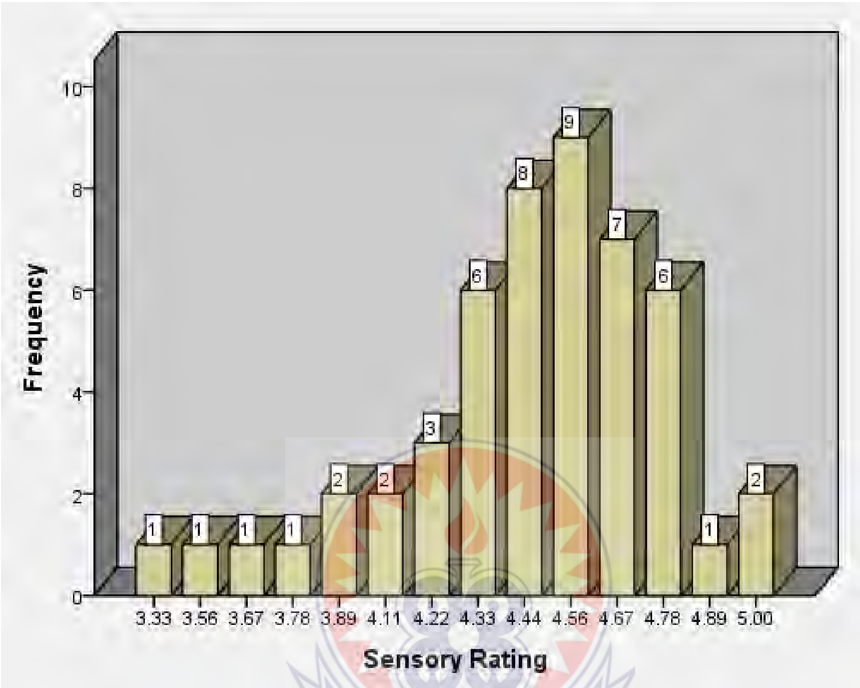

Figure 4.2: Average Acceptability of One Week Frozen Fried Laribakor Strips

4.3 Acceptability Rating of Two Week Frozen Fried Laribakor Strips

The result of the sensory evaluation conducted on the two week frozen fried Laribakor strips as shown in figure 4.3 revealed that only two (2) evaluators were undecided about whether they were satisfied or not satisfied. Five (5) indicated they were extremely satisfied and many of them forty-three (43) were satisfied.

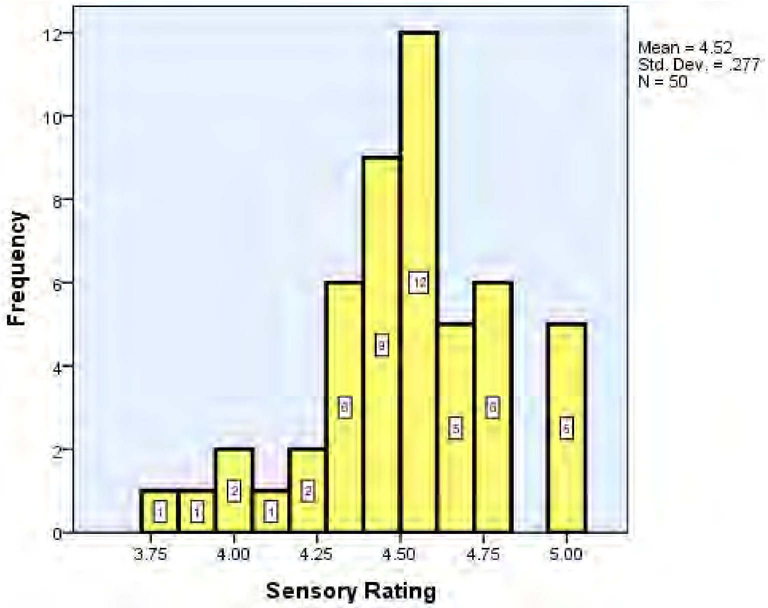

Figure 4.3 Average Acceptability of Two Week Frozen Fried Laribakor Strips

4.4 Acceptability Rating of Three Week Frozen Fried Laribakor Strips

In figure 4.4, eleven (11) consumers of the three week frozen fried yam strips were extremely satisfied and thirty-eight (38) which formed the majority of consumers were satisfied. Only one (1) person did not know whether he/she was satisfied or not. Averagely there was no response for not satisfied an d extremely not satisfied

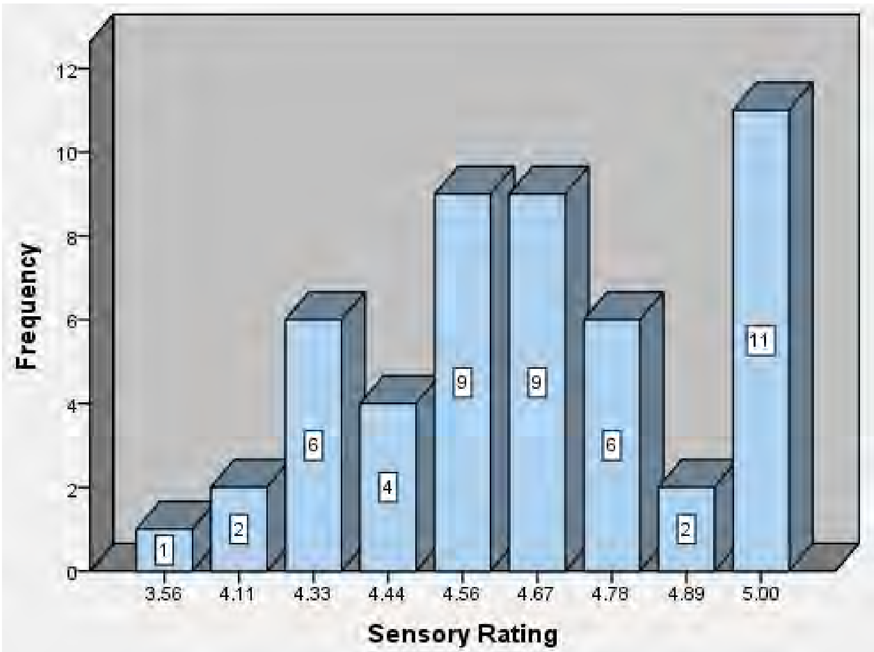

Figure 4.4: Average Acceptability of Three Week Frozen Fried Laribakor Strips

4.5 Acceptability Rating of Four Week Frozen Fried Laribakor Strips

Figure 4.5 represents the final sensory assessment conducted on the frozen fried Laribakor strips. At this stage most of the respondents 40 were satisfied with the product and 10 were extremely satisfied. There was no score for not satisfied and extremely not satisfied. On average all fifty (50) respondents were satisfied with all the parameters of the four week frozen fried Laribakor strips.

Figure 4.5: Average Acceptability of Four Week Frozen Fried Laribakor Strips

4.6 Comments on the Rating of Laribakor Strips

After having gone through the five sensory evaluation processes of the Laribakor Yam Strips, respondents gave several comments to show the level of satisfaction they derived from the product. During the first stage of the sensory evaluation conducted on the fried freshly-blanched Laribakor strips, most participants were satisfied with the sensory attributes. Those who were extremely satisfied gave comments such as: the yam strips were crispy and this make it easier to consume, perfect size and texture with great taste, exciting taste with fragrant aroma, the size is even and looks good.

Some described the product as very palatable and attractive. One respondent indicated that the taste of the yam strips was nice and thought that a lot of people will buy if it is introduced into the market. Those who were neither satisfied nor dissatisfied said that the product was good but the colour was not brown enough, the size was too long, the product was nice but salt should be added before frying, it was soggy when pressed between two fingers.

Some of the remarks of the evaluators in the form of suggestions were implemented at the next level of the assessment which enhanced the quality of the fried yam strips. At the first stage salt was added to the yam strips after it was fried but the result of this was that the salt was felt on some of the yam strips whilst others were not. This could be due to the texture of the fried yam strips. However, when the salt was added to the yam strips before frying, the result was good as there was an even distribution of salt in all the yam strips. Concerning the colour which one assessor indicated that it was not brown enough, has to do with the individual's colour preference because some people may like the yam strips to be fried slightly brown but others would prefer it golden brown.

The result of the sensory evaluation analysis carried out on the one week frozen fried Laribakor strips revealed that majority of participants were pleased with the sensory parameters of the yam strips. They pointed out that the yam strips had pleasant aroma and exciting taste, very crispy and nice, the product can be used as convenient food, and the taste was distinct were among the many comments given by the panelists. Nevertheless, some evaluators indicated that the product was good but the colour of the one week frozen fried Laribakor was poor as compared to the freshly-blanched Laribakor strips. Others also observed that some of the yam strips were crispy whereas others were moist. The observations made by this group of participants were due to the procedure used in frying the yam strips at this stage. The frozen yam strips were removed from the freezer and fried immediately. The result of this approach was that some of the yam strips appeared white even though cooked and some others seemed brown. The white coloured ones were moist whiles the brown ones were crispy. For these reasons the procedure for frying was changed at the week two stage.

During the sensory evaluation of the two week frozen fried Laribakor strips, the yam strips were removed from the freezer and thawed before frying. The result of this method used was shown in the comments of the assessors: good size, great colour with good scented aroma; very good in all aspects; the product looks attractive and taste palatable; the Laribakor strips tastes sweet and the size looks uniform; it is generally good for snack; the colour looks appetizing; the taste is exciting and appealing colour and texture and so on. Two panelists who were either satisfied or not satisfied stated that the product was generally good except for the aroma; they would have preferred some added spice.

The Laribakor strips had gained more acceptability from the respondents at the week three stage of the sensory analysis. This is because only one person was undecided about the quality of the product. The number of participants who were extremely satisfied has increased from five at week two to eleven and most of them were satisfied. They expressed themselves in the following ways: the product is really very nice and will be a good product for the market; the taste is distinct; extremely satisfied with all aspects of the fried Laribakor strips; it tastes bitter at the initial stage but the taste is better now; the product is excellent; I like the pleasant smell and it is very crispy; the product is very appealing and exciting in taste with good texture.

In week four which was the final sensory assessment conducted on the Laribakor strips; all fifty consumers approved of the quality of the yam strips. Few participants were extremely satisfied whereas most of them were satisfied. They gave similar comments as: the product is nice and should be produced on large scale; the product is very crispy; it has nice and pleasant smell and it is enjoyable; the overall product tastes good; extremely satisfied because of the taste and aroma; the product is very appetizing and the flavour is good; I generally accept this product.

4.7 Acceptability Rating of Fried Freshly-Blanched Dente Strips

Figure 4.6 depicts the findings of the sensory assessment carried out on the fried freshly-blanched Dente Strips. Most participants forty (40) ranked the sensory traits of the yam strips as satisfied. One (1) of the participants was extremely satisfied and nine (9) others were not sure whether they were satisfied or not.

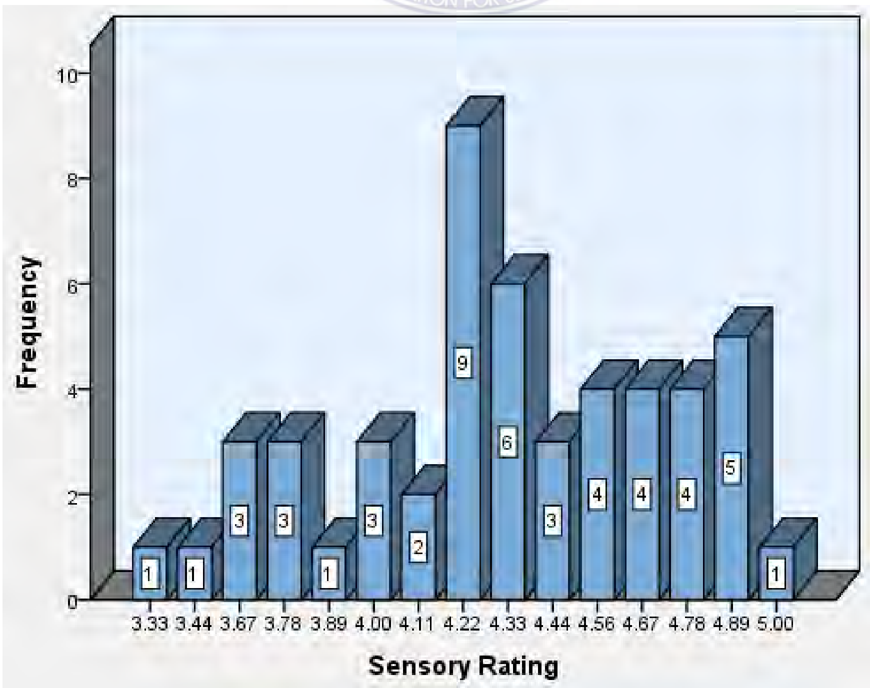

Figure 4.6: Average Acceptability of Fried Freshly-Blanched Dente Strips.

4.8 Acceptability Rating of One Week Frozen Fried Dente Strips

The bar chart in figure 4.7 illustrates the result of the sensory evaluation of the one week frozen fried Dente strips where four (4) evaluators indicated that they were extremely satisfied. Majority of the evaluators forty-one (41) were satisfied and five (5) were undecided.

Figure 4.7: Average Acceptability of One Week Frozen Fried Dente Strips

4.9 Acceptability Rating of Two Week Frozen Fried Dente Strips

According to the rating in figure 4.8, most of the respondents forty-three (43) in number stated that they were satisfied. Four (4) were extremely satisfied while three (3) were neither satisfied nor dissatisfied.

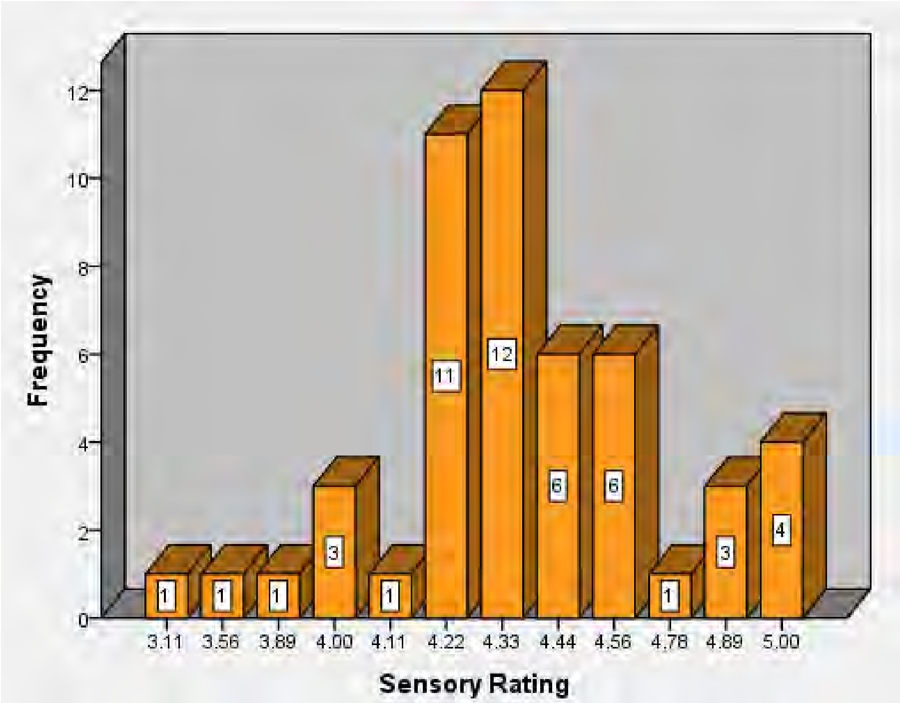

Figure 4.8: Average Acceptability of Two Week Frozen Fried Dente Strips

4.10 Acceptability Rating of Three Week Frozen Fried Dente Strips

The majority of participants forty-six (46) said that they were satisfied with the frozen fried Dente strips and three (3) were extremely satisfied. Only one (1) person was undecided. Figure 4.9.

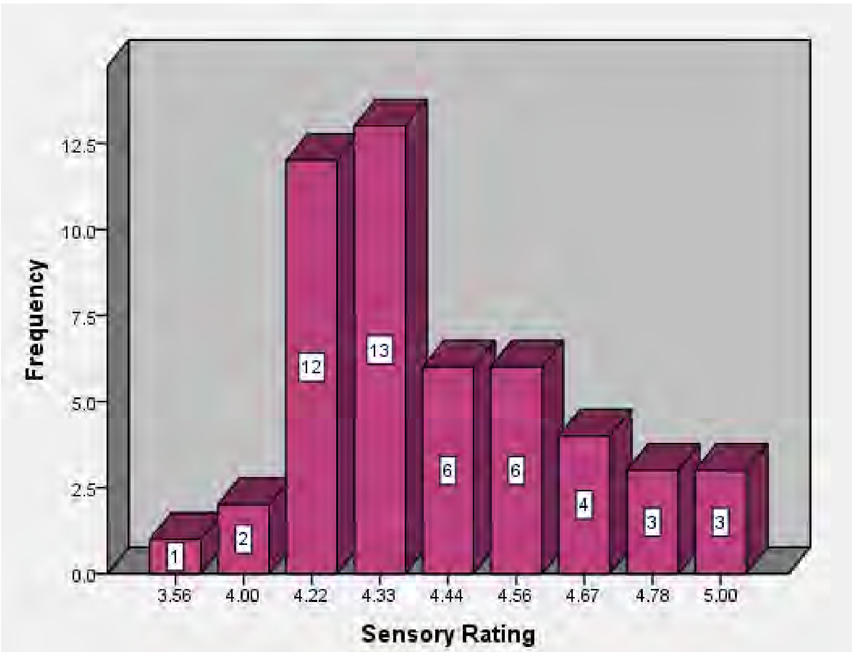

Figure 4.9: Average Acceptability of Three Week Frozen Fried Dente Strips

4.11 Acceptability Rating of Four Week Frozen Fried Dente Strips

The fourth week sensory assessment conducted on the frozen fried Dente strips in figure 4.10 revealed that majority of the assessors forty-nine (49) were satisfied while one (1) was extremely satisfied with all the sensory attributes of the Dente strips. There was no record for not satisfied and extremely not satisfied.

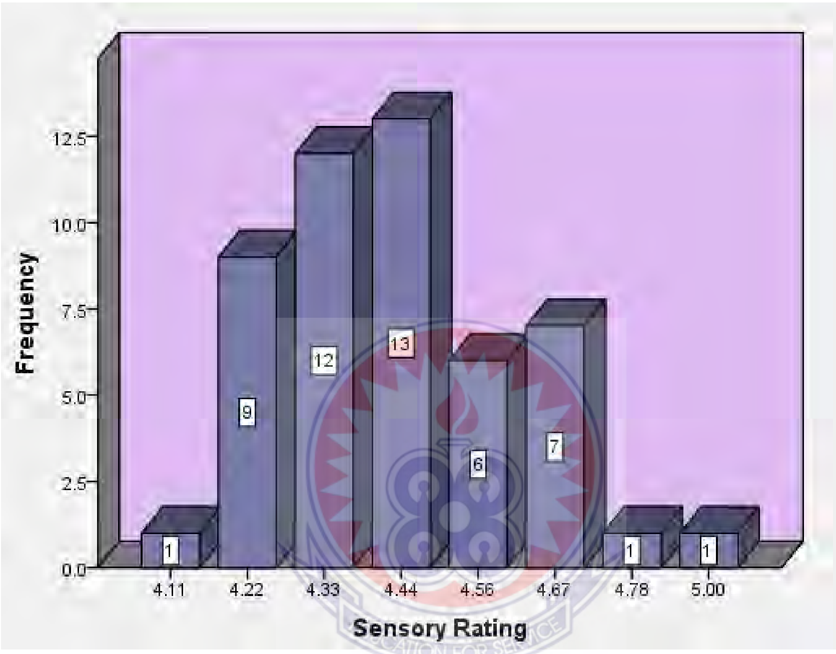

Figure 4.10: Average Acceptability of Four Week Frozen Fried Dente Strips

4.12 Comments on the Rating of Dente Strips

A considerable number of respondents indicated that they were satisfied with the fried freshly-blanched Dente Strips. Majority of them liked the sensory attributes and said the Dente Strips looks superb and delicious in taste. Those who were not sure whether they were satisfied or not gave similar comments as: good size and colour with pleasant smell but has last minute bitterness; excellent product only that it is a little bit bitter; a little bitter in taste, good in texture, hardness, crispiness and sogginess; it will do well when introduced to the market. Few participants observed that though the fried Dente Strips tastes bitter as compared to the Laribakor strips, they really enjoyed the bitterness because it makes this variety of yam unique in taste and different from Laribakor.

The one week frozen fried Dente was accepted by majority of respondents. They made comments which were identical to those made about the one week frozen fried Laribakor strips. For instance, they said some of the fried Dente strips at this stage were crispy and some were moist. However, this issue was resolved by changing the frying method as was done to the Laribakor strips at week two stage of the sensory assessment. Other observations made by the assessors were: all the sensory attributes of the one week frozen fried Dente strips were good but it tastes bitter; good and highly accepted; bitter but good aroma etc.

In week two, several participants were both satisfied and extremely satisfied with the sensory traits of the Dente strips except very few numbering three who were not sure whether they were satisfied or not satisfied. Those who were satisfied made the following remarks: the product is exciting but has a bitter taste after consumption; very appetizing and tasty; appealing golden colour and brings variety to the menu; taste very nice and appeals to the hungry eye; a very good product for the traveller who does not eat cooked food outside the home.

At the end of the third week sensory assessment of the frozen fried Dente strips only one assessor was undecided regarding the sensory attributes of the product. A great many were satisfied and extremely satisfied and observed that the Dente yam was still bitter as compared to the previous ones. Further comments passed by the respondents were: the product has a bitter taste but I really enjoyed it; crispiness is excellent just that the taste is a little bit bitter; I like all about the Dente fried strips especially the bitterness; for me as an individual I like the taste because of the bitterness.

The views of participants on the four week frozen fried Dente strips were similar to the earlier valuation conducted. At this level, all evaluators were satisfied and extremely satisfied with the sensory properties of the product. They still perceived that the Dente strips were bitter. On the other hand, most respondents were satisfied because of the bitterness. It was observed that the bitterness was due to the inherent characteristic nature of the Dente. It was more obvious especially when the yam was over fried.

4.2 Chemical Analysis Conducted on Yam samples

4.2.1 Moisture

The moisture content in any food sample is the amount of free water in the product or sample. The moisture content of Dente at the first week of analysis was 65.02% and that of Laribakor was 59.38%. The results of the second week were 66.46% and 62.49% for Dente and Laribakor respectively. The moisture results for the second week increased slightly meaning the free water content increased during the first seven days of storage. High moisture affects the physical and chemical properties such as texture, taste, mouthfeel, appearance and many more. The third week recorded moisture results as 65.29% for Dente and 59.78% for Laribakor. These results showed a reduction from the second week. The fourth week as the final week for the analysis was 65.23% and 59.26% for Dente and Laribakor respectively. Moisture in the yam samples stabilized during the third and the fourth week of study and therefore the yam samples can be preserved further. Moisture levels of yam varieties in Ghana have been documented to range from 58.5% to 70.0% (Eyeson and Ankrah, 1975). This is indicative that, the moisture from the Dente and Laribakor which fell between 59.26% to 66.46% was in the acceptable range. In general, there was no significant change in the moisture content of the samples after 4weeks of preservation in the freezer.

4.2.2 Sugars

4.2.3.1 Sucrose

The average sucrose results conducted on Dente samples gave results of 3.0% for the four weeks of study while Larebrakor also had 2.8%, 2.9%, 3.0% and 2.8% for week 1, 2, 3 and 4 respectively.

4.2.3.2 Reducing sugars

The average result of reducing sugars for Dente was 0.7% for the four weeks of study and Laribakor recorded 0.3%.

4.2.3.3 Total sugars

On the average Dente scored 3.7% for total sugars during the four weeks' period of study while Laribakor scored 3.1%.

The results obtained for sugars for all the four weeks did not show any significant change which indicates that the starch has not been converted into sugars making the sample stable during storage in freezer for this period.

4.2.4 Free Fatty Acid (FFA)

Rancidity leads to off- flavors and these in turn lead to quality deterioration. To determine if any off- flavor had developed, the free fatty acids of each sample were determined. The FFA recorded for the two different yam samples were below 10.0% (Codex standard 2010, 2003, 2005). The result for the first week of the analysis was 0.45% for Dente and that for Laribakor was 0.50%. The second week was 0.48 % for Dente while Laribakor recorded 0.53%. In week three, Dente recorded 0.50% and Laribakor had value of 0.60%. The fourth week gave results as 0.55% and 0.65% for Dente and Laribakor respectively. The results for the four weeks did not show any significant change. This means that, the oil in the two samples had stable free fatty acid and is very low and would not lead to the level where off-flavor is likely to develop.

Table 4.1 Result of Chemical Analysis Conducted On Dente and Laribakor

Parameter	Week	Unit	Dente	Laribakor
Moisture	Wk1	g/100g	65.02	59.38
	Wk2		66.46	62.49
	Wk3		65.29	59.78
	Wk4		65.23	59.26
Sucrose	Wk1	g/100g	3.0	2.8
	Wk2		3.0	2.9
	Wk3		3.0	3.0
	Wk4		3.0	2.8
Reducing sugars	Wk1	g/100g	0.7	0.3
	Wk2		0.7	0.3
	Wk3		0.7	0.3
	Wk4		0.7	0.3
Total sugars	Wk1	g/100g	3.7	3.1
	Wk2		3.7	3.1
	Wk3		3.7	3.1
	Wk4		3.7	3.1
Free Fatty Acids	Wk1	g/100g	0.45	0.50
	Wk2		0.48	0.53
	Wk3		0.50	0.60
	Wk4		0.55	0.65

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter focuses on the conclusions and recommendations. It draws conclusions from the findings and makes possible recommendations regarding the best ways to use the yam strips and also future research works on yam.

5.1 Conclusion

The two varieties of yam, "Laribakor" and "Dente", were successfully processed into strips and packaged using polyethylene bag. In terms of the acceptability to the sensory attributes (size, colour, aroma, taste, moistness, hardness, crispiness, sogginess and overall acceptability) the fried yam strips presented were found to be acceptable as most of the participants indicated that they were satisfied with the yam samples.

The physico chemical results obtained had no significant change from the first week to the fourth week of analyses. This indicated that, the sample (Dente and Laribakor) after storage in the freezer (frozen) for a month (4 weeks) had no chemical change and could therefore be further preserved.

5.2 Recommendations

1. The yam strips should be thawed before frying, for this gives a uniform texture as compared to direct frying from the frozen state.
2. It should be dipped into salt solution for some time prior to frying to ensure even distribution of salt and also to eliminate the need for additional salting

just before serving. Fried yam strips hardly hold salt and so adding salt after frying may not be ideal.

3. The ‘frozen yam strips’ is recommended for use as snack meals and for occasions such as cocktail parties.
4. The recommended frying time for Laribakor is between 6-8 minutes and that of Dente is between 8-10 minutes when using an Electric Deep Fat Fryer. However, this time frame may change due to individual preference of colour and crispiness.
5. For commercial production, the shelf life studies should be extended to one year.

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APPENDIX

APPENDIX A

PRODUCT EVALUATION FORM

Product name: **YAM STRIPS**

Please grade the following traits of this product using the scale provided and circle your score.

	Scale				
Traits	**Extremely Not Satisfied**	**Not Satisfied**	**Not sure**	**Satisfied**	**Extremely satisfied**
Size	1	2	3	4	5
Colour	1	2	3	4	5
Aroma (pleasant smell, scent, fragrance)	1	2	3	4	5
Taste (exciting, distinct, weak)	1	2	3	4	5
(Texture) moistness	1	2	3	4	5
Hardness	1	2	3	4	5
Crispiness	1	2	3	4	5
Sogginess	1	2	3	4	5
Overall acceptability	1	2	3	4	5

Comments:

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APPENDIX B

YAM STRIPS PROCESSING PICTURES

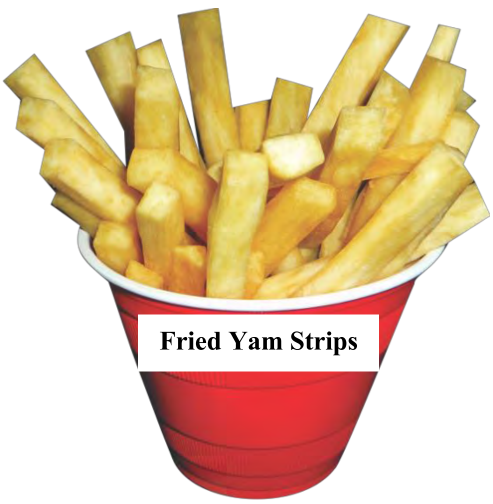
Weighing

Flash-Blanching

Draining

Packaged Yam Strips for Lab Analysis

Final Packaged Yam Strips



Fried Yam Strips

Frying

Fried Yam Strips for Sensory

Taste Panelist