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PRODUCTION AND STORAGE OF MINIMALLY PROCESSED CHIPS FROM WATER YAM (*DIOSCOREA ALATA*)

BY

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DECLARATION

I hereby declare that the work in this dissertation is the results of my own research under the supervision of Prof. W.O. Ellis and Dr. (Mrs.) I. Oduro, both of the Department of Biochemistry and Biotechnology, Kwame Nkrumah University of Science and Technology, Kumasi. The cited references have been duly acknowledged.

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(Supervisor/ Head of Department) Signature Date

ABSTRACT

Dioscorea alata (water or greater yam), which is the most widely distributed yam specie globally and the world's most popular yam after the D. rotundata/ cayenensis complex in terms of consumption is less highly regarded in West Africa, because it is not suitable for the preparation of 'fufu'. Processing of the tuber into other forms either than flour and flakes would enhance its use. This study was conducted to select the best varieties of Dioscorea alata for the production of minimally processed frozen yam chips for French fries production. Fifteen varieties of Dioscorea alata samples were used for the study. French fried samples from all the fifteen samples were presented to consumer panelist to rank them in order of preference with respect to their sensory characteristics (color, appearance (sogginess), crispiness, flavor (smell and taste), mouth feel and overall acceptability). Two of the best four samples were selected at random, steam blanched (10mins.), French fried at different times (5, 10,15mins.) and analyzed for the effect of the blanching periods on the sensory parameters. Two of the best four samples were selected at random; steam blanched and frozen at a temperature of -18 ^{o}C for storage studies over a period of twelve weeks. Sensory evaluation by trained panelists, Instrumental texture analysis and microbiological evaluation of frozen French fried samples was conducted every four weeks for twelve weeks. Steam blanching time had no significant effect on the sensory characteristics of French fried chips. Samples TDa 98/01176, TDa /001168, TDa 291 and "Matches" were the best for fried chips. sensory characteristics of TDa 291 fries were similar to that of potato fries. The two yam samples were safe for consumption in terms of microbial load over the twelve week storage period.

DEDICATION

This work is dedicated to my Husband, Mr. Kwame Afeke, my parents, Mr. & Mrs. Asiedu-Larbi and My siblings Doris, Mavis and Priscilla for their love and support in all my endeavours.

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CHAPTER ONE

1.0. INTRODUCTION

Yam (*Dioscorea* spp.), which is an annual or perennial climbing plant with edible underground tuber is native to warmer regions of both southern and northern hemispheres (IITA, 2004). According to IITA report, this thick tropical-vine tuber is popular in Africa, the West Indies, and parts of Asia, South and Central America. By virtue of its excellent palatability, yam is a high value crop (IITA, 2004), widespread throughout the world (Kordylas, 1990) and forms about 10 % of the total roots and tubers produced in the world (FAO, 2002). Out of the total world production of yam, about 70 % is produced in Nigeria and the rest are from Côte d'Ivoire, Ghana, Benin, Togo and Cameroon (FAO, 2002). In the developing world, they rank among the top 10 food crops (Scott *et al.,* 2000; Phillips *et al*., 2004; Nweke, 2004). Yam is an important food crop for many people in the yam zone of West Africa and a very important source of income in rural and marginal areas (PhAction, 2002; Vernier, 1998). It has long served as the principal source of food and nutrition for many of the world's poorest and undernourished households, and generally valued for their stable yields under conditions in which other crops may fail (Alexandratos, 1995; Scott *et al.*, 2000a).

Since several decades yam has been embedded in the population habit and has a socio-cultural significance. A considerable amount of ritualism is developed around the production and utilization of yam (IITA, 2006). There are over 600 yam species grown throughout the world, but in West Africa the most economically important species are the White yam (*Dioscorea rotundata*), Yellow yam (*Dioscorea cayenensis*) and Water yam (*Dioscorea alata*) (Vernier, 1998).

Dioscorea alata (water yam or greater yam), which is thought to have been introduced clonally in Africa (Mignouna and Dansi, 2003; Lebot *et al.*,1998) is the most widely distributed species globally (Mignouna *et al.*, 2001) and the world's most popular yam after the *D. rotundata/ cayenensis* complex in terms of consumption (Opara, 1999). Although it is an important food in the Caribbean and Melanesia where it has considerable social and cultural importance, there is very little international trade, even though significant trade in the commodity occurs within the various producing countries (Lebot *et al.*, 2005). Meanwhile large number of cultivars has been recorded throughout the tropics varying in shape and colour of leaves, stems and tuber (Lebot *et al.*, 2005).

Despite its importance, yam including *D. alata* belongs to the neglected crops and many constraints limit its production. Due to the perishability of the crop, the tubers cannot be kept for more than a few weeks after harvesting. 50% of the crops may be lost within 6 months due to rot or germination if no stabilization processes are used and this explains the volatility in fresh yam prices over the years (Vernier, 1998). Also, the high water content and fragility of fresh tubers affects transport and marketing costs. Hence for urban consumers, yam is therefore a fairly expensive product compared to other starchy foods such as cassava or cereals.

The quest for convenient, nutritious and cheap foods by consumers has made it very necessary for yam to be processed into a more stable and convenient form (Vernier, 1998). Processing is therefore necessary to overcome the perishability of the crops, enhance its nutritional value, and add economic value thereby enlarging food security in Africa. Available technologies for processing roots and tubers limit these crops from reaching their full potential as sources of both food and income. The development and introduction of new processing technologies offer potential to improve food security and local industrialization (Girardin *et al.*, 1998).

In most yam-growing areas, yams are traditionally processed into other products, as a way of utilizing tubers that are not fit for storage. Processing of stable forms of yams has been limited to the production of yam flour or flakes which are meant to be reconstituted for consumption. The flour does not make the yam available to be used in fried forms. Controlled Atmosphere Storage (CAS) and irradiation has proved to be a very efficient way of yam storage by making the yam available for frying (Girardin *et al.*, 1998a) but are rather expensive to be operated in our sub region. For example the use of cold storage for yam tubers would be advantageous in reducing storage losses due to rotting, sprouting and respiration. However the practice is at present limited by the high cost of continuous refrigeration and by the fact that yams stored at temperatures below 10°C tend to become brown and unsuitable for consumption as a result of chilling injury (Onwueme, 1997).

The growing urban populations in Africa represent a vast potential market for local food crops, provided that stable processing, transport, and marketing networks can be established between rural and urban areas. Yams have not been processed to any significant extent commercially. The utilization of water yam as well as its potential as regards to its usage in processed forms would enhance its use (Achi, 1999). This project seeks to select the best varieties of *Dioscorea alata* (water yam) for the production of minimally processed frozen chips for French fries production by

- Selecting the best variety of *Dioscorea alata* for the production of chips through sensory evaluation using consumer Panelists.
- The best pre-treatment for the frozen storage of minimally processed chips.
- Storage studies of minimally processed chips from selected samples of *Dioscorea alata* varieties.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Origin and domestication of yam

Domestication has been a traditional farmers practice in West Africa (Scarcelli *et. al.,* 2005). Guinea yams (*Dioscorea cayenensis-rotundata* complex; *D. rotundata* Poir. and *D. cayenensis* Lam.) have been described as resulting from a process of domestication of wild yams of the section *Enantiophyllum* by African farmers (Mignouna and Dansi, 2003). Guinea yams were domesticated about 7000 years ago and over the years farmers have selected genotypes that best suit their needs, and thus have generated a large number of traditional cultivars.

White yam (*Dioscorea rotundata*) originated in Africa and is the most widely grown and preferred yam species. Yellow yam (*Dioscorea cayenensis* Lam.) is also native to West Africa and very similar to the white yam in appearance. Water yam is believed to be a true cultigen that might have been domesticated in Indo-China from *Dioscorea hamiltoni* and *D. persimilis (*Agbaje *et. al, 2005*). It originated from South East Asia and it is the species most widely distributed throughout the world and in Africa is second only to white yam in popularity (Lebot *et al*., 2005). According to Lebot *et al*, (2005), it is the most widely distributed species in the humid and semi-humid tropics. Bitter yam (*Dioscorea dumetorum*) which is also called trifoliate yam because of its leaves originated in Africa where wild cultivars also exist. Genetic improvement programs at IITA (Nigeria) and at the Central Tuber Crops Research Institute (CTCRI, India) have been developing high yielding *D. alata* and *D. rotundata* varieties with pest and disease resistance to meet farmers’ requirements. To achieve breeding goals, these institutions and other yam improvement programs in different countries have collected and maintained more than 3,000 germplasm accessions that are being used for yam improvement. There is tremendous genetic variability in yam. Contrary to the situation in other crops where the deployment of improved varieties has led to loss of diversity and a narrowing of the genetic base, some kind of domestication of semi-wild yam species is still on going in West African countries, which continually augments the germplasm diversity (Mignouna and Dansi, 2003).

2.2. Varieties of yams

There are about 600 known species of yams widespread throughout the humid tropics but the edible yams are derived mainly from the most economically important species, which is; White yam (*Dioscorea rotundata* Poir). Originated in Africa and is the most widely grown and preferred yam species. The tuber is roughly cylindrical in shape, the skin is smooth and brown and the flesh usually white and firm. A large number of white yam cultivars exist with differences in their production and post-harvest characteristics.

Yellow yam (*Dioscorea cayenensis* Lam.) which derives its common name from its yellow flesh is also native to West Africa and very similar to the white yam in appearance. Its yellow flesh is caused by the presence of carotenoids. Apart from some morphological differences (the tuber skin is firm and less extensively grooved), the yellow yam has a longer period of vegetation and a shorter dormancy than white yam (Mignouna and Dansi, 2003).

Water yam (*Dioscorea alata* L.) originated from South East Asia, it is the species most widely spread throughout the world and in Africa is second only to white yam in popularity. According to Lebot *et al*, (2005), it is the most widely distributed species in the humid and semi-humid tropics. It is a vigorously growing, twining, herbaceous vine reaching 10-20 m in length. The large tubers are used as food. *D. alata* is less highly regarded than the indigenous *D. rotundata* in West Africa (Brunnschweiler, *et al*., 2004). The tuber shape is generally cylindrical, but can be extremely variable. Tuber flesh is white and "watery" in texture. It is an important food in Africa, the Caribbean, and especially Melanesia where it has considerable social and cultural importance (Lebot *et al*, 2005). There is very little international trade, even though significant trade in the commodity occurs within the various producing countries. A large number of cultivars have been recorded throughout the tropics varying in shape and colour of leaves, stems and tubers. The most widely grown cultivar in the Caribbean is 'White Lisbon', which is high-yielding, with shallow-rooting tubers with a pronounced neck and 2-3 fingerlike portions with a length of about 20 cm; outer cortex creamy white; flesh white; very palatable and storing well for 5-6 months. The' Lisbon' yams probably get their name from the port of Lisbon to which yams were taken from Sao Tome to feed slaves, who were resold there before shipping them to the New World (Onwueme, 1997).

Bitter yam (*Dioscorea dumetorum*). This is also called trifoliate yam because of its leaves. Originates in Africa where wild cultivars also exist. One marked characteristic of the bitter yam is the bitter flavour of its tubers. Another undesired characteristic is that the flesh hardens if not cooked soon after harvest. Some wild cultivars are highly poisonous, (Mignouna *et al*., 2004). Depending on the species, yam grows for six to ten months and is dormant for two to four months. These two phases usually corresponds to the wet season and the dry season. For maximum yield the yam requires an annual rainfall of over 1,500 mm distributed uniformly throughout the growing season. White, yellow and water yams normally produce a single large tuber, often weighing 5-10 kg annually. *Dioscorea rotundata* and *D. cayenensis* are the most popular and economically important yams in West and Central Africa where they are indigenous, while *D. alata* is the most widely distributed species globally, (Mignouna and Dansi., 2003).

2.3. General morphology and composition of the Yam tuber

2.3.1. General morphology

Yam (*Dioscorea* spp.) is a multi-species, polyploid and vegetatively propagated tuber crop that is cultivated widely in the tropics and subtropics. The number and shape of yam tubers vary largely between species. *D. rotundata* (white yam) tubers are generally large and cylindrical in shape with white flesh. *D. alata* (water yam) tubers have variable shape, the majority being cylindrical (FAO, 2002). The tubers can range in size from that of a small potato to behemoths over 71/2 feet long and 120 pounds. Depending on the variety, a yam's flesh may be of various shades of off-white, yellow, purple, or pink, and the skin from off-white to dark brown. The texture of this vegetable can range from moist and tender to coarse, dry, and mealy. Yams can be found in most Latin American markets, often in chunks, sold by weight (IITA, 2004). The difference in tuber shape and size can is due to genetic and environmental factors. However, cultivated forms generally produce tubers that are more or less cylindrical in shape and 3-5 kg in weight. Yam tuber grows from a corm-like structure located at the base of the vine. Occasionally this corm remains attached to the tuber after harvest and sprouts will develop from it. When the corm separates from the tuber sprouting occurs from the tuber near to the point at which the corm was attached (Huber, 1998).

The number and shape of yam tubers vary largely between species (Huber, 1998). *D. rotundata* (white yam) tubers are generally large and cylindrical in shape with white flesh. *D. alata* (water yam) tubers have variable shape, the majority being cylindrical. The tuber shape of Water yam is generally cylindrical, but can be extremely variable. Tuber flesh is white and "watery" in texture. It is an important food in Africa, the Caribbean, and especially Melanesia where it has considerable social and cultural importance, (Lebot *et al*, 2005). Tubers of *D. cayenensis* (yellow yam) are in many respects similar to that of D. *rotundata* (white yam). Yellow yam (*Dioscorea cayenensis* Lam.); Derives its common name from its yellow flesh, which is caused by the presence of carotenoids. It is also native to West Africa and very similar to the white yam in appearance. Apart from some morphological differences (the tuber skin is firm and less extensively grooved), the yellow yam has a longer period of vegetation and a shorter dormancy than white yam. Bitter yam (*Dioscorea dumetorum*) which is also called trifoliate yam because of its leaves originated in Africa where wild cultivars also exist. One marked characteristic of the bitter yam is the bitter flavour of its tubers. Another undesired characteristic is that the flesh hardens if not cooked soon after harvest. Some wild cultivars are highly poisonous.

2.3.2. Composition of yam

2.3.2.1. Nutritional composition

Yam is far from being a balanced food and deficiency diseases are prevalent within the poorer population of yam-growing areas, but yam is greatly superior to cassava, sweet potato and taro with regard to protein and vitamin C and its replacement by the more easily growing cassava may be a factor for the spread of deficiency diseases in many tropical regions (Coursey, 1983). *D. alata* cultivars possess a higher content of protein, vitamin C and low lipids than *D.* cayenensis, *D. escunlenta*, *D. rotundata* and *D. trifida* (Muzac-Tucker *et al*., 1993). *D. dometorum* is a yam species with the highest nutritional qualities, containing high protein and mineral values. However, this latter species has not been studied as widely as other species (Martin *et al.*, 1984). Post-harvest losses are large in *D. dometorum*, because if tubers are not cooked within a few days after harvest they become hard and inconsumable (Treche &Delpeuch, 1982; Sealy *et al*., 1985; Afoakwa and Sefa-Dede, 2002 a and b).Yams have high contents of moisture, dry matter, starch, potassium, and low vitamin A. Yams contain about 5-10 mg.100 g^{-1} vitamin C, and the limiting essential amino acids are isoleucine and those containing sulphur. They 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 $C_{13}H_{19}O_2N$) and steroid derivatives. Table 2.1 provides a summary of the nutritional values of yams while Table 2.2 shows the nutritional values for individual yam species. It should be noted that the method 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 100g edible portion)

Nutrient	**Tuber**	**Bulbils**
Calories	71.00 - 135.00	78.0
Moisture (%)	81.00 - 65.00	79.4
Protein (g)	1.4-3.50	1.4
Fat (g)	0.40-0.20	0.2
Carbohydrates(g)	16.40-31.80	18.0
Fibre (g)	0.40-10.00	1.2
Ash	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	

Source: (Opara, 1999).

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. esculenta Lesser yam**	**D. rotundata White yam**
Water (ml)	69	65 -76†	71- (79)‡	80	70 -74†	80
Calories	119	135- 87	112- (78)	71	112- 102	71
Protein (g)	1.9	2.3 -1.9	1.5 -(1.4)	1.5	3.5 -1.5	1.5
Fat (g)	0.2	0.1 -0.2	0.1 -(0.2)	0.1	0.1 -0.2	0.1
Carbohydrate (g)	27.8	31 -20	26 -(18)	16	25 -24	16
Fibre (g)	0.8	1.5- 0.6	0.9 -(1.2)	0.6	0.5 -0.6	0.6
Calcium (mg)	52	28 -38	69 -(40)	36	62 -12	36
Phosphorous (mg)	61	52 -28	29 -(58)	17	53 -35	17
Iron (mg)	0.8	1.6 -1.1	(2.0)	5.2	0.8	5.2
Vitamins						
□-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	

†Two values reported; ‡Bulbil or aerial tuber. Source: (Opara, 1999).

2.3.2.2. Antinutritional components

The edible, matured, cultivated yam does not contain any toxic principles. However, bitter principles tend to accumulate in immature tuber tissues of *D. rotundata* and *D. cayenensis*. They may be polyphenols or tannin-like compounds. Wild forms of *D. dumetorum* do contain bitter principles, and hence are referred to as bitter yam. The bitter principle has been identified as the alkaloid dihydrodioscorine, while that of the Malayan species, *D. hispida,* is dioscorine. These are water-soluble alkaloids, which, on ingestion, produce severe and distressing symptoms. Severe cases of alkaloid intoxication may prove fatal. There is no report of alkaloids in cultivated varieties of *D. dumetorum*. The bitter principles of *D. bulbifera* (called the aerial or potato yam) include a 3-furanoside norditerpene called diosbulbin. These substances are toxic, causing paralysis. Extracts are sometimes used in fishing to immobilise the fish and thus facilitate capture. Toxicity may also be due to saponins in the extract. Zulus use this yam as bait for monkeys, and hunters in Malaysia use it to poison tigers. In Indonesia an extract of *D. bulbifera* is used in the preparation of arrow poison (Sanni *et al*, 2003).

2.4. Agronomic properties of yam and yam production

2.4.1. Agronomic properties

Yam is grown and cultivated for its energy-rich tuber. It is adaptable to fairly fertile soils and is suitable for intercropping with grain legumes such as cowpeas, soybeans and a variety of leafy vegetables. A well-drained, rich, loamy soil however is the most favourable. Yam requires a warm, humid climate; however, the crop possesses considerable drought resistance. It gives more calories per unit of land area than most crops and matures within seven months. On soils of average fertility, between 20 and 30 tonnes per hectare of tubers can be obtained, and up to 55 tonnes per hectare on fertile soils; it also stores very well. It has quite demanding labour and maintenance requirements, such as hilling the soil around each plant to form mounds, to ensure a pulverised soil favourable for tuber development. Storage of tubers occurs after harvest in barns or heaps covered with grass, (Nweke *et al*., 1991).

Yams (*Dioscorea* spp.) rarely produce seed. Instead they are vegetative propagated through planting pieces of yam tuber. Yams are cultivated throughout the tropics, and in parts of the sub-tropics and temperate zones. They are adaptable to fairly fertile soils and are suitable for intercropping with grain legumes such as cowpeas, soybeans and a variety of leafy vegetables. A well-drained, rich, loamy soil however is the most favorable (Nweke *et al*., 1991. Yam requires a warm, humid climate; however, the crop possesses considerable drought resistance. It gives more calories per unit of land area than most crops and matures within seven months. On soils of average fertility, between 20 and 30 tonnes per hectare of tubers can be obtained, and up to 55 tonnes per hectare on fertile soils; it also stores very well (NRI, 1987). It has quite demanding labour and maintenance requirements, such as hilling the soil around each plant to form mounds, to ensure a pulverized soil favorable for tuber development. Storage of tubers occurs after harvest in barns or heaps covered with grass (Nweke *et al*., 1991).

2.4.2. Yam Production

2.4.2.1. Global production

There are over 150 species of yam grown throughout the world. The global annual yam production was estimated to be 25 million Mt in 1974. This increased to 24 million Mt in 1992 and in 1993; it was estimated to be at 28.1 million tons. Out of the total of world production, 96% came from West Africa, with the main producers being; Nigeria 71%; Côte d'Ivoire 8.1 %; Benin 4.3 % and Ghana 3.5 %. Over a period 5 years, total world production increased from 32.7 million Mt in 1995 to 37.5 million Mt in 2000 (Table 2.3). During this same period, export quantity declined slightly while export income remained fairly steady. During the period 1975-1990, total yam cultivated area increased by about 38.8% globally, while the total production increased by 45.8 % (Opara, 1999). Between 1990 and 2002 yam production increased from 18 million metric tonnes to estimates of over 39 million. In 2000, global yam production was approximately 37.5 million tonnes, 96% of this in Africa. Nigeria alone accounts for about 70 percent of the world production. More than 95 percent (2.8 million ha) of the current global area under yam cultivation is in sub-Saharan Africa, where mean gross yields are 10 t/ha. The domestic market is developed in the yam producing areas making the crop the main source of cash for a large majority of small-scale farmers including many women.

In the humid tropical countries of West Africa yams are one of the most highly regarded food products and are closely integrated into the social, cultural, economic and religious aspects of life. The ritual, ceremony and superstition often surrounding yam cultivation and utilization in West Africa is a strong indication of the antiquity of use of this crop. Nigeria, the world's largest yam producer, considers it to be a "man's property" and traditional ceremonies still accompany yam production indicating the high status given to the plant (PhAction news, 2002).

Table 2.3: World's leading yam producers in 1990.

World	Area (103 ha)	% of World Area	Production (103 Mt)	% of World Production	Yield (kg.ha-1)	% of World Yield
	2,928	100	29,447	100	10,057	100
Africa	2,789	95.3	28,249	95.6	10,127	100.7
West Indies	59	2.0	350	1.2	6,122	60.9
Oceania	18	0.6	284	1.0	15,818	157.3
Asia	15	0.5	198	0.6	12,876	128.0
Nigeria	1,900	64.9	22,000	74.7	11,579	115.1
Cote d'Ivoire	266	9.1	2,528	8.6	9,504	94.5
Benin	90	3.1	992	3.4	11,026	109.6
Ghana	200	6.8	168	2.4	3,500	34.8
Togo	40	1.4	420	1.4	10,500	104.4
Zaire	38	1.3	270	0.9	7,200	71.6

Source: Adapted from (FAO, 1991).

Table 2.4: World production and trade in yams (1995 and 2000).

	2000	**1999**	**1998**	**1997**	**1996**	**1995**
Production, Mt	37,532,138	37,552,383	35,753,519	34,705,657	33,587,195	32,765,435
Exports-Mt	-	23,198	21,080	28,069	27,493	26,264
Exports-1000US$	-	20,077	19,212	20,873	20,810	21,108

Source: (FAO/STAT, 2000).

2.4.2.2. Production in Africa

Yam which is the second most important root/tuber crop in Africa is also a primary agricultural commodity in West Africa and New Guinea. Its level of production is about one third that of cassava. Over 90% of world yam production occurs in the yam belt zone of West and Central Africa with Nigeria alone accounting for about 68 percent of the world's total (FAO, 2002). More than 95% of the world's yams are currently grown in sub-Saharan Africa, with the remainder being grown in the West Indies, parts of Asia and South and Central America. In 2000, 96% of the global yam produced was from Africa. Nigeria alone accounted for about 70 percent. More than 95 percent (2.8 million ha) of the current global area under yam cultivation is in sub-Saharan Africa, where mean gross yields are 10 t/ha. The domestic market is developed in the yam producing areas making the crop the main source of cash for a large majority of small-scale farmers including many women. There are over 600 yam species grown throughout the world, but in West Africa there are 3 main species. These are white yam, yellow yam, and water yam (Nweke *et. al*., 1991).

2.4.2.3. Production in Ghana

Yam production in Ghana has been on the decline despite the increasing demand for local consumption and for export. In a survey carried out in three ecological zones to find out the constraints and prospects to yam production, it was observed that farmers commercially cultivate mainly *Dioscorea rotundata* (26 varieties) and to a lesser extent 13 varieties of *Dioscorea alata* (water or greater yam). A few farmers grow *D. cayenensis, D. bulbifera, D. dumetorum,* and *D. esculenta* for home use. The greater yam (*Dioscorea alata* L.) is the most widely distributed species of the genus in the humid and semi-humid tropics. It is an important food in Africa, the Caribbean, and especially Melanesia where it has considerable social and cultural importance (Coursey 1976).

Table 2.5: Production statistics for yam -2004

Continent	Country	Percentage
Africa	Nigeria	66
	Ghana	10
	Côte d'Ivoire	8
	Benin	6
	Togo	1
Asia	-	1
South America	-	2
Other SSA	-	4
Rest of world	-	2

Source: Adapted from FAO/STAT (2005)

2.5. Prospects and constraints of production and marketing

From comparison of 235 varieties collected world wide in the 1970s, it was concluded that the centre of variation of *D. alata* is first Papua New particular. Selection could overcome the difficulty of producing new varieties in a crop where flowering is sporadic and hand pollination complex. Lucrative urban markets require the smaller, round or oval varieties with white tuber flesh, free of oxidation (Brown 1995). Few studies have been conducted on the physico-chemical variation of *D. alata* tubers. Martin (1974) observed in Puerto Rico that high dry weights are associated with fine structure, dense feel, high quality, and concluded that high density is a varietal character that is not changed much by environmental influences. In the Pacific, although some preliminary work has been done at the inter-specific level (Bradbury and Holloway 1988), the lack of information on the variation within *D. alata* hinders its prospective utilization as a high quality exportable vegetable. Egesi *et al*. (2003) studied the extent of genetic diversity existing for organoleptic properties in 40 water yam varieties cultivated in Nigeria. Two thirds of their accessions were identified as being suitable for boiled yam, while more than half of these accessions were good for pounded yam. Their results were, however, based on the respective quality attributes evaluated but the physicochemical characteristics of the tubers were not quantified, Furthermore, *D. alata* is thought to have been introduced clonally in Africa and its genetic base is narrow as demonstrated by the limited isozyme variation detected between African cultivars (Lebot *et al.*, 1998). In Vanuatu, indigenous knowledge claims that there is tremendous variation between the culinary and palatability properties of *D. alata* varieties, some being suitable for certain types of preparation, while others are not, and some being cooked much faster than others. When the tuber of some varieties is cut open, the colour of the surface begins to change rapidly with the oxidation of polyphenolic compounds and become yellowish or brown. Polyphenolic oxidation is also associated with off-flavours, bitterness and deserves in some cases, special preparations. In most islands of Vanuatu, only certain varieties are suitable for the preparation of the national dish, laplap, a pudding made from freshly and finely grounded tubers steam cooked in Heliconia indica leaves. Others have to be boiled or roasted in order to be palatable (Bourrieau, 2000). More than 1000 varieties are currently grown in Melanesia although there are signs of genetic erosion in farmers fields (Jackson, 1994). Traditionally, farmers maintain a wide range of diversity, including varieties with tubers irregular in shape and therefore hard to peel and others with smooth skin and regular shape which are more convenient to use. Harvesting alone can account for 20% of the total production costs and is also largely dependent on tuber shape (Onwueme and Charles 1994).

2.6. Harvesting and post harvest losses

2.6.1. Harvesting

Yam harvesting is a labour-intensive operation that involves standing, bending, squatting, and sometimes sitting on the ground depending 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. 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. Aerial tubers or bulbils are harvested by manual plucking from the vine. Although some success in mechanical yam harvesting has been reported, especially for *D. composita* tubers for pharmaceutical uses (Nystrom *et al*., 1987), 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, 1997). Current crop production practices and species used poses 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. 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. Periods of 8-10 months and 4-5 months from planting or emergence to maturity have been recommended for double-harvesting (Martin *et al*., 1984; Onwueme, 1977); harvest first at 5-6 months after planting and then 3-4 months later has also been reported (Bencini, 1991).

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’. In single harvesting, each plant is harvested once and this occurs at the end of the season when crop has matured. 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. 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). In the production of water yam, two kinds of practice exist with respect to the timing of the harvest. In double harvesting, each yam plant is harvested twice. A first harvest is done at about 5 months after emergence. During this harvest, the farmer digs carefully to expose the tuber without damaging the plant's roots. The tuber is then severed from the rest of the plant at a point just below the corm. The tuber is removed and the roots are covered up again with earth. The plant continues to grow and later produces a new tuber. After the plant has finally died at the end of the season, the second harvest is done. The tuber recovered at the second harvest is firmer in texture and more irregular in shape than that from the first harvest. Single harvesting involves waiting until the end of the season when the vines have died, before harvesting the yams. Each plant is therefore harvested once.

Double harvesting has the advantages of making the new crop available for consumption earlier in the season, and of producing excellent planting material at the second harvest. However, double harvesting also has several disadvantages compared to single harvesting. Firstly, double harvesting requires at least double the labour for the harvesting operation, yet experiments have shown that the combined yields of the two harvests are no higher than that obtainable by single harvesting. Secondly, the first harvest of the double harvest is extremely delicate because of the need to avoid root damage. As such, prospects of mechanizing this operation are extremely remote. Thirdly, double harvesting produces tubers that are poorer for consumption than the tubers from single harvesting. The tubers from the first harvest are often watery and not completely mature, while tubers from the second harvest are woody in the head region. All told, double harvesting is appropriate only for traditional agriculture and will, with time, be progressively replaced by the practice of single harvesting. Mechanical harvesting is not a common practice at present, but it is certainly desirable for the future. Efforts are in progress in the West Indies and in West Africa towards developing mechanical harvesters for yams. Selection is being carried out for cultivars with globoid tubers, firm skin, and the ability to yield well without staking. For mechanical harvesting the mean size of each tuber should not be very large, but this can easily be achieved by reducing the set weight used for planting.

2.6.2. Post harvest loses

After harvesting of yam tubers there are some losses which are incurred during storage. These losses are caused by rotting, tuber respiration and tuber sprouting. During storage respiration and sprouting utilize the stored material of the tubers. There is also and appreciable loss of moisture from the tuber. It had been reported that considerable amounts of yam were regularly lost between harvests and market. In a project developed in 1995 to examine the post-harvest handling and marketing systems within Ghana to determine the nature, causes and implications of the losses so as to develop appropriate technologies or protocols to reduce the losses, much of the losses were found to be due to rotting of diseased or damaged tubers. A subsequent project was established in 2000 to establish strategies for grading yams by quality, and for excluding diseased tubers from entering the marketing chain. An “electronic nose” system was tested for identifying diseased tubers in batches destined for export from Ghana.

The use of cold storage for yam tubers would be advantageous in reducing storage losses due to rotting, sprouting and respiration. However the practice is at present limited by the high cost of continuous refrigeration and by the fact that yams stored at temperatures below 10°C tend to become brown and unsuitable for consumption of Yams (Onwueme, 1997).

2.7. Food Storage and storage methods

2.7.1. Food Storage

Food storage which is both a traditional and domestic skill is also important industrially. Food is stored by almost every human society and by many animals. The main purposes of storing food includes preparation for periods of scarcity or famine, taking advantage of short term surplus of food as at harvest time, enabling a better balanced diet throughout the year, preparing for special events and celebrations, planning for catastrophe or emergency and protection against predators or others (Kordylas,1990).

2.7.2. Storage methods

There are three common methods of storing the yam tubers after harvesting. These are storing tubers in barns, on platforms and underground. The barn is the commonest form of yam storage in West Africa. It is erected in an open place and consists essentially of a series of vertically-oriented poles to which the yams are tied with rope. In platform storage, the yams are laid horizontally on an elevated platform; while in underground storage the tubers are placed together in a large ditch and then covered with soil or dry vegetation. Whichever method of yam storage is adopted, it is essential that the tubers should be well aerated and well shaded. In addition, the stored tubers should be inspected frequently so that rotting ones can be removed, and the sprouts can be removed from those that begin to sprout (Onwueme 1997).

Aeration, reduction of temperature, and regular inspection of produce are the three main conditions necessary for successful yam storage. 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. The recommended storage temperature is in the range 12°C-16°C. Optimum conditions of 15°C or 16°C at 70-80 % rh or 70 % rh have been recommended for cured tubers (Martin *et al.*, 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 °C-29 °C, 46-62 % rh), *D. trifida* will begin 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 12.5 °C 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 important yam cultivars.

Table 2.6: 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

Source: (Opara, 1999).

There is several traditional storage structures used for yam storage and these includes leaving the tubers in the ground until required, the yam barn, and 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. The yam barn is the principal traditional yam storage structures in the major producing areas. Barns are usually located in shaded areas and constructed so as to facilitate adequate ventilation while protecting tubers from flooding and insect attack. Barns consist of a vertical wooden framework to which the tubers are individually attached. Two tubers are tied to a rope at each end hung on horizontal poles 1 to 2 m high. Barns up to 4 m high are uncommon. Depending on the quantity of tuber to be stored, frames can be 2 m or more in length. The ropes are usually fibrous, but in South-eastern Nigeria, they are made from the raffia obtained from top part of Palm wine tree. Many farmers have permanent barns, which need annual maintenance during the year's harvest. In these situations, growing trees are used as vertical posts, which are trimmed periodically to remove excessive leaves and branches. Palm fronds and other materials are used to provide shade. The vegetative growth on the vertical trees also shades the tubers from excessive solar heat and rain. The use of open-sided shelves made from live poles, bamboo poles or sawn wood has been recommended to enable careful handling and easy inspection in comparison with tying tubers to poles which can cause physical damage and rotting (Bencini, 1991). In barn storage, yams have a maximum storage life of 6 months and are therefore most suited for long-term varieties. Storage losses can be high and up to 10-15 % in 3 months, and 30-50 % after 6 months if tubers are not treated for rotting using fungicides such as Benlate, Captan or Thiabendazole.

2.8. Yield, consumption and utilization of yam

2.8.1. Yield

Yield growth rates of roots and tubers in Sub-Saharan Africa have been disappointing except in the case of yam. On a world scale, yams represent less than 10 % of all root and tuber crops produced and, of these, 75 % are grown in West Africa. In West Africa, Nigeria and Ghana grow significant quantities of yam, though Tanzania is reported to produce some 11 x 103 Mt pa (Nigeria = 26 x 106 Mt pa). According to FAOSTAT, (2005), Yield of yams in Ghana has increased from about 5 Mt/ha in the late 1980s to about 14 Mt/ha in 2004. The pattern of yields over the last 40 years in Nigeria is difficult to interpret, though the gradual decline in yield from about 12 Mt/ha in the late 1980s to about 8 Mt/ha in 2004 has been attributed the use of shorter fallow periods and use of more marginal lands for yam production because of demand to feed the increasing human population. In Tanzania, where yams are mainly a low-input, food security crop grown on a very small scale, yields are reported to have remained relatively static at about 6 Mt/ha. Yams are relatively more expensive to grow compared to the other root crops because they require staking in many areas, and they require greater labour input for land preparation (clearing and mounding), stake-tying and careful harvesting (FAOSTAT,2005).

2.8.2. Consumption

Yams are mainly grown for direct human consumption and are marketed as fresh produce in all the growing regions. In 1996, 16 million tons of the total yams produced were consumed as food (Ravi *et al.*, 1996). In West Africa the preferred method of yam preparation is pounding yam or the reconstitution of yam flour to a thick paste that are consumed with a soup. Tubers may also be consumed directly after boiling or cooking in a pottage with protein sources and oils added. The mixing of yam flour with soy flour can improve upon the protein content of reconstituted yam paste. The incorporation of proteins, lipids and certain minerals into traditionally consumed forms of yam is substantial without diminishing the acceptability of the products from the consumer side. Furthermore, frying and roasting are important cooking methods of yam (Achi,1999; Asiedu *et al*., 1997; Fotso *et al*., 1994). In the Ivory Coast, the main consumed yam dishes in the consuming areas includes pounded yam (Foutou), boiled yam and boiled yam in sauce (ragout) (Konan *et al*., 2003). Among these dishes, pounded yam is the most consumed dish, particularly in villages where cooking habits allow long food preparation times. The traditional procedure of pounding yam includes continuous addition of water by hand during pounding to avoid the yam paste from sticking at the mortar or pestle and to give the product its preferred consistency.

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 (*Dioscorea alata*), are often mixed with gari and pounded with gari to prepare fufu of 'soft' texture. Onayemi & Potter (1974) reported that drum-drying of *D. rotundata* Poir in Nigeria yield high quality flakes. The food yam in Nigeria is reported to be consumed as boiled yam, pounded yam, fried yam in oil, fried mashed yam balls, soup thickener, and is also used in baked products (bread and pastries, made from yam flour solely or mixed with cereal flour), (Egesi *et al*., 2003). In Puerto Rico yam flakes are produced for the purpose of preparing instant mashed yam alternatively to freshly prepared yam (Rodríguez-Sosa & González, 1972; Rodríguez-Sosa *et al*., 1972). From Asia, Salda *et al*. (1998) reported that yam finds its uses as ice cream flavouring, powdered yam, preserves and candies besides fresh products. A few yam species, i.e. *D. fandra* in Madagascar or *D. alata* in tropical Asia are sometimes consumed in the raw state (Degras, 1986).

2.8.3. Utilization

Yams are essentially used as food. It is mainly a carbohydrate with relatively high protein and ascorbic acid (Vitamin C) content compared to cassava or sweet potato. By far the greater part of the of the World's yam crop is consumed fresh; the tubers are commonly eaten as a vegetable either boiled, baked or fried. "Fufu", stiff, gelatinous dough (pounded yam) prepared by pounding boiled tuber pieces in a mortar, is the preferred form in most of West Africa.

To a limited extent, yam flour is also produced in Ghana where the reconstituted dough is known as "Yam Kokonte". Traditionally, processed yam products are made in most yam-growing areas, usually as a way of utilizing tubers that are not fit for storage. Attempts to manufacture fried yam chips, similar to french fried potatoes have been reported from Puerto Rico (Scott *et al*, 2000b). Recent attempts at more sophisticated processing of yam for export or the production of starch or alcohol have not met commercial successes, largely owing to the high cost of the raw material.

Dioscorea species are not only known for their food value but also for their secondary metabolites. They contain steroidal saponins, diterpenoids and alkaloids, which are toxic and have been exploited in one way or the other. In the

African *Dioscorea* species alkaloids (dioscorin) appear to be dominant, whereas steroidal sapogenins (diosgenin, yamogenin and cryptogenin) are not reported. The poisonous alkaloid dioscorin and its dehydro-derivatives were in the past used in poison-making, i.e. hunting arrow-poison, criminal poison etc., in different parts of the world (Neuwinger, 1996). *D. dumetorum* species contain dioscoretin which is responsible for the hypoglycaemic activity of the tubers (Iwu *et al*., 1990). The main species of *Dioscorea* for pharmaceutical purposes originate from Central America (*D. composita* Hemsl., *D. floribunda* Mart. & Gal. and *D. mexicana* Giullem) and northern South America (*D. trifida* L.) (Chu & Figueiredo-Ribeiro, 1991). Sapogenic precursors of cortisone and steroidal hormones such as progesterone led to the improvement of wild species for higher production of these secondary plant metabolites, e.g. in Mexico (Martin & Ortiz, 1963; Franke, 1997). The antifungal compound pendulin and several saponins were isolated from *Dioscorea* species native to Brazil (Haraguchi *et al*., 1999). In *Dioscorea* species used for food purpose toxicity is generally weak or has been eliminated by ennoblement (Burkill, 1985).

2.8.3.1. Prospects and constraints of the utilization of yam

In the humid tropical countries of West Africa yams are one of the most highly regarded food products and are closely integrated into the social, cultural, economic and religious aspects of life. The ritual, ceremony and superstition often surrounding yam cultivation and utilisation in West Africa is a strong indication of the antiquity of use of this crop. Yam as a staple and traditional food is not always available at affordable prices to the poor, and farmers complain of low and unattractive prices which does not cover their cost of production. Nigeria, the world's largest yam producer, considers yam to be a "man's property" and traditional ceremonies still accompany yam production indicating the high status given to the plant. The overall significance of yam is gradually declining due to increased competition with other food sources such as cassava and wheat bread. The multiple weeding required to get good yield is a major cost and limitation to yam cultivation, especially for medium-scale smallholders who do not have sufficient family labour. Current estimates indicate that quantitative losses are high and this translates into substantial amounts when the labour involved in bush clearing, planting, weeding and harvesting are included. Qualitative and nutritional losses are also high in yams and these have both economic, social and health implications particularly in the growing areas where it is a major food material. The higher the exposed surface area of tissue during processing, the higher the incidence of losses in minerals and vitamins. Both sun drying and milling contribute to losses in thiamine, riboflavin and B vitamins. Developing improved unit operations for yam processing could assist in improving the nutritional status of rural people in the yam regions.

2.9. Processing and Product development from yam

Industrial uses of yam includes starch, poultry and livestock feed, and production of yam flour. Readers interested in detailed information on specific yam processing methods, equipment, and packaging techniques can find this information in an FAO technical compendium (Bencini, 1991). 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. 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.

Common methods 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. Tubers are also processed into several food products such as the yam flour, which are enjoyed in many parts of the tropics.

2.9.1. Traditional processing

Traditionally, processed yam products are made in most yam-growing areas, usually as a way of utilizing tubers that are not fit for storage. Since pounded yam has so much prestige and is the most popular way of eating yam, two attempts have been made to commercialize the process. The first was the production of dehydrated pounded yam by drum drying. This product could then be reconstituted without further processing. This production was first attempted in

Côte d'Ivoire in the mid1960s, under the trade name "Foutoupret", by air-drying precooked, grated or mashed yam. Attempts to produce fried yam chips, similar to french fried potatoes have been reported from Puerto Rico (Scott *et al*, 2000). Recent attempts at more sophisticated processing of yam for export or the production of starch or alcohol have not been commercial successes, largely owing to the high cost of the raw material.

2.9.2. Industrial processing and product development

Industrial processing and utilizations of yam include starch, poultry and livestock feed, and production of yam flour. Yams have not been processed to any significant extent commercially. Dehydrated yam flours and yam flakes have been produced by sun drying. The production of fried products from *D. alata* has also been attempted recently. Both chips and French fries similar to that of potatos have been produced. Preservation of yam in brine has been attempted, but with little success.

2.10. History of Potato and Production Trends in Ghana

Potatoes were likely cultivated within the present borders of Ghana prior to 1898, presumably first introduced by Europeans (Akyeampong 1975). Production however was minor prior to the Second World War when the British imported seed potatoes to support their garrisons in the then Gold Coast with locally produced potatoes. The crop grew well and was adopted by many farmers at high elevations at Mampong (Ashanti), Mpraeso-Abetefi-Pepease areas and Amedzoje (Agble 1981). In 1945 a Potato Farmers' Association was established to assist in marketing the crop (Akyeampong 1975). Seed was imported from the UK. After the war production declined as ehe markets disappeared (Agbe 1981, Kore 1976).

In 1962 the Ghana State Farms Corporation (GSFC) was established to produce food crops, including potatoes. Seed tubers were imported from the USA, UK, Israel, the Netherlands and elsewhere and planted without preliminary variety trials. Although some reasonable yields were achieved, local production was unable to compete with imports, and GSFC abandoned potato cultivation completely (Agble 1981).

In 1965 another attempt was made to revive potato production in Ghana. Several Irish varieties were imported, evaluated, and rejected as unsuitable to local soil and climate. Further trials, especially with several Dutch varieties were more promising (Agble 1981). In the 1970s a need was identified to increase production in response to a growing demand among expatriates which had to be met through imports (Kore 1976; Ako Nai 1976; Agble 1981). Support for intensive research and extension for potato production continues to be irregular, inconsistent, and very limited (Ako-Nai 1976; Agble 1981).

FAO did not include data on potato production for the period 1961-1985 in 1986 indicating annual production of less than 500 tons throughout this period.

2.10.1 Zones of Production

Potato production is largely confined to areas of the high plateau essentially above 400 m asl. Production mainly occurs in the Ashanti/Mampong District, Kwahu, and Amedzofe (Ako-Nai 1976; Akyeampong 1975).

Kwahu and Mampong are on the Ashanti Plateau north and east of Kumasi. Mampong, at about 400 m asl, receives about 1300-1500 mm/yr of rainfall. Pepease, near Kwahu, at about 450 m asl receives about 1500-1800 mm of precipitation annually. Amedzofe is located at about 700 masl in the far southeast of Ghana near the Togo border. Annual precipitation is also roughly 1500-1800 mm (Akyeampong 1975).

Rainfall in all these areas is bimodal with the first, main rainy season occuring between March and July followed by a short "semi-dry" period in August. A second, shorter rainy season begins in September and tapers off in late November. Except during severe dry periods temperatures are around 26-28 degrees C and relative humidity between 80-90%. (Akyeampong 1975; Ako-Nai 1976). Soils are mainly medium loans, deep and dark brown. Manpong and pepease have as parent material, lower voltarian sediments. Vegetation is mostly secondary forest (Akyeampong 1975).

2.10.2 Storage and Processing

Ghana has no cold storage facilities for potatoes. Losses in storage and during transport of imported seed potatoes is a major problem. (Akyeampong 1975; Agble 1981; Aka-Nai 1976). Storage of ware potatoes is also problematic. Storage structures are marketing and very simple; a raised wood platform on which a palm mat is spread. Protected from rain by bamboo roofing. Major losses are due to shrinking, rotting, and sprouting. No methods have been developed to solve these problems; in 1956 trial use of a sprout suppressant increased rotting losses after 24 weeks from 70% to 99%. Ware potatoes must be sold within 2 months of harvest (Akyeampong 1975).

2.10.3 Distribution

Akyeampong (1975) reported that demand for potatoes exceeds supply and that marketing, other than storage, is not a problem.

2.10.4 Preparation and Consumption

Potatoes play little role in the diet of most Ghanaians. The most important demand is among expatriates and the hotels and restaurants that cater to their needs (Ako-Nai 1976; Agble 1981; Akyeamong 1975). In these settings potatoes are prepared in manners similar to those employed in Europe and North America.

Table 2.7. Characteristics of Major Potato Growing Areas in Ghana

Area	**MASE**	**Annual Rainfall (mm)**	**Rainfall (mm in growing season)**	**HAS**
Mampong	396,5	1270,0-1524,0	547,6-610,6	70,8
Anansu/ Amedzofe	686,3-732,0	1397,0-1651,0	554,2-820,7	232,5
Pepease Kwahu	457,5	1524,0-1778,0	403,2 614,7	142,6
Bukuruwa	457,5	1524,0 1778,0	403,2-614,7	810,0

Source: www. Potato Production in Ghana.htm

2.11. French fries

French fries which is also called chips, fries, or french-fried potatoes are thin strips of potato that have been deep-fried. They are popular in many countries and go by many names in various languages. A distinction is sometimes made between fries and chips. North Americans often refer to any elongated pieces of fried potatoes as fries, while in other parts of the world, long slices of potatoes are sometimes called fries to contrast them with the thickly cut strips, which are often referred to as chips. French fries are known as frites or pommes frites in many parts of Europe, and have names that mean "french potatoes" in others (Icelandic Franskar kartöflur, Finnish Ranskalaiset perunat) Merriam-Webmaster Dictionary (2007).

American heritage dictionary, (2000), the term French fries means potatoes fried in the French sense of the verb "to cook", which can mean either sautéing or deep-grease frying, while its French origin, frire, unambiguously means deep-frying. In the early 20th century, the term "French fried" was being used for foods such as onion rings or chicken, apart from potatoes.

2.11.1 History of French fries (chips)

As a world food, potatoes are second in human consumption only to rice. And as thin, salted, crisp chips, they are America's favorite snack food. Potato chips originated in New England as one man's variation on the French-fried potato, and their production was the result not of a sudden stroke of culinary invention but of a fit of pique **(**Crum 1853**).**

In the summer of 1853, Native American George Crum was employed as a chef at an elegant resort in Saratoga Springs, New York. On Moon Lake Lodge's restaurant menu were French-fried potatoes, prepared by Crum in the standard, thick-cut French style that was popularized in 1700s France and enjoyed by Thomas Jefferson as ambassador to that country. Ever since Jefferson brought the recipe to America and served French fries to guests at Monticello, the dish was popular and serious dinner fare.

At Moon Lake Lodge, one dinner guest found chef Crum's French fries too thick for his liking and rejected the order. Crum cut and fried a thinner batch, but these, too, met with disapproval. Exasperated, Crum decided to rile the guest by producing French fries too thin and crisp to skewer with a fork. The plan backfired. The guest was ecstatic over the browned, paper-thin potatoes, and other diners requested Crum's potato chips, which began to appear on the menu as Saratoga Chips, a house specialty.

In 1860 George opened his own restaurant in a building on Malta Avenue near Saratoga Lake, and within a few years was catering to wealthy clients including William Vanderbilt, Cornelius Vanderbilt, Jay Gould, and Henry Hilton. His restaurant closed around 1890 and he died in 1914 at the age of 92 **(**Crum 1853**).**

The idea of making them as a food item for sale in grocery stores came to many people at around the same time, but perhaps the first was William Tappendon of Cleveland, OH, in 1895. He began making chips in his kitchen and delivering to neighborhood stores but later converted a barn in the rear of his house into "one of the first potato chip factories" in the country.

At that time, potatoes were tediously peeled and sliced by hand. It was the invention of the mechanical potato peeler in the 1920s that paved the way for potato chips to soar from a small specialty item to a top-selling snack food. For several decades after their creation, potato chips were largely a Northern dinner dish.

In 1921, Bill and Sallie Utz started the Hanover Home Brand Potato Chips in Hanover, Pennsylvania. Salie Utz used her knowledge of good Pennsylvania

Dutch cooking to make the chips in a small summer house behind their home. The hand-operated equipment Salie used made about fifty pounds of potato chips per hour. While Salie stayed home making chips, Bill delivered them to "mom and pop" grocery stores and farmer's markets in the Hanover, PA and Baltimore, MD area.

Out in Monterey Park, California the Scudders Company started making potato chips in 1926. Laura Scudder is credited with developing the wax paper bag for potato chips which made a wider distribution possible because of its preserving properties. Prior to this, bagged potato chip were dispensed in bulk from barrels or glass display cases.

In 1932, Herman Lay founded Lay's in Nashville, Tenn., which distributed potato chips from a factory in Atlanta, Ga. Herman Lay, a traveling salesman in the South, helped popularize the food from Atlanta to Tennessee. Lay peddled potato chips to Southern grocers out of the trunk of his car, building a business and a name that would become synonymous with the thin, salty snack. Lay's potato chips became the first successfully marketed national brand (Hess and Karen, 2005).

The industry that George Crum launched in 1853 continued to grow and prosper. Potato chips have become America's favorite snack. U.S. retail sales of potato chip are over $6 billion a year. In 2003 the U.S. potato chip industry employed more than 65,000 people.

Some claim that the dish was invented in Spain, the first European country in which the potato appeared via the New World colonies, and assumes the first appearance to have been as an accompaniment to fish dishes in Galicia, from which it spread to

2.11.2 Production of French fries.

French fries are normally produced from Irish potatoes. Other tuber crops including are also used. Some of these tuber crops are yam and sweet potatoes due to their high nutritional values.

Table 2.8. Nutritional contents of Potato and *Dioscorea alata*

Nutritional content per 100g	**Irish Potato**	***Dioscorea alata***
Water (g)	79.9	65 -76
Energy (kcal)	78.0	135- 87
Protein (g)	2.4	2.3 -1.9
Carbohydrates (g)	16.8	31 -20
Calcium (mg)	36.0	28 -38
Phosphorus (mg)	49.0	52 -28
Iron (mg)	1.1	1.6 -1.1
Thiamine (mg)	0.12	0.05- 0.10
Riboflavin (mg)	0.06	0.03- 0.04
Niacin (mg)	2.2	
Ascorbic acid (mg)	31.0	

Source: FNRI-DOST 1997, Philippines.

2.11.3 Tuber characteristics determining quality of fries

The quality characteristics of tuber that translates into the quality of the final French fries produced are size and shape of tubers**,** injuries and defects, dry matter content and colour. The external quality of potatoes is extremely important in the processing industry. Characteristics of particular interest are the shape, the occurrence of diseases on the skin, and the extent of external damages (Rui *et.al.*, 2001)

Size, shape and shallow eyes are important with regard to the appearance of the product and the influence on wastage during peeling. French fries producers prefer long-oval or long tubers with a size of at least 50 mm. For the production of crisps, round tubers are required with a size range of 40-60 mm. Rough handling of the potatoes during harvesting and transportation causes internal bruising. The internal tissue cells crack and brown stains are formed in the tuber, which is an impediment to processing. Internal defects such as hollow or black heart are also undesirable (Gould, 1988).

One of the most important problems the industry often has to deal with is black spot. This blue to greyish-black discoloration in the tubers is more inclined to occur during transport and grading if the potatoes are not handled and stored in the proper way. As a result of tissue injury, chemical conversions take place, which after a day or two cause a dark discoloration. Therefore it is necessary to handle potatoes as carefully as possible to prevent black spot. In addition, potatoes should be heated to about 15¨¬C before grading. Some varieties are far more susceptible to black spot than others. Almost all potato varieties are more or less susceptible to common scab. But this disease can be effectively controlled by keeping the soil moist, especially during the susceptible period of tuber initiation until about four weeks later (Talburt *et. al.*, 1987)

The term dry matter content means the mass fraction (%) that remains after the water fraction (%) has been removed by drying. The opposite term moisture content is also used. Both the processing efficiency and the quality of the finished product benefit from a high dry matter content. If the dry matter content is too low, the French fries or crisps will be too soft or too wet. In addition, more energy will be required, since more water must be evaporated. A high dry matter concentration results in a lower fat content (Brunnschweiler, 2004). This lowers the processing costs and is better for the health of consumers. However, if the dry matter content is too high, the French fries will be too hard and dry and the crisps will be too brittle. The dry matter content also partly determines the texture of both the fresh and the processed potato. The requirements in respect of the dry matter content are determined by the end product. For the production of French fries, potatoes with a dry matter content of 20 - 24% are preferred. For the production of crisps, preference is given to potatoes with a dry matter content of 22 - 24%. For the flakes industry, potatoes with rather high dry matter content (higher than 21%) are required (Toma, *et.al.,* 1986)

The frying colour is an important criterion for potatoes destined for the French fries and crisps industry. The frying colour of the fried products is determined to a large extent by the reducing sugar content in the potatoes. The higher the content of reducing sugars the darker the frying colour. A dark frying colour results in a bitter taste, which is unacceptable in the production of French fries and crisps. Another important aspect is colour distribution. Unevenness in colour distribution results in French fries with a brown colour at one end. The causes of this phenomenon are senescence after long storage and secondary growth. Some varieties are prone to the so called ¡®sugar ends¡¯ as a result of senescence after long storage. In extreme cases of secondary growth, starch is abstracted from the primary tuber. The abstraction starts at the heel-end of the potatoes and may lead to glassiness. Glassiness is when the potato tissue of a re-sprouted tuber, or the top end of a long tuber, looks watery-translucent when cut. It may even have a spongy texture (Brunnschweiler, 2004).

The requirements with regard to the content of reducing sugars depend on the end product. Of all processing industries, the crisps industry makes the highest demands on the content of reducing sugars; the reducing sugar content may not exceed 0.2 - 0.3% of the fresh weight. For the French fries industry the standard is less than 0.5% of the fresh weight. For flakes and granules used in snack production, the reducing sugar content should not exceed 0.3% of the fresh weight (Brunnschweiler, 2004).

2.9. Nutritive value of potato fries

Energy and nutritive value calculated for 100 g of product		
Nutrient	**Measure unit**	**Quantity**
Energy value	Kcal	115
Energy value	kJ	480
Total proteins	g	2,60
Total carbohydrates	g	19,60
Total fat	g	3,40

Data source: www.podravka.com

2.11.4 Method of French fries production

French fried potatoes have long been popular as a convenience food, particularly potatoes that have been frozen, and may be easily reheated. Oil has traditionally been the secret behind making a fantastic fry because it tastes good, and creates a pleasing texture and mouth feel. However from a health standpoint, fried foods, including French fries has a terrible reputation among nutritionists since as much as 20% of French fry calories come from oil (Talburt *et. al.,* 1987*).*

Conventional French fries product is made from specific types of whole raw potatoes such as russet potatoes, processed in several steps starting with steam-peeling and blanching at 160-180° F. for about 15-40 minutes in order to remove natural sugars, to stabilize enzymes and to create a good texture. Blanched, steam-peeled whole potatoes are cut into typical French fries strips, which are inspected electronically for defects. The inspected strips are placed onto shakers in order to remove those pieces, which are too small or misshapen from the main processing line. Blanched strips are coated with a sugar solution for flavor and to give a golden coloring. The sugar coated strips are removed from the sugar solution, drained and placed inside a gas-powered dryer to remove moisture, then coated with a thin batter. The battered French fries strips are put in a fryer for 45-120 seconds at 350-270° F. The fried French fries strips are pre-cooled by placing them inside a freezing-tunnel for 15 minutes to lower the temperature to 0° F., and then placed inside a freezer at -40° F. for 30 minutes, prior to packaging them into bags which are stored into a cold storage .

2.11.5 Some effects of fat content of fries on health of consumers

French fries are conventionally prepared by deep frying the frozen product in oil. Therefore, the conventional French fries at the point of consumption by individual consumers have been fried in oil at rather high temperatures two times, which means that its fat content is between 15% and 20%. It is well known that French fries may contain a large amount of fat (usually saturated) from frying and from some condiments or topping and may be bad for the health of those who consume them regularly. Some researchers have also suggested that the high temperatures used for frying such dishes may have results harmful to health (i.e., acrylamides). In the United States about 1/4 of vegetables consumed are prepared as French fries and are believed to contribute to widespread obesity. For example, frying French fries in beef tallow adds saturated fat to the diet. Replacing tallow with tropical oils simply substitutes one saturated fat for another. Moreover, replacing tallow with partially hydrogenated oil reduces cholesterol but adds trans fat. Therefore, there is a need of a method for preparing healthier frozen French fry-style food products (food editorials.com).

2.12. Basic principles of deep frying food

Deep-frying involves the immersion of food in hot oil or fat to cook it to a crisp golden colour. Meat, fish and poultry are usually coated with crumbs or batter. The popularity of deep-fried food makes it a part of every catering operation. Since the development of good frying compounds and improved deep-fryer design, the responsibility rests with the cook to produce first-class deep-fried food (food editorials.com).

Frying medium heated on top of the range in fritures should be discouraged because it is a safety hazard. An alternative is to use a bench-model fryer with a thermostatically controlled electric immersion element. The best fryers, however, are those which stand on the floor and have well positioned thermostats and controls. They should also have an insulated drain tap and a built-in receiver for the oil. This type of fryer is impossible to tip over, unlikely to overheat, and easy to maintain (food editorials.com).

2.12. Thermostats

Thermostats are delicate calibrated instruments that may incorporate an on-off switch, but their main purpose is to set and maintain a maximum operation temperature. This temperature can be adjusted by the cook, according to the type of food to be fried and the frying medium being used. It must be understood that setting the thermostat at a high temperature will not make the oil heat faster. On the contrary, in a busy kitchen, the cook is likely to forget to reset it to the correct temperature, with the result that the oil overheats and becomes too hot for frying. When the thermostat calls for heat, all available energy is released into the fryer.

The amount of energy available is determined at the time of manufacture of the fryer and cannot be altered later. Therefore it is important to set the thermostat at the correct temperature and wait for the oil to reach the operating temperature you have set.

2.12.3 Steps To Operate A Deep-Fryer

1. Make sure the drain tap is closed.

2. Place a quantity of frying medium (fat or oil) into the fryer and melt it on the coolest setting possible. Some fryers have a melt cycle. If the fryer is set at a high temperature, the fat or oil touching the heated surface will burn and break down before the rest of the fat is melted.

3. When the oil is melted, add more oil to fill the fryer to operating level as shown by a mark in the fryer. If the oil is already above this line, remove the excess. The pan should be half to two-thirds full.

4. Set the thermostat to operating temperature 170-190C.

5. When the temperature is reached, place the well-drained and dried food frozen food in a frying basket and immerse the basket gently. If the oil foams up, lift the basket for a moment and then immerse it again. Sometimes the food is placed directly in the oil, as in the case of food coated with batter. Lay the food onto the oil, passing your hand away from you so that any spatter will be toward the back of the fryer.

6. Turn the food with a spider, or shake the basket to aid even cooking.

7. When the food is golden brown, lift it, drain it over the fryer, and serve as soon as possible.

8. Do not allow the basket to drip oil on the floor.

9. Using a fat skimmer, at regular intervals skim off food particles left behind (food editorials.com).

CHAPTER THREE

3.0. SOURCE OF MATERIALS AND METHODOLOGY

3.1. Source of materials

Fifteen (15) freshly harvested, clean and whole water yam (*Dioscorea alata*) varieties were selected for the study. These were obtained from the Savanna Agriculture Research Institute (SARI) Nyankpala in the Northern region of Ghana. The samples used were TDa 99/00208, TDa 98/01166, TDa 99/00528, TDa 297, TDa 291, TDa 98/01176, TDa 98/ 001168, TDa 99/00240, TDa 99/000480, TDa 99/00199, TDa 98/01174, TDa 99/00214, TDa 99/00049 and two local varieties Matches'' and Red water yam. Par-fried potato chips (Pom, France) and Maggi Tomato Ketch-up to be used as a control and a condiment for overall acceptability respectively were obtained from Shoprite supermarket, Accra.

3.2. Sample preparation

3.2.1. Preparation of French fried yam chips for acceptability test

Washing

↓

Peeling (4-5mm)

↓

Size reduction [large (5cm long x 1.5cm thick) and small (5cm long x 0.5cm thick)]

↓

Discarding of uneven strips

↓

Washing

↓

Deep Frying/ French frying (180 ºC, 7mins)

↓

Draining (1.5mins)

Figure 3.1: Flow diagram for the preparation of fried yam *chips* from *Dioscorea alata*

3.2.2. Preparation of minimally processed steam blanched French fried yam chips for acceptability test

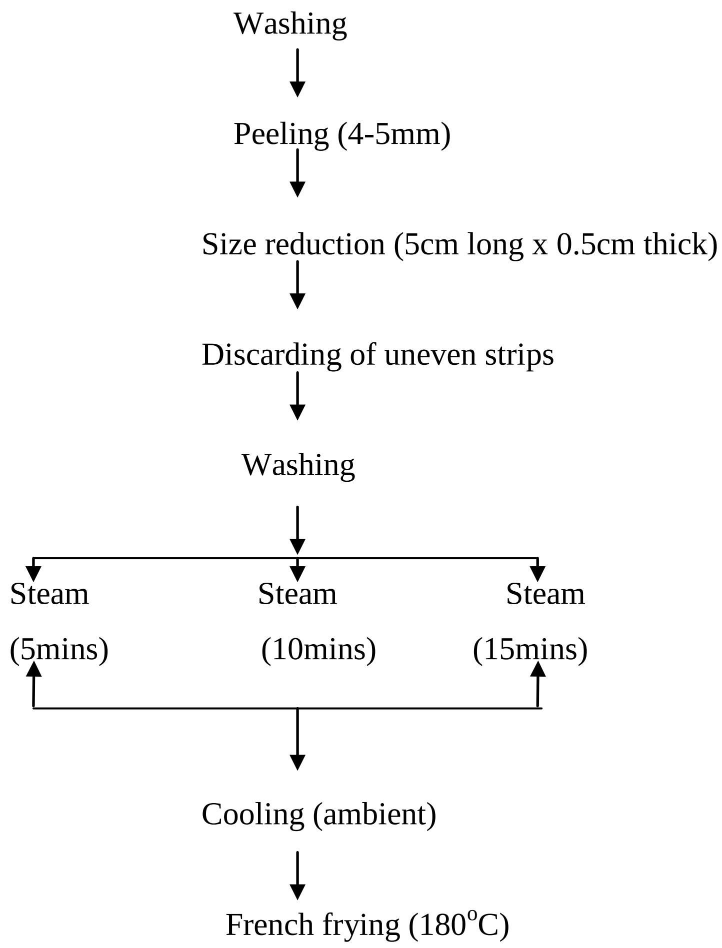

Figure 3.2: Flow diagram for the preparation of minimally processed steam blanched French fried chips from *Dioscorea alata*

3.2.3. Preparation of minimally processed steam blanched French fried yam chips for frozen storage

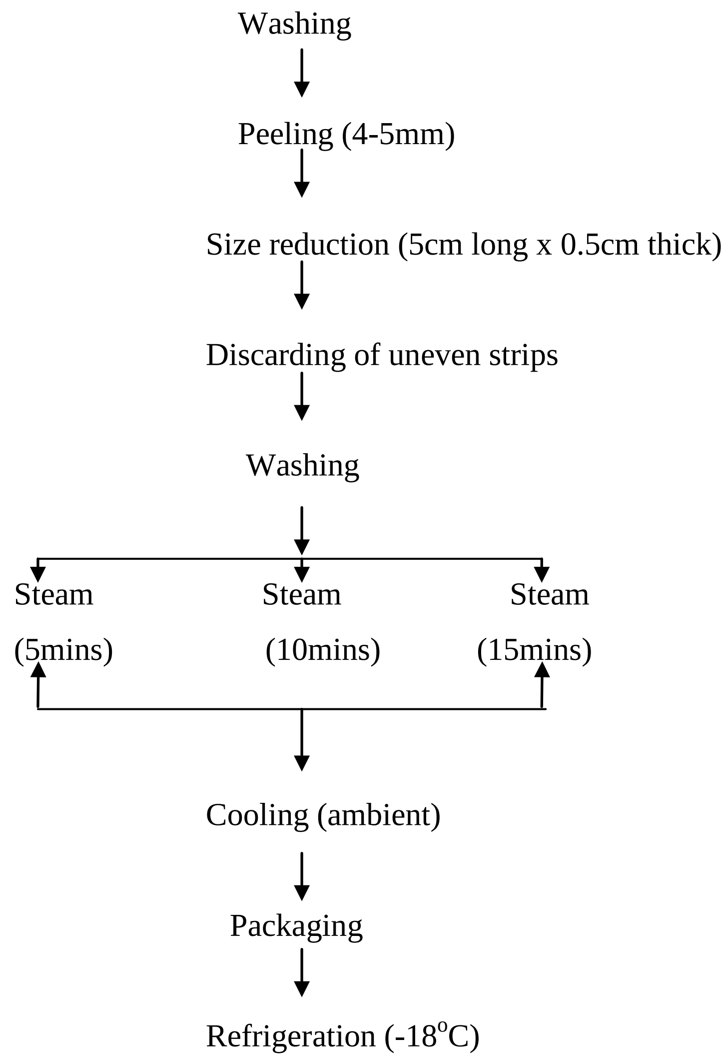

Figure 3.3: Flow diagram for the preparation of minimally processed chips from *Dioscorea alata for frozen storage*

3.2.4. Preparation of frozen chips for sensory evaluation

Three liters (3 litres) of soybean oil (UNOLI) was poured into an electrical deep fryer and heated up to a temperature of 180 ºC. Three hundred grams (300g) of the freshly cut yam chips or minimally processed frozen yam chips were put into the oil and deep fried for seven minutes (7mins). Samples were then removed from the oil and drained for one and half minutes (1.5mins). Samples were immediately served to the trained panelists for evaluation.

3.3. Physico-chemical analysis of *Dioscorea alata tubers*

3.3.1. Determination of moisture and dry matter content of fresh *Dioscorea alata* tubers

Two grams (2 g) of each sample was weighed into a previously dried and weighed glass crucible. The samples were dried in a thermostatically controlled oven at 105 ^{o}C for 24 hours. The glass crucibles containing the dried sample were placed into a desiccator to cool and then weigh. The moisture content was then obtained by difference and expressed as percentage of the initial weight of the sample (Appendix).

3.3.2. Amylose content determination in *D. alata* Starch

The amylose content of the starch samples were determined based on the iodine colorimetric method described by McCready and Hassid (1943).

3.3.2.1. Preparation of Starch Sample for Amylose Determination

The starch (20 mg) was weighed into a 50 ml beaker; 10 ml of 0.5 M potassium hydroxide solution was added and dispersed using a stirring rod until fully dispersed. The dispersed sample was transferred into a 100 ml volumetric flask and diluted to the mark with distilled water with careful rinsing of the beaker (AOAC, 1990). An aliquot of the test starch solution (10 ml) was transferred into a 50 ml volumetric flask and 5 ml of 0.1 M hydrochloric acid and 0.5 ml iodine reagent B was added. The mixture was diluted to 50 ml. The absorbance of the solution was measured after 5 minutes of standing in a Spectrophotometer (Spectronic 21D, Milton Roy UK) at a wavelength of 625 nm. The absorbances of the solution were read against a control solution which contained no starch in a spectrophotometer. The concentration of amylose was determined using equation derived from the standard curve.

Calibration was performed with pure amylose as described above. Amylose (20 mg) was dissolved in water, transferred to 100 ml volumetric flask and 10 ml of 0.5 M KOH was added and diluted to the mark. Aliquots were pipetted in 50 ml volumetric flasks covering the volume range from 0.5 ml to 5 ml. The absorbances of the solutions were read after 5 min of standing in a Spectronic 21D, (Milton Roy UK) at a wavelength of 625 nm (AOAC, 1990). Linear regression analysis was carried out to derive an equation for determination of percentage amylose (Appendix B). The standard curve for amylose is given in (Appendix B).

3.3.2.2. Preparation of iodine solution

3.3.2.2.1. Preparation of solution A

Twenty grams (20 g) Potassium iodide and 2 g resublimed iodine were weighed into 100 ml beaker, dissolved in a minimum amount of water, transferred into a 100 ml volumetric flask and made to the mark. This solution referred to as iodine solution A, was stored in a brown bottle in the dark.

3.3.2.2.2. Preparation of solution B

Ten millilitres (10 ml) of the stock solution (solution A) was pipetted into a volumetric flask and diluted to 100 ml with distilled water to form iodine solution B.

3.3.3. Determination of Specific Gravities of *D.alata* varieties

Five whole tubers of each variety were weighed in air using a weighing balance. The weight in air for each variety was recorded as W_0. Samples were then weighed in water by completely immersing in a container of water to obtain the weight in water (W_1). The specific gravity was calculated as being equal to W_0/ (W_0-W_1) (*Knoxfield*, 2000).

3.4. Consumer acceptability test of *Dioscorea alata tubers*

The sensory evaluation of fried yam samples was conducted using thirty healthy (Self claim) yam consumers from different departments of Kwame Nkrumah University of Science and Technology (KNUST). Panelists were presented with three (3) coded samples and sensory score sheets. They were then asked to indicate the degree of liking of samples using a seven point hedonic scale where the scale one (1) indicates like very much and seven (7) indicates dislike very much (Kramer and Twingg, 1980).

3.4.1. Assessment of the sizes of French fried yam chips

Two water yam varieties were fried using two different sizes [large (5cm long x 1.5cm thick) and small (5cm long x 0.5cm thick)]. The panelists were asked to assess their degree of likeness of the samples based on the sizes of the samples that were presented to them.

3.4.2. Determination of the best variety of *Dioscorea alata* for French fried chips

The 15 varieties of water yam under study were deep fried and were assessed by consumer sensory panelist to select the best variety for fried yam chips. The sensory parameters focused on were colour, appearance (sogginess), crispiness, flavour (smell and taste), mouth feel and overall acceptability.

3.4.3. Determination of the effect of pre-processing (steam blanching) of yam chips on the sensory acceptability of fried chips

Two varieties were selected for minimal processing based on the overall acceptability test. The varieties that were steam blanched at three different blanching times (5, 10, 15mins) were fried and presented to consumer panelists for evaluation. The parameters evaluated were colour, flavour (smell and taste), mouth feel (texture) and overall acceptability of the samples.

3.4.4. Storage Studies of frozen *Dioscorea alata* chips

Storage studies of the minimally processed steam blanched (10mins) frozen yam chips were conducted over a period of twelve weeks using Randomized complete block design in selecting the samples for analysis over the storage period.. The frozen samples were French fried and analyzed through sensory evaluation by trained panelists and Instrumental texture analysis. Microbiological analyses were also carried out on the frozen samples. Samples were kept for twelve weeks with ten replicates. Samples were evaluated every four weeks.

3.5.1. Sensory evaluation by trained panelists

3.5.1.1. Training of Panelist.

Potential Panelists selected from Food Research Institute (FRI) and Ghana Standards Board (GSB) was trained on the French fried products. Sensory parameters of interest (taste, appearance, flavour, colour, texture) were defined, described and discussed based on the product to be analysed. Terminologies for the description of the products sensory characteristics (hard, soggy, flavour strength, taste, and chewy, crunchy, mouth feel, uniformity of appearance, surface dryness, sour taste, and yam taste) were also discussed with the potential panelist. Sensory test on the parameters was conducted using similar local products (fried white yam, fried potatoes, plantain chips). Sensory parameters that Panelists had difficulty in evaluating correctly were reviewed. The same food products were evaluated repeatedly by panelist and discussed until Panelists were comfortable with the sensory or product terminologies. Fifteen individuals who were consistent in evaluating the samples correctly were selected for subsequent sensory evaluation over the storage period (Stone and Sidel, 1993).

3.5.1.2. Sensory Evaluation of French fried chips obtained from frozen samples by Trained Panelist

Minimally processed steam blanched frozen yam samples were deep fried and presented to a fifteen member sensory trained Panelist consisting of staff from Food Research Institute (FRI) and Ghana Standards Board (GSB) every four weeks for twelve weeks. Panelists were presented with three coded samples (i.e. TDa291, TDa98/01176, and Potato) which had been French fried on white disposable plates in fluorescent lighted rooms. They were also presented with sensory score sheets and asked to indicate the intensity of the sensory parameters on an interval scale. At each sitting, the sensory attributes for the three samples were evaluated (Stone and Sidel, 1993).

3.5.2 Instrumental texture analysis of French fried frozen yam chips

The texture profile analysis (TPA) test was carried out on a universal testing machine (Texture expect version 2.61). Samples that underwent this test were in rectangular shapes of 5cm in length and 0.5cm thick. Frozen samples were fried before analyzed. During the analysis two compressions were made on the French fried samples, each at fifty percent (50 %) of the original height of the samples using a crosshead speed of five seconds (5 s). Force-time data were collected using a personal computer. The test was carried out on the steam French fried samples on the first day and on the frozen French fried samples for subsequent evaluations on the fourth week, eighth and twelve weeks (Bourne *et al*., 1966).

3.5.3. Microbiological analysis of frozen chip samples

3.5.3.1. Sample culture preparation

One gram (1 g) of minimally processed yam chips samples were homogenized with 9 ml saline peptone water in stomacher bag for 30 s. A serial dilution of 10^{-1} to 10^{-4} was prepared. All plating was done by the pour plate method.

3.5.3.2. Total Plate count

Using a fresh pipette, 1ml aliquots of each serial dilution was transferred into sterile petri dishes having a label corresponding to the dilution. To each dilution in the sterile petri dish, 15 ml of molten PCA media was added to cover the base of the petri dishes. The petri dishes were swirled clockwise and anticlockwise to ensure uniform mixing and allowed to set. Plates were incubated at 37˚C for 24 hours.

3.5.3.3. Yeast and Mould Count

To 1ml of each dilution in the sterile Petri dishes, 15 ml of molten Oxy – Tetracycline – Glucose Yeast Extract Agar (OGYE) was added to cover the base of the petri dishes. The petri dishes were swirled clockwise and anticlockwise to ensure uniform mixing and allowed to set. All plates were incubated at 25 ˚C for 3 – 5 days.

3.5.3.4. Coliforms

To 1ml of each dilution in the sterile petri dishes, 15 ml of molten Triptone Soya Agar was added to cover the base of the petri dishes. The petri dishes were swirled clockwise and anticlockwise to ensure uniform mixing and allowed to set. This was followed by addition of Violet Red Bile Agar which was also allowed to set after clockwise and anti clockwise swelling. Plates were incubated at 37 ˚C for 24 hours. Colonies between 50 and 150 which look dark purple with a clear zone around them were counted.

3.5.3.4.1. Confirmatory test

Five (5) suspected colonies were picked randomly into a test tubes containing already sterilized Brilliant Green Bile Broth. This was incubated for 37˚C for 24 hours. The tubes that showed gas productions were positive for Coliforms.

3.5.3.5. Escherichia – Coli

About 0.1 ml of broth from tubes that have tested positive for Coliforms are picked into a Violet Red Bile broth (E – coli broth). Covas reagent was added and incubated at 44 ˚C for 24 hours. Tubes that showed red rings were positive for *E, Col.i*

3.6. Data analysis

Analysis of variance (ANOVA), and mean separations were conducted using Stat graphics statistical package (Centurion edition). Significant differences were determined at $p < 0.05$. Microsoft Excel was used in the graphical representations.

CHAPTER FOUR

4.0. RESULTS AND DISCUSSION

4.1. Moisture and dry matter content of fresh *Dioscorea alata* tubers

The range of moisture content of all the fresh tubers used for the study was between 65.87 % and 79.85 % (Figure 4.1). TDa 99/00240 recorded the highest value of 79.85 % whilst TDa 297 recorded the lowest value of 65.87 %. This result is comparable to moisture values of *D. alata* reported by Asiedu *et al.* (1997); Souci *et. al*. (1994) and Opara (1999), which, ranges from 65 % to 78.6 %, and that reported for Irish potatoes which ranges from 50 % to 81 % (FAO, 1987). The moisture content of the yam tubers was related to their dry matter content (r = -0.98). The samples with low moisture content had a corresponding high dry matter content and vice versa. The dry matter content of the samples ranged between 20.15 % and 34.13 % for TDa 297 and TDa 99/00240 respectively (Figure 4.2). This result is comparable to that obtained for potatoes (Iritani *et al*., 1986) and *D. alata* (22.77 % to 32.62 %) after 3 to 5 months of storage (Brunnschweiler, 2004). The differences between the moisture content and the dry matter content of varieties under study were significant ($p < 0.05$) as shown in appendix 5B. These differences could be attributed to cultivar-intrinsic and environmental factors (Golubowska and Lisinska, 2004).

High dry matter with corresponding low moisture content is one of the two most important qualities of potato tubers to be used in the production of good French fries (Golubowska and Lisinska, 2004). High dry matter has been shown to be associated with quality and dense mouth feel of French fries (Martin, 1974; Bourrieau, 2000). It has also been reported to be needed to ensure a distinct, mealy texture and a hearty flavour which absorb less oil and produce crispier fries. For less shrinkage, improved yield and extended plate coverage of French fries, tubers with low moisture content have been very useful (Golubowska and Lisinska, 2004). The minimum dry matter and moisture content of potatoes which have been reported to make a good French fries was 20 % and 80 % respectively (Golubowska and Lisinska, 2004).This implies that based on the moisture and dry matter content alone, all the *D. alata* varieties under study could make French fries of acceptable textural qualities. However, TDa 297, TDa 99/00199 and TDa 98/01166 which where the three varieties with the lowest moisture content and the highest dry matter (Fig. 4.1 and 4.2) could make the best quality French fries, with fine structure, dense feel in the mouth, less shrinkage during frying, improved yield and extended plate coverage out of all the varieties assessed. Even though the dry matter content of yam tubers is important in making fried yam of good texture, the white flesh colour of the tubers, which are not susceptible to oxidation when exposed to air is also equally vital obtain an appealing appearance (Lebot *et al*., 2005).

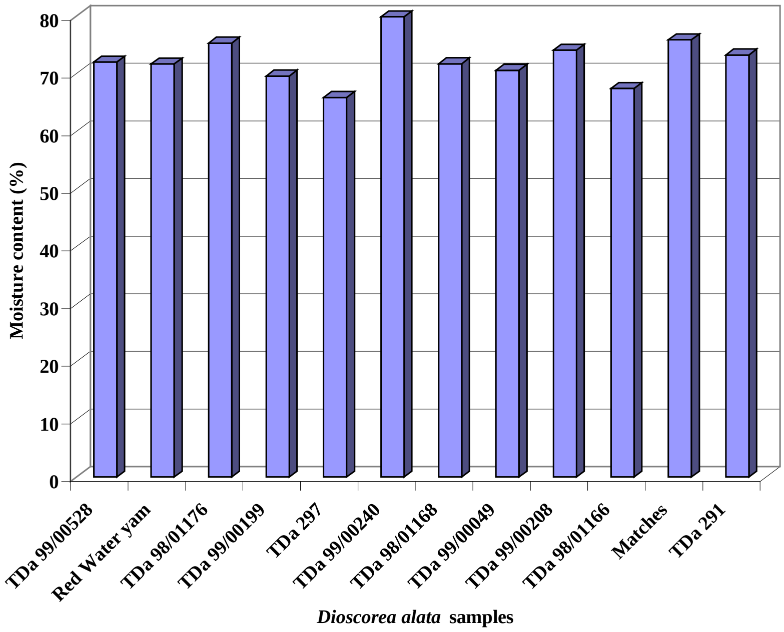

Figure 4.1: Moisture content of fresh *Dioscorea alata* tubers

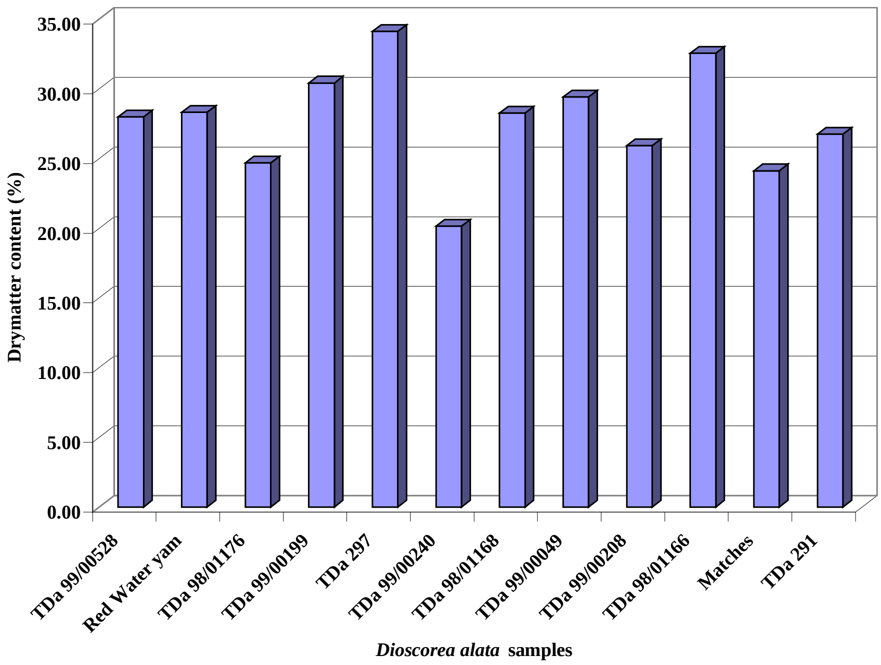

Figure 4.2: Dry matter content of fresh *Dioscorea alata* tubers

4.2. Amylose content of Dioscorea alata varieties

The variability of the amylose content of the starches was significant ($p < 0.05$). The amylose content of the starch analyzed ranged from 25.00 g/Kg to 39.36 g/Kg (Appendix 5F). These values compared to values reported by other researchers for yams which includes; 290 g/Kg (McPherson and Jane, 1999), 270 g/Kg (Hoover and Vasanthan, 1994), 285 g/Kg (Gunaratne and Hoover, 2001), and 300 g/Kg (Mali et al., 2002 and Alves et al., 1999). However Riley et al. (2006) recorded values of between 20 g/Kg – 23 g/Kg for some *Dioscorea alata* samples assessed. These latter results seem to be closer to what was recorded in this study. These differences might be explained by the different growing conditions, lipid content and amylose determination technique (Mali et al., 2002). . The genetic make up of the samples could also have contributed to the low values obtained. Meanwhile Crogham, (1998) has reported an amylose content of 20-30g/kg for potato varieties which are comparable to results obtained in this study.

Low amylose contents (20-27) enhances swelling and paste stability of starch granules during processing due to the corresponding high amylopectin content. (Tester and Morrison, 1990). In the production of French fries, the low amylose content of tubers aids in more expansion, retainment of lightness, crispiness and crunchiness of fried product and reduction of oil pick up (sogginess) (Wurzburg,1986). This was further explained by MaCdougall, (1999) that amylose has excellent film forming properties which is advantageous in the reduction of oil absorption in fried snacks. The result obtained gives an indication that, most of the varieties can be used in the production of French fries.

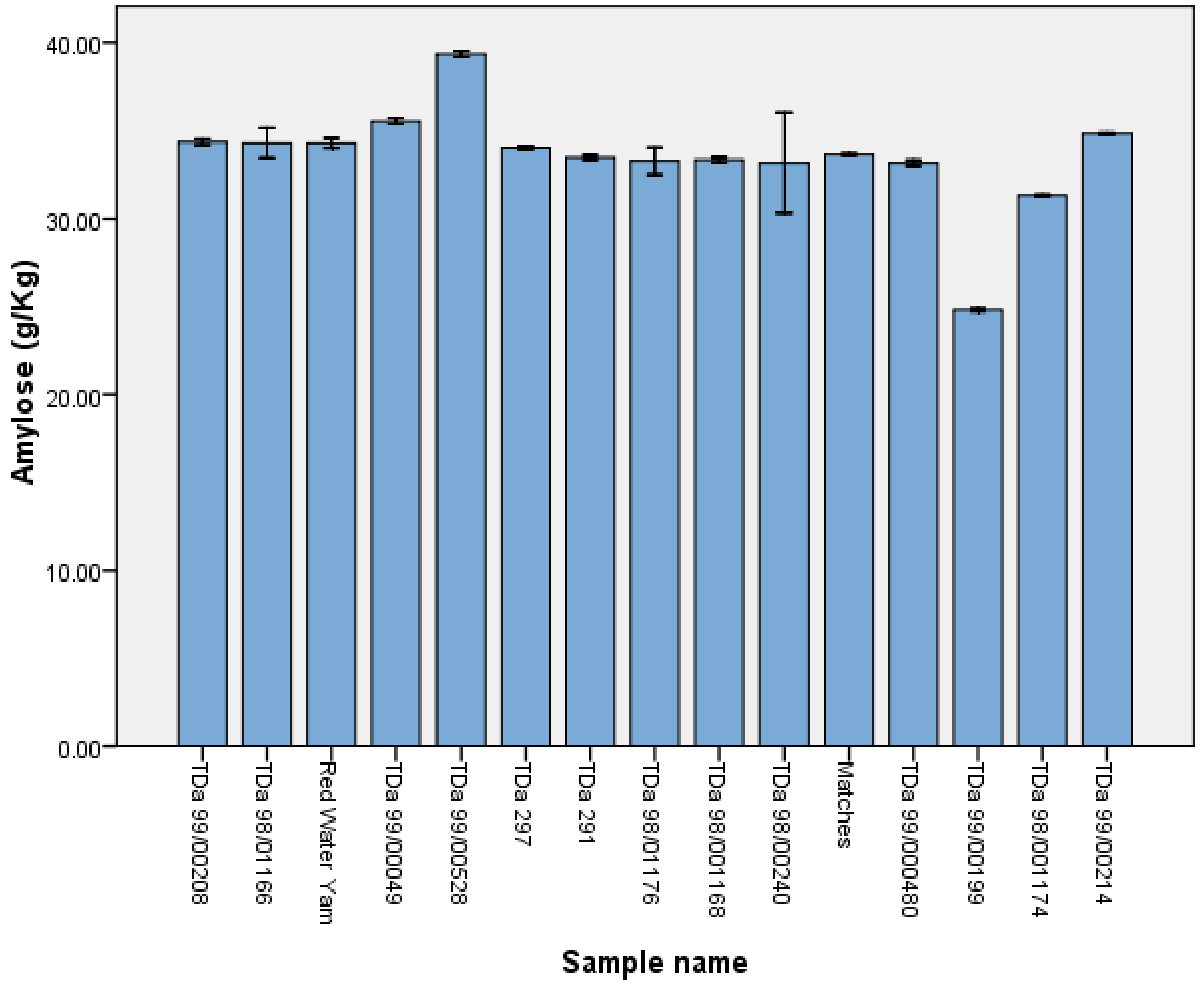

Figure 4.3: Comparison of the Amylose content of the different starches obtained from *Dioscorea alata* varieties

4.3. Comparison of Specific Gravities of *Dioscorea alata* varieties

Results indicate that, specific gravity of the samples ranged between 1.046 and 1.099 (Figure 4.3). The highest value was recorded for TDa 297 whilst TDa 99/00240 recorded the lowest value. The differences observed between the specific gravity values for all the samples, were significant ($p < 0.05$). The differences could be ascribed to cultivar intrinsic factors (Golubowska and Lisinska, 2004).

There was a positive correlation between the specific gravity and dry matter content of the yam samples ($r = 0.98$). Specific gravity values were high for varieties that had high dry matter content. This result is comparable to that reported for raw potatoes and yam by Iritani *et al*. (1986); Onayemi et al. (1987); Gould (1988) and Salamoni *et al.* (2000). According to Iritani and Weller (1974), Schippers (1976) and Salamoni *et al*. (2000), specific gravity of tuber crops is negatively correlated with the reducing sugar content of tubers and positively correlated with dry matter and starch content of tubers. In a study to analyse the effect of surface freezing and specific gravity of raw potatoes on the quality of French fried potatoes, Iritani *et al*. (1986) reported a specific gravity range of 1.070 to 1.10 for raw potatoes. Specific gravity ranges between 1.042 and 1.119 have also been reported for some yam varieties (Onayemi *et al*., 1987).

According to Lulai and Orr, 1979, potato varieties which are expected to give the best results in terms of yield, oil absorption and colour of finished product during the frying processes in French fry production, will be those with high specific gravity values. Iritani and Weller (1974), reported that potatoes with high specific gravity accumulates less reducing sugar during storage thereby producing golden coloured French fries. High consumer preference for golden coloured French fries have also been reported (Lisinska & Leszczynski, 1989). The intensity of the golden colour of French fried products could be attributed to the quantity of reducing sugars present (Gould, 1988).

TDa 297, TDa 99/00199 and TDa 98/01166 which were the variety with the highest specific gravity will produce good quality French fries in terms of colour, yield and oil absorption.

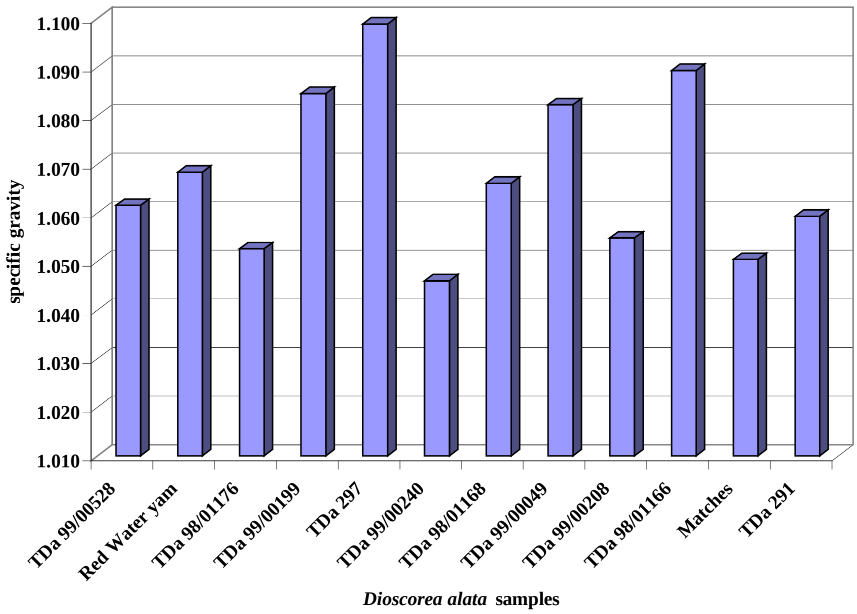

Figure 4.5: Comparison of Specific Gravities of *Dioscorea alata* varieties

4.4. Consumer assessment of fried yam chips through sensory evaluation

4.4.1. Consumer size preference of French fried yam chips

There was significant difference in the consumer acceptability of the two different sizes of the chips ($p < 0.05$) (Table 4.1). From the Kruska-Wallis analysis of the results, the small size chips (5cm long x 0.5cm thick) were the preferred choice of the Panelists. The lower the mean rank, the better the preference since the hedonic scale used started from 1 (like very much) to 7 (dislike very much). It could be said that the consumers found the small size chips to be more attractive than the large sizes. Small size chips were therefore selected to be the sizes of chips to be used for further analysis.

Table 4.1: Mean ranking of consumer size preference for fried yam chips

Sample	Mean Rank	Ranks
Small size	30.90	1
Large size	90.10	2

P value: 0.0000

4.4.2. Consumer acceptability of French fried yam chips

Sensory evaluation of the fried chips from the different variety of *Dioscorea alata* samples was conducted to determine the best variety for fried chips. Untrained in-house consumer panels (30) were selected to represent the general public. This method was used to provide initial information on the acceptability of the products. The sensory parameters assessed were colour, flavour, texture (mouth feel and crispiness), and sogginess.

4.4.2.1. Colour acceptability

Sensory evaluation results showed significant differences ($p < 0.05$) in the consumer preference for the colour of the fried yam chips. Samples which were most preferred for colour were TDa 98/01176, TDa 98/001168, TDa 291, and ‘‘Matches’’, in a decreasing order of preference as shown in the Table 4.2. Varietal differences could have accounted for the differences in colour of the fried samples. The samples that were most preferred for colour produced a golden colour after frying. This confirms the observation made by Lisinska and Leszczynski, (1989) that, consumers like French fries which are golden coloured. The other samples which were not too acceptable to the Panelists were also golden coloured but with higher intensity with the presences of some dark patches. Darkening of the fried samples obtained from these tubers could be due to enzymatic browning leading to the increase in levels of polyphenolic substances and anthocyanins (Gomez and Valdiviesom,1983) and non-enzymatic browning as a result of reactions between reducing sugars, amino acids lysine and proteins (Gould,1988). From the results obtained, it implies that in the selection of varieties for the production of French fries with the acceptable colour, samples TDa 291, ‘‘Matches’’, TDa 98/001168 and TDa 98/ 01176 in order of preference could be used.

Table 4.2: Mean Ranking of *Dioscorea alata* varieties in order of colour preference of fried chips

Method: 95.0 percent LSD	
Sample	**Mean**
TDa 98/ 01176	1.66^{a}
TDa 98/001168	1.97^{ab}
TDa 291	2.33^{b}
Matches	2.37^{b}
TDa 98/01166	3.7^{c}
Red Water yam	3.97^{cd}
TDa 99/0004	4.1^{cd}
TDa 99/00528	4.1^{cd}
TDa 98/01174	4.27^{cd}
TDa 99/00214	4.42^{de}
TDa 99/00240	4.47^{de}
TDa 297	4.93^{ef}
TDa 99/00049	5.43^{fg}
TDa 99/00199	5.43^{fg}
TDa 99/00208	5.83^{g}

Values not statistically different at ($p > 0.05$) shares the same letters.

4.4.2.2. Flavour acceptability

The assessment of flavour was done by the combination of taste and smell. The differences in the flavour acceptability of the fried yam chips were significant ($p < 0.05$). The variations in the flavour of the samples may be due to varietal differences and differences in sugar levels and other desirable flavour of the samples. According to Hamann *et al.* (1980) the increase in desirable flavour is due to both an increase in sugars and other desirable flavour components over time. Even though frying contributes to the texture and flavour of foods, the difference in flavour could not have been attributed to the oil used. This is because fresh soybean oil was used in frying each batch of sample at a temperature of 180ºC. This was to prevent variations due to frying oil and frying temperatures used. Table 4.3 shows the flavour preference of the French fried yams in a decreasing order. The flavour of TDa 98/ 01176, TDa 291, and ‘‘Matches’’ cultivars were the most preferred choices of the Panelists. There was no significant difference in the flavour acceptability of these samples as shown in table 4.3. Therefore these varieties could give the best flavour if used in the production of French fries.

Table 4.3 Mean Ranking of *Dioscorea alata* varieties in order of *Flavour* chips *preference* for Fried Yam sample

Method: 95.0 percent LSD	
Sample	**Mean**
TDa 98/ 01176	1.97[a]
TDa 98/001168	2.0[a]
TDa 291	2.2a
Matches	2.47[ab]
TDa 98/01166	3.03[bc]
Red Water yam	3.16[c]
TDa 99/0004	3.2[c]
TDa 99/00528	3.23[c]
TDa 98/01174	3.37[cd]
TDa 99/00214	4.0d[e]
TDa 99/00240	4.13[e]
TDa 297	4.53[e]
TDa 99/00049	4.6[e]
TDa 99/00199	4.63[e]
TDa 99/00208	5.7[f]

Values not statistically different at ($p > 0.05$) shares the same letters.

4.4.2.3. Texture acceptability

The texture of the fried yam samples after frying, were evaluated with respect to mouth feel, crispiness and sogginess. The mouth feel of a food sample shows how smooth the food feels in the mouth. The results showed significant differences ($p < 0.05$) in the mouth feel of the fried samples. The differences in the mouth feel could be attributed to the differences in dry matter content. High dry matter has been shown to be associated with fine structure, dense feel in the mouth and quality (Martin, 1974; Bourrieau, 2000). The sample TDa 98/001168, TDa 98/ 01176, TDa 291, and ‘‘Matches’’ were the first five preferred for mouth feel to the other samples (Table 4.4). However these samples recorded lowest dry matter contents compared to the other varieties under study. This imply that even though high dry matter is necessary for good mouth feel of fried yam chips, samples with too high dry matter content could result in undesirable mouth feel when fried.

Table 4.4: Mean ranking of *Dioscorea alata* varieties in order of mouth feels preference for fried chips

Method: 95.0 percent LSD	
Sample	**Mean**
TDa 98/ 01176	1.67^{a}
TDa 98/001168	1.72^{a}
TDa 291	1.77^{a}
Matches	2.5^{b}
TDa 98/01166	$3.0b^{c}$
Red Water yam	3.16^{c}
TDa 99/0004	3.23^{c}
TDa 99/00528	3.3^{c}
TDa 98/01174	3.6^{cd}
TDa 99/00214	4.2^{de}
TDa 99/00240	4.37^{ef}
TDa 297	4.93^{fg}
TDa 99/00049	5.23^{gh}
TDa 99/00199	5.5^{gh}
TDa 99/00208	5.8^{i}

Values not statistically different at ($p > 0.05$) shares the same letters.

The crispiness of TDa 98/01176 was the most preferred whilst TDa 99/00208 was the least preferred (Table 4.5). There were significant differences ($p < 0.05$) between the crispiness of the fried chips from the different yam varieties. The ranking of the samples in order of preference for crispiness confirms that consumers like French fries with crispy texture (Lisinska & Leszczynski, 1989).

Table 4.5: Mean ranking of *Dioscorea alata* varieties in order of Crispiness Preference

Method: 95.0 percent LSD	
Sample	**Mean**
TDa 98/ 01176	4.46^{a}
TDa 98/001168	4.6^{ab}
TDa 291	4.81^{abc}
Matches	4.83^{abc}
TDa 98/01166	4.83^{abc}
Red Water yam	5.0^{abcd}
TDa 99/0004	5.03^{abcd}
TDa 99/00528	5.27^{abcde}
TDa 98/01174	5.43^{abcde}
TDa 99/00214	5.5^{bcde}
TDa 99/00240	5.8^{cde}
TDa 297	5.97^{de}
TDa 99/00049	6.17^{ef}
TDa 99/00199	6.2^{ef}
TDa 99/00208	7.17^{f}

Values not statistically different at ($p > 0.05$) shares the same letters.

The differences between the sogginess of the fried yam samples was significant ($p < 0.05$) and it was negatively correlated with dry matter content ($r = -0.82$). Although all the samples were soggy to some extent, the most preferred was sample TDa 98/01176 and the least preferred was TDa 99/00208 as shown in table 4.6 below. TDa 98/01176 sample which was the most preferred by the panelist was the least soggy. This confirms that consumers like French fries which are not oily or soggy (Lisinska & Leszczynski, 1989).

Table 4.6: Mean Ranking of *Dioscorea alata* varieties in order of Sogginess preference

Method: 95.0 percent LSD	
Sample	**Mean**
TDa 98/ 01176	3.77[a]
TDa 98/001168	4.43[ab]
TDa 291	4.90[bc]
Matches	5.10[bcd]
TDa 98/01166	5.13[bcd]
Red Water yam	5.17[bcd]
TDa 99/0004	5.59[de]
TDa 99/00528	5.87[def]
TDa 98/01174	6.2[fgh]
TDa 99/00214	6.33[fgh]
TDa 99/00240	6.67[ghi]
TDa 297	6.71[i]
TDa 99/00049	7.17[i]
TDa 99/00199	7.30[ij]
TDa 99/00208	8.00[j]

Values not statistically different at ($p > 0.05$) shares the same letters.

4.4.2.4. Overall acceptability

There was a positive correlation between the overall acceptability of the fried chips with colour ($r = 0.72$), flavour ($r = 0.72$) and mouth feel ($r = 0.90$). This implies that the colour, flavour and mouth feel of the fried chips from water yam varieties, are the most important sensory attributes that influence the consumer's overall acceptability of the product. From the results, TDa 98/01176, TDa 98/001168, TDa 291 and ‘‘Matches’’ will make the best French compared to the other samples under this study (Table 4.7).

Based on the overall acceptability and the availability of samples, samples TDa 291, ‘‘Matches’’ and TDa 98/001176 were selected for subsequent analysis of the effect of steam blanching time on the acceptability of French fried samples and shelf life studies by trained panelist.

Table 4.7: Ranking of *Dioscorea alata* varieties in order of Overall acceptability

Table 9: Overall Acceptability for Fried Yam samples

Method: 95.0 percent LSD	
Sample	**Mean**
TDa 98/ 01176	1.77^{a}
TDa 98/001168	1.8^{ab}
TDa 291	1.97^{b}
Matches	2.43^{b}
TDa 98/01166	3.5^{c}
Red Water yam	3.53^{c}
TDa 99/0004	3.59^{c}
TDa 99/00528	3.67^{c}
TDa 98/01174	3.77^{c}
TDa 99/00214	3.77^{c}
TDa 99/00240	4.5^{d}
TDa 297	4.77^{d}
TDa 99/00049	5.5^{e}
TDa 99/00199	5.83^{ef}
TDa 99/00208	6.23^{f}

Values not statistically different at ($p > 0.05$) shares the same letters.

4.5. Steam blanching of minimally processed yam chips

Based on the overall acceptability results obtained from the consumer acceptability test, two out of the best four samples were selected at random for further analysis on the effect of three different steam blanching times (5, 10, and 15mins) on the sensory attributes of fried chips.

4.5.1. Effect of steam blanching times on the sensory attributes of minimally processed yam chips

From the results, the three blanching times (5min, 10min and 15min) did not have any significant effect ($p < 0.05$) on the sensory attributes (colour, flavour, texture, mouth feel and overall acceptability) of the fried chips as shown in Tables 4.8 4.9 4.10 and 4.11 According to Mate *et al.*, (1998), blanching for more than two minutes does not bring about any significant changes in the finished product during French fry production compared to those observed after blanching for two minutes.

Table 4.8: Consumer preference for colour of blanched fried chips

	Blanching time		
Sample	**5min**	**10min**	**15min**
‘‘Matches’’	1.53a	1.52a	1.50a
TDa 291	1.33b	1.32b	1.30b

Values not statistically different at ($p > 0.05$) shares the same letters

Table 4.9: Consumer preference for flavor of blanched fried chips

	Blanching time		
Sample	**5min**	**10min**	**15min**
‘‘Matches’’	2.56a	2.50a	2.50a
TDa 291	1.76b	1.80b	1.74b

Values not statistically different at ($p > 0.05$) shares the same letters.

Table 4.10: Consumer preferences for mouth feel of blanched fried chips

	Blanching time		
Sample	**5min**	**10min**	**15min**
‘‘Matches’’	2.65a	2.60a	2.59a
TDa 291	1.93b	1.93b	1.90b

Values not statistically different at (p > 0.05) shares the same letters.

Table 4.11: Consumer preference for overall acceptability of blanched fried chips

	Blanching time		
Sample	**5min**	**10min**	**15min**
‘‘Matches’’	2.43a	2.45a	2.45a
TDa 291	1.90b	1.92b	1.90b

Values not statistically different at (p > 0.05) shares the same letters.

4.5.2. Storage studies of minimally processed yam chips

The storage studies conducted included sensory evaluation by trained panelists, instrumental texture analysis and microbiological evaluation for twelve weeks.

4.5.2.1. Sensory evaluation by trained panellist

The sensory parameters analysed were basically the flavour (presence of yam flavour and flavour acceptability), appearance (golden brown, presence of black specks and uniformity), taste (sour taste and acceptability), texture (surface dryness and sogginess, hardness, crunchiness, chewiness and mouth feel) and the overall acceptability of French fried minimally processed yam samples.

4.5.2.2 Comparison of sensory attributes of Dioscorea alata samples to Potato before freeze storage

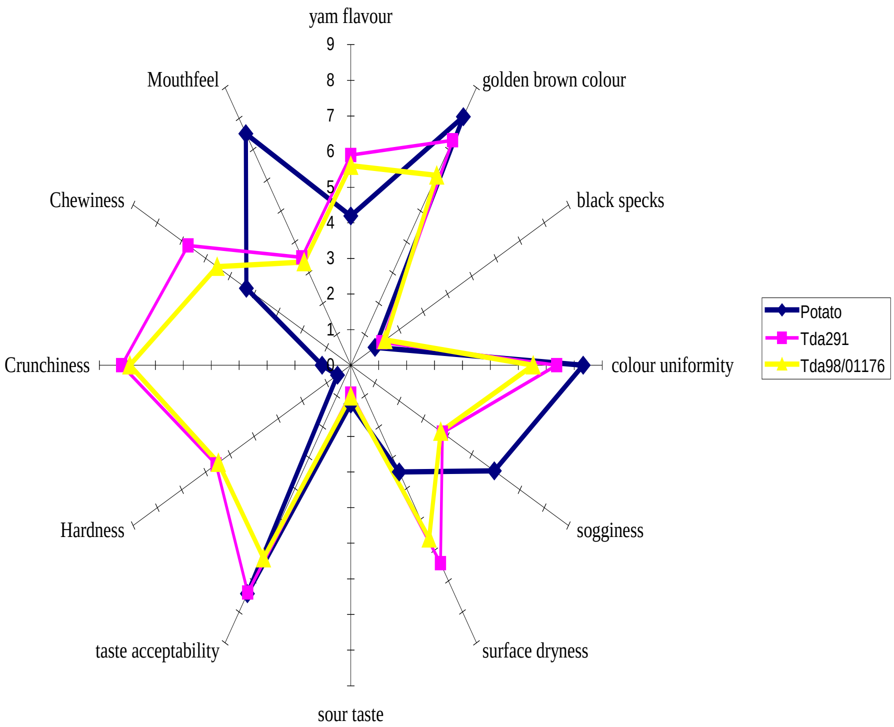

Figure 4.6: Comparison of sensory attributes of steam blanched French fried chips to potato fries before freeze storage.

4.5.2.2.1 Week 0- Comparison of sensory attributes of steam blanched French fried chips to potato fries before freeze storage.

Sensory attributes of steam blanched French fried samples were evaluated before samples were stored in the freezer.

4.5.2.2.2 Appearance

Before the freeze storage, French fries obtained from both TDa291 and TDa98/01176 had appearance that was similar to that of potatoes. The intensity of golden brown colour, black specks and colour uniformity which make up the appearance of final product in this study, was similar to that of potato. Though there were no significant difference between the fries obtained from samples and potato fries, the results indicated that fries obtained from TDa291 was closer to that of TDa98/01176 in terms of appearance as shown in figure 4.5 above. From the results, it was observed that fries obtained from potatoes had the best golden brown colour, least black specks and the highest uniformity followed by TDa 291 which had good golden brown colour, less black specks and good colour uniformity with TDa 98/01176 with the most black specks, least colour uniformity and golden brown colour.

The variability of the presence of black specks between the two yam samples after steam blanching for ten minutes (10mins.) could not be attributed to enzymatic browning but to non-enzymatic browning (Millard reaction) during frying as a result of reactions between reducing sugars (glucose and fructose), amino acid (lysine) and proteins or after cooking darkening due an oxidation reaction between iron and O-hydrine phenols to produce coloured compounds (Gould, 1986). According to Gould, 1986, Although the activities of the enzymes, polyphenoloxidase (Almenteros & Del Rosatio. 1985; Ozo *et. al*, 1984) and peroxidase (Asemota, *et. al.*,1992) leads to the production of polyphenols and derived products (Osagie & Opoku,1984) and anthocyanins bring about discolouration (Ravindran & Wanasundera, 1992 and Akossie *et al*., 2003), steam blanching for ten minutes (10min.) can effectively inactivates or denature the enzymes thereby controlling the enzymatic reaction leading to discolouration (Jeremiah, 1996).

4.5.2.2.3 Flavour

Flavour of French fried samples in this study was evaluated using yam flavour. From the sensory evaluation analysis conducted, it was observed that panelist rated the *Dioscorea alata* samples higher than the potato fries for the presence of yam flavour. From figure 4.5 above, it could be observed that the intensity of yam flavour in sample TDa291 was higher than that of TDa98/01176 though not significant. As indicated in appendix 7, sample TDa291 scored 5.9 whereas sample TDa98/01176 scored 5.6. It was also observed that Potato fries had some yam flavour with a score of 4.19 as shown in appendix 7. The presence of yam flavor in the final products could be attributed to the presence of flavour compounds responsible for yam flavour. From the results it could deduced that potatoes contain some flavour compounds similar to that found in the D. alata samples. The difference in the intensity of the yam flavour between the D. alata samples could be attributed to varietal differences. On a scale of 1 to 10, sample TDa 291was rated the highest in terms of the degree of the intensity of yam flavour followed by TDa 98/01176 with potato fries being the least before samples were frozen.

4.5.2.2.4 Taste

The taste of French fried samples was evaluated using the degree of sourness and its acceptability. Results indicated that, the variation between the intensity of sourness was lower in the potato fries than that obtained from the D. alata samples. Potato fries scored 1.09 for the sourness whilst TDa291 and TDa98/01176 scored 0.80 and 0.87 respectively as indicated in appendix 7. The variations were not significant as could be deduced from figure 4.5 above. It could be observed that the sour taste for both yam varieties were similar to that of potatos. The sour taste could be attributed to

The taste acceptability of TDa 291 was similar to that of potatoes as shown in figure 4.5. The taste acceptability for TDa291 fries was higher than that of TDa98/01176. TDa 291 scored 7.37 whereas TDa98/01176 scored 6.25 as shown in appendix 7. Figure 4.5 above illustrates the intensity of the acceptability of the taste. The sour taste did not have any significant effect on the acceptability of the final product

4.5.2.2.5 Texture

Texture of each of the samples was evaluated for both the yam samples and the potato. Evaluation was based on the intensity of surface dryness, sogginess, hardness, crunchiness, chewiness and mouthfeel of the French fried samples.

The surface dryness of the two *Dioscorea alata* samples were rated higher than that of the potato fries. From Figure 4.11, TDa 291 scored the highest for surface dryness, followed by TDa 98/01176 and potato fries.

Sample TDa 291 had the highest degree of hardness, crunchiness and chewiness followed by sample TDa 98/01176. The potato fries was the softest, the least crunchy and chewy (Figures 4.13, 4.14 and 4.15). Potato fries was said to have the smoothest mouth feel followed by TDa 291 and TDa 98/01176. the variability in the texture of the samples could be attributed to the dry matter and amylase contents of the samples. High dry matter has been shown to be associated with fine structure, dense feel in the mouth and quality (Martin, 1974; Bourrieau, 2000). According to Tester and Morrison, 1990 amylose to amylopectin ratio inhibits starch granule swelling leading to the hardening of tubers after cooking (Tester and Morrison, 1990).

4.5.2.3 Week 4 to Week 12- comparison of sensory attributes of French fried over the storage period

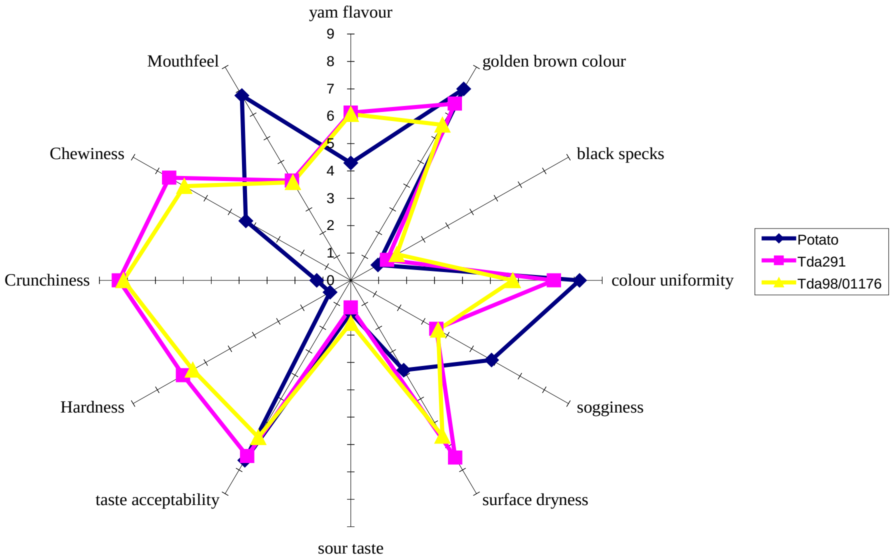

Figure 4.7: comparison of sensory attributes of French fried chips four weeks after freeze storage period

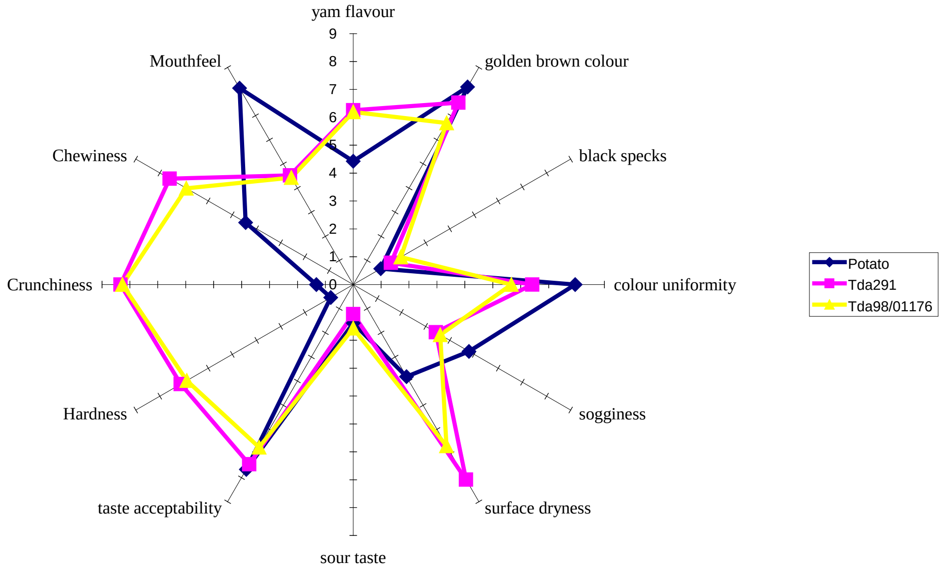

Figure 4.8: comparison of sensory attributes of French fried chips eight weeks after freeze storage period

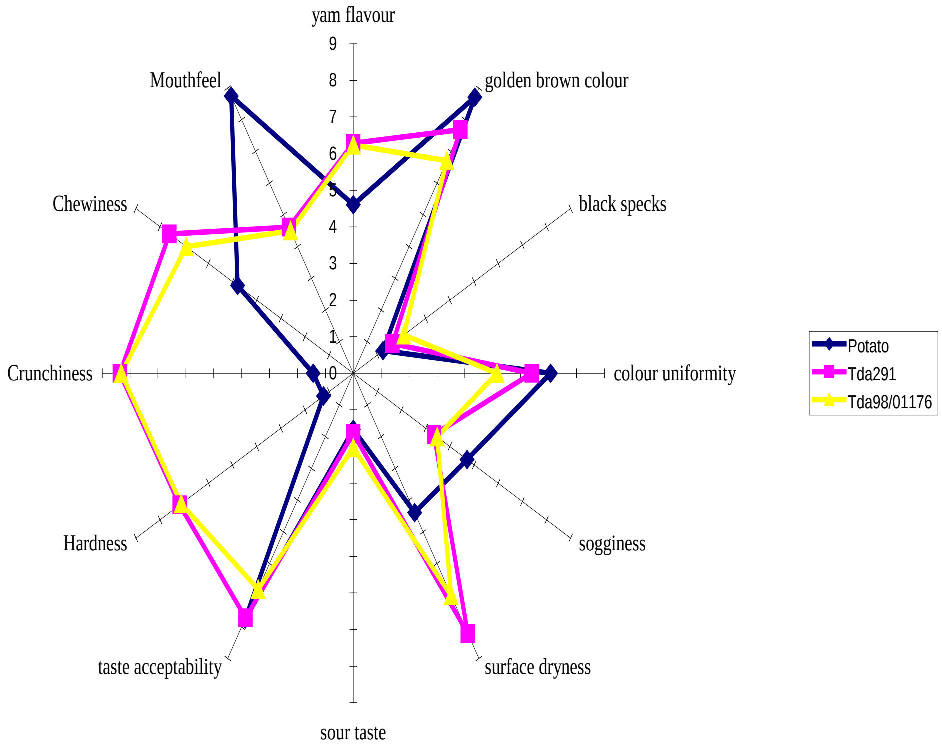

Figure 4.9: comparison of sensory attributes of French fried chips twelve weeks after freeze storage period

4.5.2.3.1 Appearance

Over the frozen storage of twelve weeks, it was observed that there were no significant changes in the appearance of the two *Dioscorea alata* samples as shown in figures 4.6, 4.7 and 4.8. Slight changes occurred in the appearance of the yam samples and the potatoes as shown in appendix 7. The changes in the golden brown colour and the uniformity of the colour could be attributed to the increase the number of black specs over the storage period as a result of non-enzymatic browning during storage. According to Asemota *et. al.,* reactions between reducing sugars (glucose and fructose), amino acid lysine and proteins leads to the release of polyphenols and derived products leading discolouration.

4.5.2.3.2 Flavour

Over the storage period it was also observed that the strength of the yam flavour for each of the samples showed slight increment over the storage period. From the fourth to the twelve week after storage, it was observed that there were slight increments in the intensity of the flavour for both yam samples (appendix 7). Over the storage period the flavour for both TDa 98/01176 and TDa 291 were rated to be similar but higher than that of potato fries. Results indicated that the increments in the flavour acceptability of the samples over the storage period were not statistically significant ($p < 0.05$).

4.5.2.3.3 Taste

Over the period of storage there were no significant changes in the taste acceptability and the sour taste of the yam samples used. Although there was a slight increase in the sour taste of the samples as indicated in figures 4.6, 4.7, and 4.8, it was not significant so it did not affect the acceptability of the final products.

4.5.2.3.4 Texture

Generally, there was increase in the surface dryness of fried samples over the storage period. The increase in the surface dryness of the chips over storage period, corresponded with a decrease in the sogginess of the samples ($r = -0.91$; $p < 0.01$). The increment in the yam samples after storage for the first month was higher than that observed for both the second and third months. The increment in the surface dryness over the storage period could be attributed to loss of water leading to an increase in dry matter content. This implies that storage condition and frying influenced the surface dryness of French fried product. The sogginess and dry matter content of the fresh tubers were also negatively correlated ($r = -0.82$). This implies that sogginess and surface dryness of the finished product (French fries) depends on the amount of dry matter present in the raw material used in the production of French fries.

Only slight changes occurred in the hardness, crunchiness, and mouth feel of the fried samples over storage period. The difference in the texture (hardness, crunchiness and chewiness) between fried samples may be due to Varietal differences (high dry matter content) and the thermal processes (frying, steam blanching) the samples were exposed to before obtaining the final products. Thermal processes (blanching and frying) during French fry production, has been said to cause the occurrence of a skeleton consisting of varied proportions of carbohydrate compounds in the tissues (Golubowska and Lisinska, 2003) and the loss of water which is likely to be responsible for the texture of the finished products (Golubowska and Lisinska, 2005). According to Aguilera and Gloria (2000), the development of crunchy or crispy structure begins with pre drying and during first sixty seconds (60 s) of frying. Crispy surface is developed due to the migration of oil to intracellular spaces formed during frying as a result of cell wall shrinkage and water evaporation (Costa Rui *et al.*, 2001). Aguilera and Gloria (2000) reported that starch granules are subject to rapid pasting during frying, so that they fill the entire surface of the cell without causing any damage.

4.5.2.4. Instrumental Texture Analysis

Texture which is a major factor in determining the consumer acceptability of French fries depends on both raw material and processing history (Du Pont *et. al.*, 1992). In this study, the texture in terms of hardness and chewiness of minimally processed and frozen French fried yam chips was measured.

4.5.2.4.1. Hardness and chewiness of French fried samples

Hardness value which is the peak force of the first compression of the product showed some difference between the samples and increased over the storage period (Table 4.12). The hard texture of sample TDa 291 was higher than that of TDa 98/01176 before and during the storage period. The hardness of the samples was between 92.283N and 85.23N for samples TDa 291 and TDa 98/01176 respectively. There was a positive correlation between the instrumental and sensory measurements for hardness (r = 0.82).

Sample TDa 291 recorded a higher value for chewiness (24.048N) than TDa 98/01176 (21.05N) on the first day of preparation. Chewiness has been defined as the force required masticating a solid food to state ready for swallowing. It is the combination of the harness, cohesiveness and springiness of a product (Civille and Szczesniak, 1973). During the storage period the force which is required to masticate the sample over time increased. From the first month to the third month, the force used to break samples increased from 27.513 N to 31.586 N and 23.28 N to 29.01 N for TDa 291 and TDa 98/01176 respectively. It was also observed that the chewiness measured using panelist correlated positively (r = 0.947) with that from the texture profile analysis.

The differences in the texture (hardness and chewiness) between fried samples obtained from the different samples may be due to Varietal differences (high dry matter content), the technological parameters used for processing (frying, steam blanching) the samples and storage condition (low temperature). According to Alverez and Canet, 1999, the technological parameters for blanching significantly affect the texture of plant tissues and consequently the texture of French fries. Golubowska and Lisinska, (2005) observed an increase in the dry matter content after steam blanching and frying during French fry production. According to Asp (1996), the increase is due to the losses of non-fibre substances. Thermal processes (blanching and frying) during French fry production, has been said to cause the occurrence of a skeleton consisting of varied proportions of carbohydrate compounds in the tissues (Golubowska and Lisinska, 2003) and the loss of water which is likely to be responsible for the texture of the finished products (Golubowska and Lisinska, 2005). Although blanching, a heat treatment in vegetables preserves texture in the freezer **(**Hendley, 1994)**,** water is loss or ice crystals evaporate from the surface of a food product making the surface dry and tough. The loss of water from the product contributes to an increase in dry matter content thereby leading to the increase in hardness and chewiness of the final product.

Table 4.12: Comparison of instrumental hardness and chewiness over the storage period

Measurement	**Sample**	**Storage period**			
		Week 0	**Week 4**	**Week 8**	**Week 12**
Hardness (N)	TDa 291	92.283	111.23	125.496	138.214
	TDa 98/01176	85.23	100.85	115.50	128.00
Chewiness (N)	TDa 291	24.048	27.513	28.301	31.586
	TDa 98/01176	21.05	23.28	25.067	29.01

4.5.2.5. Changes in Microbiological quality of frozen samples during storage

From the study it was observed that, there were some microbes on the steam blanched samples before storage at a temperature of -18^{o}C but the total number reduced over the storage period. Those that were observed were bacteria, yeast and mould and coliform as indicated in tables 4.8, 4.9 and 4.10

4.5.2.5.1. Aerobic plate count

This gives an indication of the total bacteria found in food. From the study it was observed that the steam blanched samples of both TDa 98/01176 and TDa 291 contained some amount of bacteria. The Aerobic Plate Count for TDa 98/01176 was observed to be higher than that of TDa 291 before being stored at -8 ºC. The difference between the Aerobic Plate Count of the samples was significant ($P < 0.05$). The Aerobic Plate Count was 9.9 x 10^{3} CFU/g for TDa 98/01176 and that for TDa 291 was 4.2 x 10^3 CFU/g. Over the storage period there was significant decrease in the total number of aerobic plate count for both varieties. Over the storage period of three (3) months, there was a drastic decrease from 9.9 x 10^3 CFU/g to 2.2 x 10^3 CFU/g for TDa 98/01176 and 4.2 x 10^3 CFU/g to 1.7 x 10^3 CFU/g for TDa 291 before and after freeze storage as shown in table 4.13. The decrease could be attributed to the low temperature (-18ºC) storage used (Potter and Hotchkiss, 1995). The presence of bacteria on the samples after steam blanching could be because of the bacteria was thermophilic in nature or there was cross contamination during cooling of the blanched product. According to Adams and Moss (1995), microbial growth can occur over a temperature range of about -8ºC to 100ºC at atmospheric pressure depending on the presence or absence of water. Bacteria spores (thermopiles) are usually far more heat resistant than the vegetative cells and can withstand temperatures above 100ºC (Adams and Moss, 1995). Over the storage period, the gradual decrease observed in the total aerobic plate count could be ascribed to the effect of the storage temperature on the growth of bacteria. According to Porter and Hotchkiss (1995), total bacteria count can be lowered during freezing of food. Freezing leads to a reduction in temperature and the availability of water thereby preventing the growth of microbes (Gould, 1989). However, there will be sufficient populations still present to multiply in numbers and cause spoilage of the product when it thaws (Hendley, 1994).

The results obtained from this study implies that, in the processing and storage of minimally processed French fries at -18^{o}C, although there is a gradual decline in the amount of bacteria, sufficient amounts could be present after storage for twelve weeks.

Table 4.13: Aerobic plate count (bacteria) over the storage period

Sample	Storage period (weeks)/ Aerobic plate count (x 10^3 CFU/g)			
	0	4	8	12
TDa 291	4.2	3.6	3.2	1.7
TDa 01176	9.9	4.1	2.8	2.2

4.5.2.5.2. Yeast and Mould Count

Yeast and mold were found on the samples to be used for the storage studies on. The number of yeast and mold observed on TDa 98/01176 after steam blanching was 4×10^3 CFU/g and that of TDa 291 was 45 CFU/g as indicated in table 4.14. After the first four weeks of storage at a temperature of -18 ºC, there was no mold and yeast growth on the pretreated frozen samples.

The presence of yeast and moulds on the steam blanched samples could be attributed to the blanching temperature and the environment. Although yeast and moulds are normally killed by temperatures at or below 100^{o}C (Adams and Moss, 1995), a few can survive by means of spore formation and other means of heat tolerance (Jay, 1978). This is because ascopores and the asexual spores of moulds are heat resistant than the vegetative cells (Adams and Moss, 1995) and some carbohydrate foods are known to confer some protective effects on some organisms in them. The ability of these microbes to attack foods is largely due to their versatile environmental requirements (i.e. temperature range 10º to 35ºC,the majority require free oxygen for growth, pH requirement is broad, ranging from pH 2 to pH 9, low Moisture requirements (water activity of 0.85 or less)

(Hendley, 1994). The absence of yeast and moulds one month after freezer storage could be ascribed to the low storage temperature (-18^{o}C). This is because pathogens common to foods cannot grow below 3.3 ^{o}C.

Table 4.14: Yeast and Mould Count over the storage period

Sample	Storage period (weeks)			
	0	4	8	12
TDa 291	45 CFU/g	0	0	0
TDa 01176	4 x 10^{3} CFU/g	0	0	0

4.5.2.5.3. Coliform Count

There were some Coliforms on sample TDa 98/01176 but none on TDa 291(table 4.15). Over the entire storage period, it was observed that there was no growth of Coliforms. The presence of Coliforms on TDa 98/01176 may be due to cross contamination during the processing period (Porter and Hotchkiss, 1996) before samples were frozen. The absence of coliforms during storage may be due to the low temperature at which samples were stored. According to Porter and Hotchkiss, (1996), pathogens common to food cannot grow below 3.3 ºC.

Table 4.15: Coliform Count over the storage period of frozen samples

Sample	Storage period (weeks)			
	0	4	8	12
TDa 291	0	0	0	0
TDa 01176	40 CFU/g	0	0	0

CHAPTER 5

5.0 CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

The best varieties of *Dioscorea alata* for the production of French fried chips TDa 98/01176, TDa /001168, TDa 291 , and ‘‘Matches’’ in decreasing order of acceptability. Steam blanching of yam chips for 5 minutes, 10 minutes and 15 minutes did not have any statistically significant effect on the sensory quality of the fried products. Hence any of these steam blanching times could be used in combination with refrigeration to preserve minimally processed chips.

Frozen French fries obtained from Sample TDa 291 were rated to be similar to that of potato fries in terms of its sensory characteristics. At the end of the storage period of twelve weeks, sensory characteristics of samples TDa 98/01176 and TDa 291 were acceptable and safe for consumption in terms of microbial load.

5.2. RECOMMENDATIONS

At the end of the studies, it is recommended that:

- Further studies should be done on the use of *D. alata* for the production of other products (yam balls) from the frozen samples.
- Further studies should be done on the use of *D. alata* for the production of minimally processed frozen chips by blanching samples in oil before freezing.
- There should be promotion of the product in restaurants and eateries to increase the knowledge of it and its use.
- Training should be conducted for all stakeholders and restaurants operators on how *D. alata* could be processed into French fries.

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PLATES

Plate 1: Pictures of various varieties of *Dioscorea alata*

1A: TDa 297

1B: TDa 99/00240

1C: Red Water Yam

1D: TDa 291

1E: TDa 99/00199

1F: TDa 99/00214

G: TDa 99/00049

H: TDa 99/00528

1I: TDa 98/01166

1J: ‘‘Matches’’

1K: TDa 99/00208

1L: TDa 98/01174

Plate 2: FRENCH FRY PRODUCTION IN PICTURES

2A: Washing of samples

2B: Peeling of samples

2C: Samples cut into chips

2D: Steam blanching of samples

2E: cooling of Steam blanched samples

2F: deep frying of samples

2G: Draining of fried samples

2H: Samples ready to be served

2I: front view of Packaged minimally processed yam chips

2J: back view of Packaged minimally processed yam chips

APPENDICES

Appendix 1: Score sheet used by consumer panelists for the portion size evaluation of fried chips from *Dioscorea alata* samples

Name…………………………………… Age…………………………………

Date……………………………………..

Instructions: You have provided with fried chips from different varieties of yam. Please access them based on the quality attributes listed below in order in which the samples have been presented.

Size: please observe the sizes of the samples tick in box that describes how best you like or dislike the sizes of the samples.

	Sample…………	Sample…………	Sample…………..
1.	Like extremely [ ]	Like extremely [ ]	Like extremely [ ]
2.	Like [ ]	Like [ ]	Like [ ]
3.	Like slightly [ ]	Like slightly [ ]	Like slightly [ ]
4.	Neither like nor dislike [ ]	Neither like nor dislike [ ]	Neither like nor dislikes [ ]
5.	Dislike slightly [ ]	Dislike slightly [ ]	Dislike slightly [ ]
6.	Dislike [ ]	Dislike [ ]	Dislike [ ]
7.	Dislike extremely [ ]	Dislike extremely [ ]	Dislike extremely [ ]

Appendix 2: Score sheet used by consumer panelists for the evaluation of fried *Dioscorea alata* samples

Name…………………………………… Age…………………………………

Date……………………………………..

Instructions: You have provided with fried chips from different varieties of yam. Please access them based on the quality attributes listed below in order in which the samples have been presented.

Colour & Appearance: please observe the colour of the samples tick in box that describes how best you like or dislike the colour & appearance of the samples

Sample…………	Sample…………	Sample…………..
1. Like extremely [ ]	Like extremely [ ]	Like extremely [ ]
2. Like [ ]	Like [ ]	Like [ ]
3. Like slightly [ ]	Like slightly [ ]	Like slightly [ ]
4. Neither like nor dislike [ ]	Neither like nor dislike [ ]	Neither like nor dislikes [ ]
5. Dislike slightly [ ]	Dislike slightly [ ]	Dislike slightly [ ]
6. Dislike [ ]	Dislike [ ]	Dislike [ ]
7. Dislike extremely [ ]	Dislike extremely [ ]	Dislike extremely [ ]

Texture (Hardness)

Hardness: Please place sample between molar teeth and bite down evenly, evaluating the force required compressing the sample

	Sample ………	Sample…….	Sample……..
1.	Too hard [ ]	Too hard [ ]	Too hard [ ]
2.	Hard [ ]	Hard [ ]	Hard [ ]
3.	Slightly hard [ ]	Slightly hard [ ]	Slightly hard [ ]
4.	Neither hard Nor soft [ ]	Neither hard Nor soft [ ]	Neither hard Nor soft [ ]
5.	Slightly Soft [ ]	Slightly Soft [ ]	Slightly Soft [ ]
6.	Soft [ ]	Soft [ ]	Soft [ ]
7.	Too Soft [ ]	Too Soft [ ]	Too soft [ ]

Taste

	Sample…………	Sample…………	Sample…………..
1.	Like extremely [ ]	Like extremely [ ]	Like extremely [ ]
2.	Like [ ]	Like [ ]	Like [ ]
3.	Like slightly [ ]	Like slightly [ ]	Like slightly [ ]
4.	Neither like nor dislike [ ]	Neither like nor dislike [ ]	Neither like nor dislikes [ ]
5.	Dislike slightly [ ]	Dislike slightly [ ]	Dislike slightly [ ]
6.	Dislike [ ]	Dislike [ ]	Dislike [ ]
7.	Dislike extremely [ ]	Dislike extremely [ ]	Dislike extremely [ ]

Overall acceptability: Please assess the overall acceptability of the sample with the tomato ketch-up provided.

Sample…………	Sample…………	Sample…………..
1. Like extremely [ ]	Like extremely [ ]	Like extremely [ ]
2. Like [ ]	Like [ ]	Like [ ]
3. Like slightly [ ]	Like slightly [ ]	Like slightly [ ]
4. Neither like nor dislike [ ]	Neither like nor dislike [ ]	Neither like nor dislikes [ ]
5. Dislike slightly [ ]	Dislike slightly [ ]	Dislike slightly [ ]
6. Dislike [ ]	Dislike [ ]	Dislike [ ]
7. Dislike extremely [ ]	Dislike extremely [ ]	Dislike extremely [ ]

Appendix 3: Sensory Score Sheet for trained panelist

Name: _._ Date:--------------

Sample code:_.

Please assess the ***French fries*** samples in front of you. Rinse your mouth with water before tasting each sample.
Please make a firm vertical line on the horizontal line to indicate your rating for the attributes

Yam flavour Presence — Weak |————————| Strong

Flavour acceptability — Weak |————————| Strong

Golden Brown Colour — Not |————————| Very

Appearance (Black Specks) — None |————————| All

Very uniform — Not uniform
Appearance (Uniformity) |————————|

Surface dryness — Not dry |————————| Very dry

Attribute	Low end	High end
Sogginess	Not Soggy	Very Soggy
Taste (sour)	Not sour	Very sour
Taste Acceptability	Not acceptable	Very acceptable
Hard texture	Not hard	Very Hard
Crunchiness	Not crunchy	Very crunchy
Chewiness	Not chewy	Very chewy
Mouth feel	Rough	Smooth

Comments :

Appendix 4: Formulae used in calculations

4A: Percentage Moisture content

$$\% \text{ moisture} = \frac{\text{loss in weight of sample}}{\text{Original weight of sample}} * 100$$

% Dry matter = 100 - % moisture

Appendix 5: ANOVA tables

5A: ANOVA summary table for the Moisture of fresh *Dioscorea alata* tubers

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	318.054	11	28.914	173.328	0.000
Within Groups	2.002	12	0.167		
Total	320.056	23			

5B: Mean Moisture content of Fresh *Dioscorea alata* samples

Sample	**Mean Moisture content (%)**
TDa 297	65.87^{a}
TDa 98/01166	67.43^{b}
TDa 99/00199	69.57^{c}
TDa 99/00049	70.57^{d}
Red water yam	71.67^{e}
TDa 98/01168	71.73^{e}
TDa 99/00528	72.00^{e}
TDa 291	73.25^{f}
TDa 99/00208	74.07^{f}
TDa 98/01176	75.29^{g}
Matches	75.87^{g}
TDa 99/000240	79.85^{h}

Values not statistically different at ($p > 0.05$) shares the same letters

5C: ANOVA summary table the Dry matter content of fresh *Dioscorea alata* tubers

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	377.824	11	34.348	66479.258	0.000
Within Groups	0.006	12	0.001		
Total	377.830	23			

5D: Mean Dry matter content of Fresh *Dioscorea alata* samples

Sample	**Mean Moisture content (%)**
TDa 297	34.13[l]
TDa 98/01166	32.57[k]
TDa 99/00199	30.43[j]
TDa 99/00049	29.43[i]
Red water yam	28.33[h]
TDa 98/01168	28.27[g]
TDa 99/00528	28.00[f]
TDa 291	26.75[e]
TDa 99/00208	25.93[d]
TDa 98/01176	24.71[c]
Matches	21.13[b]
TDa 99/000240	20.15[a]

Values not statistically different at ($p > 0.05$) shares the same letters

5E ANOVA summary table of Amylose content of *Dioscorea alata* starch

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	247.733	14	17.6952	996.91	0.0000
Within groups	0.26625	15	0.01775		
Total	247.999	29			

5F Mean amylose content of *Dioscorea alata* starches

Sample	Amylose content (g/Kg)
TDa 99/00208	34.48^{h}
TDa 98/01166	34.30^{fgh}
Red water yam	34.40^{gh}
TDa 99/00049	35.56^{j}
TDa 99/00528	39.36^{k}
TDa 297	34.04^{f}
TDa 291	33.48d^{e}
TDa 98/01176	33.28^{cd}
TDa 98/001168	33.35^{cd}
TDa 99/00240	34.17^{fg}
'Matches'	33.66^{e}
TDa 99/000480	33.16^{c}
TDa 99/00199	24.81^{a}
TDa 98/01174	31.32^{b}
TDa 99/00214	34.86^{i}

Values not statistically different at ($p > 0.05$) shares the same letters.

5G: ANOVA summary table the Specific gravity of *Dioscorea alata* tubers

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	0.006	11	0.001	230.681	0.000
Within Groups	0.000	12	0.000		
Total	0.006	23			

5H: Mean Specific gravity values of *Dioscorea alata* samples

Sample	Mean Moisture content (%)
TDa 297	1.099^{h}
TDa 98/01166	1.089^{g}
TDa 99/00199	1.085^{f}
TDa 99/00049	1.082^{f}
Red water yam	1.068^{e}
TDa 98/01168	1.066^{e}
TDa 99/00528	1.062^{d}
TDa 291	1.059^{d}
TDa 99/00208	1.055^{c}
TDa 98/01176	1.053^{bc}
Matches	1.050^{b}
TDa 99/000240	1.046^{a}

5I: ANOVA summary table the effect of steam blanching time on the colour of fried chips from Matches.

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	0.000933333	2	0.000466667	0.41	0.6950
Within groups	0.0034	3	0.00113333		
Total (Corr.)	0.00433333	5			

5J: ANOVA summary table the effect of steam blanching time on the flavour of fried chips from Matches.

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	0.00413333	2	0.00206667	0.61	0.6003
Within groups	0.0102	3	0.0034		
Total (Corr.)	0.0143333	5			

5K: ANOVA summary table the effect of steam blanching time on the mouth feel of fried chips from Matches.

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	0.00413333	2	0.00206667	1.03	0.4556
Within groups	0.006	3	0.002		
Total (Corr.)	0.0101333	5			

5L: ANOVA summary table the effect of steam blanching time on the overall acceptability of fried chips from Matches.

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	0.000533333	2	0.000266667	1.33	0.3852
Within groups	0.0006	3	0.0002		
Total (Corr.)	0.00113333	5			

5M: ANOVA summary table the effect of steam blanching time on the colour of fried chips from TDa 291.

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	0.000933333	2	0.000466667	0.58	0.6109
Within groups	0.0024	3	0.0008		
Total (Corr.)	0.00333333	5			

5N: ANOVA summary table the effect of steam blanching time on the flavour of fried chips from TDa 291.

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	0.0012	2	0.0006	0.08	0.9283
Within groups	0.0236	3	0.00786667		
Total (Corr.)	0.0248	5			

5O: ANOVA summary table the effect of steam blanching time on the mouth feel of fried chips from TDa 291.

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	0.0012	2	0.0006	1.50	0.3536
Within groups	0.0012	3	0.0004		
Total (Corr.)	0.0024	5			

5P: ANOVA Table for the effect of steam blanching time on the overall acceptability of fried chips from TDa 291.

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	0.000533333	2	0.000266667	0.44	0.6776
Within groups	0.0018	3	0.0006		
Total (Corr.)	0.00233333	5			

Appendix 7: Scores of the sensory attributes assessed by trained panelists

Presence of yam flavour

Sample	Month 0	Month 1	Month 2	Month 3
Potato fries	4.19	4.29	4.42	4.6
TDa 291	5.9	6.13	6.25	6.28
Tda 98/01176	5.6	6.07	6.19	6.23

Golden brown colour

Sample	Month 0	Month 1	Month 2	Month 3
Potato fries	8.05	8.08	8.18	8.70
TDa 291	7.29	7.45	7.53	7.68
Tda 98/01176	6.15	6.56	6.69	6.70

Black specks

Sample	Month 0	Month 1	Month 2	Month 3
Potato fries	1.00	1.12	1.14	1.23
TDa 291	1.29	1.50	1.56	1.62
Tda 98/01176	1.42	1.90	1.97	2.09

Colour uniformity

Sample	Month 0	Month 1	Month 2	Month 3
Potato fries	8.32	8.19	7.95	7.07
TDa 291	7.37	7.27	6.41	6.39
Tda 98/01176	6.53	5.80	5.66	5.15

Sogginess

Sample	Month 0	Month 1	Month 2	Month 3
Potato fries	5.93	5.82	4.79	4.71
TDa 291	3.99	3.54	3.42	3.34
Tda 98/01176	3.72	3.61	3.6	3.47

Surface dryness

Sample	Month 0	Month 1	Month 2	Month 3
Potato fries	3.46	3.79	3.81	4.39
TDa 291	6.42	7.48	8.08	8.20
Tda 98/01176	5.61	6.56	6.68	7.01

Sour taste

Sample				
	Month 0	Month 1	Month 2	Month 3
Potato fries	1.09	1.19	1.38	1.53
TDa 291	0.80	0.99	1.06	1.64
Tda 98/01176	0.87	1.56	1.57	2.03

Taste acceptability

Sample				
	Month 0	Month 1	Month 2	Month 3
Potato fries	7.4	7.59	7.65	7.74
TDa 291	7.37	7.41	7.44	7.71
Tda 98/01176	6.25	6.62	6.74	6.81

Hardness

Sample				
	Month 0	Month 1	Month 2	Month 3
Potato fries	0.55	0.86	0.93	1.23
TDa 291	5.57	6.93	7.13	7.18
Tda 98/01176	5.47	6.53	6.88	7.12

Crunchiness

Sample				
	Month 0	Month 1	Month 2	Month 3
Potato fries	1.03	1.22	1.32	1.44
TDa 291	8.2	8.3	8.33	8.36
Tda 98/01176	7.91	8.14	8.26	8.31

Chewiness

Sample				
	Month 0	Month 1	Month 2	Month 3
Potato fries	4.32	4.34	4.45	4.79
TDa 291	6.72	7.5	7.59	7.6
Tda 98/01176	5.53	6.88	6.9	6.91

Mouth feel

Sample				
	Month 0	Month 1	Month 2	Month 3
Potato fries	7.51	7.8	8.13	8.74
TDa 291	3.5	4.21	4.52	4.61
Tda 98/01176	3.34	4.14	4.43	4.49