KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

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THE EFFECT OF VARIOUS DRYING METHODS ON DRYING CHARACTERISTICS, SENSORY AND NUTRITIONAL QUALITIES OF YAM

BY

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DECLARATION

CANDIDATE DECLARATION

I hereby declare that this thesis is the outcome of my original research and that it is neither in part nor whole be presented for another certificate in this university or elsewhere.

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ABSTRACT

The effects of three drying methods: open sun drying (OSD), solar drying (SD) and solar adsorption drying system (SADS) on nutritional qualities, drying characteristics and sensory properties of dried yam were investigated. Three cultivars of white yam species (*Dioscorea rotundata*) and one cultivar water yam (*Dioscorea alata*) were subjected to various drying methods, i.e. OSD, SD and SADS. Proximate, mineral, vitamin C, water activity, colour and sensory of the processed yams and the fresh samples were analyzed using recommended methods. The initial moisture content of fresh yam cultivars ranged between 60 %-71 %. The initial moisture content did not have any regular relationship with the fresh content of ash, crude protein, and crude fat except carbohydrate, which showed some positive relationship. All the three drying methods significantly reduced the vitamin C content of sample however; there was no significant difference between SD and SADS methods. The reduction in the vitamin C content in OSD was much higher compared to the other two drying methods. Meanwhile, the vitamin C contents in *Pona* and *Dente* cultivars were relatively higher than other cultivars. The SADS and SD had similar effect on vitamin C and mineral content due to fact that the time of exposure to SADS was higher than that of the SD, while the OSD had higher effect on the vitamin C. In all the cultivars, the SADS, which is the combination of adsorption and solar drying, removed the free water faster than the SD system, which is only solar drying. However, OSD was less effective in terms of moisture removal compared to SADS and SD methods. Sensory evaluation results showed *amala* from SDLI had higher acceptability.

DEDICATION

This work is dedicated to my daughter Emmanuella Obeng Asare.

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TABLE OF CONTENTS

DECLARATION ..... **ii**
ABSTRACT ..... **iii**
DEDICATION ..... **iv**
ACKNOWLEDGEMENT ..... **v**
TABLE OF CONTENTS ..... **vi**
LIST OF TABLES ..... **x**
LIST OF FIGURES ..... **xi**
LIST OF PLATE ..... **xii**

CHAPTER ONE **1**
INTRODUCTION **1**
1.1 Background of the Study 1
1.2 Problem Statement 4
1.3 Justification 4
1.4 Objectives 5
1.4.1 General Objective 5
1.4.2. Specific Objectives 5

CHAPTER TWO **6**
LITERATURE REVIEW **6**
2.1 Drying processes of foods 6
2.1.1 Importance of drying 7
2.1.2 Drying curve 7
2.1.3 Drying methods 8
2.1.3.1 Open Sun drying (Sun drying) 8
2.1.3.2 Solar drying 10
2.1.3.3 Types of solar dryers 10
2.1.3.3 1 Direct solar dryers 10
2.2.1.3.3 Indirect Solar Dryers 12
2.2 Botanical and Agronomical Characteristics of Yam 14
2.3 Nutritional Value of Yam 16
2.4 Uses of yam 18

2.4.1 Food uses of yam 18
2.4.2 Industrial uses 19
2.5 Production and Storage 19
2.5.1 Production 19
2.5.2 Production of Yam in Major West African producing countries 20
2.6 Storage of Yam 20
2.7 Yam export in Ghana 21
2.8 Effects of drying on nutrient content of food 21
2.9 Food colour 23
2.9.1 Effects of drying on colour and texture 23
2.10 Water activity 24
2.11 Drying Characteristics 25
2.11.1 Effective moisture diffusivity 25
2.11.2 Moisture content 27
2.12.3 Moisture Ratio (MR) 27

CHAPTER THREE 28
MATERIALS AND METHODS 28
3.1 Materials 28
3.1.1 Measurement and data collection of yam 28
3.1.2 Sampling for laboratory analysis and drying experiment 28
3.2 Sample preparation prior to drying 28
3.2.1 Drying process 29
3.3 Drying characteristics 31
3.3.1 Moisture ratio (MR) = ... 31
3.3.2 Effective diffusion 31
3.4 Chemical analysis 32
3.4.1 Proximate composition determination 32
3.4.1.1 Moisture content 32
3.4.1.2 Ash 32
3.4.1.3 Crude Protein content 33
3.4.1.4 Crude Fat Content 33
3.4.1.5 Crude fibre content 34
3.4.1.6 Carbohydrate content 35

3.5 Mineral Determination....35
3.5.1 Sample preparation....35
3.5.2 Calcium determination....35
3.5.3 Phosphorus....36
3.5.4 Iron determination....37
3.7 Instrumental determination of colour....38
3.8 Determination of water activity....38
3.9 Sensory evaluation....40
3.9.1 Recruitment....40
3.9.2 Preparation of dried food products....40
3.10 Experimental design and statistical analysis....40

CHAPTER FOUR....42
RESULTS AND DISCUSSION....42
4.1 Proximate composition of fresh yam....42
4.1.1 Moisture content....42
4.1.2 Ash content....43
4.1.3 Crude protein....43
4.1.4 Crude fibre....44
4.1.5 Crude fat and carbohydrate (CHO) content....44
4.2 Preliminary work....44
4.3 Mositure distribution in fresh white yam....46
4.4 Drying behavior of yam at different drying methods....47
4.4.1 Varietal effect of yam on drying behavior....47
4.4.2 Effective moisture diffusivity....50
4.5 Proximate composition of dried yam....51
4.6 Mineral and vitamin C content of fresh and dried yam cuts....53
4.7 Effect of drying methods and yam cultivars on some minerals and vitamin C....57
4.8 Effect of drying method and yam cultivar on colour and water activity of fresh and dried yam cut....60
4.9 Sensory evaluation of *amala*....61

CHAPTER FIVE 65
CONCLUSION AND RECOMMENDATION 65
5.1 Conclusion 65
5.2 Recommendation. 66

REFERENCES 67

Appendix A: Formulae Used in Calculation 86
Appendix B: Minerals, (Phosphorus, Calcium and Iron) and Vitamin C Content of Fresh and Dried Yam Sample (mg/100 g) 87
Appendix C Colour and water activity for both fresh and dried yam. 87
Appendix: D Questionnaire for Sensory Evaluation of *Amala* 88
Appendix E: some pictures in the thesis 90
Appendix F: Sensory Evaluation of *amala* Prepared from Cultivars *Matches* (*D.alata*); *Pona*, *Dente* and *Lilii* (*D. rotundata*) with Drying Methods OSD and SD 91

LIST OF TABLES

Table 2.1 Nutrient contents of yam species (*Dioscorea spp*.) per 100 g fresh edible tuber portion. 17

Table 2.2 Moisture diffusivity (m^2/s) of *D. alata* for two varieties (9509-21 and 9506-27) of two geometries (circular and square) 26

Table: 4.1 Proximate composition of fresh yam sample (%) 42

Table: 4.2-A Average dimensions of the selected cultivars of fresh white yam (*Dioscerea rotundata)* 45

Table 4.2 B Mean dimension of the cultivars of fresh white yam (*D. rotundata*) 46

Table 4.3 Effective moisture diffusivity (m^2/s) of four yam cultivars using various drying methods. 50

Table: 4. 4 Proximate composition of dried yam samples using three methods (SADS, SD and OSD %) 52

LIST OF FIGURES

Fig: 4:1 Average Moisture content distribution in five cultivars of white yam (D.rotundata).....46
Figure 4.2 Same drying methods: SADS (A), SD (B) and OSD (C) on different cultivars of D. rotundata.....48
Figure 4.3a Effect of drying methods on drying behaviour of Pona. 49
Figure 4.3b Effect of drying methods on drying behaviour of Lilii. 49
Figure 4.3c Effect of drying methods on drying behaviour of Dente.....50
Figure 4.4b Different drying methods on the calcium content of various yam varieties .55
Figure 4.4c Different drying methods on the iron content of various yam cultivars.....56
Figure 4.5 Different drying methods on the vitamin C content of various yam cultivars. 57
Figure 4.6a Different drying methods on the colour (a*) of yam.....59
Figure 4.6b Different drying methods on the colour (b*) of yam 59
Figure 4.6c Different drying methods on colour (L*value) and water activity of yam..59
Figure: 4.7 show the sensory of amala prepared from cultivars – Matches (D.alata); Pona, Dente and Lilii (D. rotundata) with drying methods OSD and SD 64

LIST OF PLATE

Plate 2.1 Marquee Solar Dryer Source: Minka (1996) 11
Plate: 2.2 Solar tunnel dryer 12
Plate 2.3 Indirect solar cabinet dryer 12
Plate. 2.4 A picture of Yam plants intercropped with maize. 16
Plate 2.5 Fresh white yam tuber 16
Plate 3.1 Solar Adsorption Dryer System. 30
Plate 4.1a Amala from open sundried Lilii 62
Plate 4.1b Amala from solar dried Lilii 62
Plate 4.2b Amala from solar dried Dente 63
Plate 4.2a Amala from solar dried Pona 63

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Drying is an energy intensive process (Carsky, 2008; Dincer, 2000; Dincer and Cengel, 2001; Dincer and Sahin, 2004; Shi *et al*., 2008) which involves the removal of moisture from a crop until the moisture content of the crop is in equilibrium with the surrounding air (Agoreyo *et al*., 2011). It involves simultaneous heat and mass transfer. The main goal of drying agricultural products is to reduce the moisture content to a level that halts or control microbial growth and to reduce deteriorative chemical reaction in order to extend the shelf life of food (Mujumdar and Law, 2010). Therefore, in most agricultural based economies like Ghana, large quantities of food products dried improve shelf life, reduce packaging costs, lower weights, enhance appearance, retain original flavor and most importantly maintain nutritional quality (Baysal *et al*., 2003; Demir *et al*., 2007; Simal *et al*., 2000;, Ertekin and Yaldiz, 2004).

Open Sun, solar and oven drying are common methods used for drying agricultural crops. The traditional method of drying, known as Open Sun Drying (OSD), involves simply laying the product in the open sun on raffia, mats, roofs or drying floors. This causes the loss of some nutrients, such as vitamin C, food losses, and contamination by dust, stones and insect (Sharma *et al*., 2009). There is therefore the need to remedy this situation by introducing novel drying techniques that will mitigate the negative effects of the OSD. In the recent years, several attempts have been made to construct and develop different types of solar dryers to preserve nutritional, textural as well as sensory quality of agricultural and horticultural produce. Solar drying has been reported in literature to affect the concentration of some nutrients (Hassan *et al.*, 2007).

A new integrated drying technique that can be used as an alternative to the existing solar dryers to improve aesthetic and enhancing sensory qualities of food and possibly reduce drying time is Solar Adsorption Drying System (SADS). Solar- Adsorption drying combines adsorption and solar drying technologies. This involves using solar collectors to convert the solar energy into heat energy and indirectly channeling the heated air into a drying chamber for drying during the day. Night drying is made possible by utilizing the adsorbent because of phase change from water vapour to liquid on an adsorbed surface give output temperature above 65°C at which about 70 % of adsorbed water can be removed. The average temperature in drying chamber during the day is approximately 45 °C. The integration of solar and adsorption drying will facilitate moisture removal during the day and night.

Ghana has an annual sunshine hours between 1800 - 3000 (Edjekumhene *et al*., 2001) with yearly mean hourly solar irradiance of between 4.0-6.0 kW/m^2 and daily hour by hour radiation between 0- 920 W/m^2 (Akuffo, 1991) within geographical location of latitude 4^0 and 12^0 N and longitude 30^0 W and 1^0E. This resource places Ghana in a position to utilize solar radiation in unit operations such as drying agricultural products. Products that are dried in Ghana include cassava, yam, maize, rice, cocoa, leafy vegetables etc. This work seeks to dry yam and therefore information on yam is necessary.

Yam, *Dioscorea species* belongs to family *Dioscoreaceae* and forms one of the major staple foods in West Africa (Badajide *et al.*, 2006). West Africa produces about 90 % of the worldwide production of yam with Nigeria being the largest contributor followed by Ghana, Ivory Coast and Togo (FAO, 2003). However, Ghana is the largest exporter of yams globally with export value of approximately 21,000 metric

tons and compound annual growth rate of yam exports between 2000 and 2008 was 6.6 % (Ghana Export Promotion Council, 2009).

Yam tubers have traditional food uses as well as industrial uses. Yam is consumed when boiled, fried or baked. The cooked yam is served with stew or soup. Dried yam chips can be used to prepare a product called "*amala*" which is consumed by people of Bénin and Nigeria. In the Northern part of Ghana, dried yam chips can be used to prepare a flour and reconstituted to form a paste called *Wasawasa* and eaten with soup.

Yam is an important food crop in Ghana but is highly perishable due to its high moisture content about 70 % (Fioreze and Morini, 2000). This makes fresh yams susceptible to microbial spoilage. This phenomenon has challenged scientists and product developers to engineer novel approaches to address the challenge. Notable among them is drying technology (Xiao *et al*., 2010). On the other hand, due to simultaneous heat and mass transfer, considerable undesired quality changes occur in the product during the drying process. However, most of the drying methods cause a reduction in the quality of agricultural crops after drying. Literature is replete with data on the effect of drying methods on the nutritional, sensory and textural qualities of food crops as far as OSD and SD are concerned (Agoreyo *et al*., 2011: Hassan *et al*., 2007).

Krokida and Maroulis (1997) reported that drying methods and the variables of drying influence both the quality and physicochemical characteristics of the dried products. The quality of the dried products can be assessed by the appearance, colour and other physical properties such as shrinkage and porosity. The aim of this research is to investigate the effect of three drying methods: Solar-Adsorption Dryer System (SADS), Solar Drying (SD) and Open Sun Drying (OSD) on drying characteristics,

sensory and nutritional qualities of yam and to increase the variability of uses of yam example is incorporating yam powders in soups or baking products.

1.2 Problem Statement

Yam has a moisture content of about 70 % when harvested (Fioreze and Morini, 2000) which makes it perishable especially when bruised. Post-harvest loss of yam is estimated to be about 30 % (Alhassan, 1994), while more than 20 % had been reported by the Ministry of Agriculture (MOFA, 2007). These losses serve as a driving factor for processing this staple food into a product such as yam flour through drying process of longer shelf life (Jimo and Olatidoye, 2009). One of these processing technologies is to dry the fresh yam into chips and further process it into flour which can be stored for about 12- 18 months. In Ghana, the traditional method of drying, known as Open Sun Drying (OSD). This method causes the loss of some nutrients, such as vitamin C, food losses, and contamination by dust, stones and insect. There is therefore the need to remedy this situation by introducing novel drying techniques that will mitigate the negative effects of the OSD.

1.3 Justification

Ghana has an annual sunshine hours between 1800-3000 and daily hour by hour radiation from 0-920 W/m^2 (Akuffo, 1991 and Edjekumhene *et al.*, 2001) and therefore solar radiation can be exploited as effective means of drying agricultural crops in order to reduce post-harvest loss in Ghana. Methods of drying that used solar radiation for drying common to the Ghanaian are (OSD) and (SD). Various researchers have reported that OSD and SD affect some nutrient composition, sensory and drying characteristics of the dried products. This is due to direct exposure of food to the sun with accompanying long drying time (Hassan *et al.*, 2007) and therefore this new low temperature of drying method SADS, can be used to dry agricultural products such as

yam in Ghana. This system comprises of solar drying and adsorption drying system. The sun drying uses the sun energy during day and adsorption drying is done at night at low temperature.

These methods (OSD, SD and SADS) may affect differently the nutrient, sensory and drying characteristics of dried cut yam. Research data on SADS is unavailable therefore since drying method affect nutritional and sensory characteristics of food (Fellows, 2000; Agoreyo *et al*., 2011) it is vital to investigate the effect of drying methods (OSD SD and SADS) on the nutrient composition, drying characteristics and sensory attributes of yam.

1.4 Objectives

1.4.1 General Objective

To investigate the effect of three drying methods (OSD, SD and SADS) on drying characteristics, sensory and nutritional qualities of some selected varieties yam.

1.4.2. Specific Objectives

- To assess the effect of drying methods and cultivars on some nutritional composition of three selected cultivars of yam: *D. rotundata (Dente, Lilii, and Pona)* and one cultivar of *D. alata* (*Matches*).
- To study the effect of drying methods viz: (OSD, SD and SADS) and cultivars on some physical properties of dried yam chips.
- To evaluate the effect of drying methods (SD and OSD) and cultivars on consumer acceptability of a formulated diet (*amala*) using yam flour.

CHAPTER TWO

LITERATURE REVIEW

2.1 Drying processes of foods

Drying is a process of simultaneous heat and mass transfer operation for which energy must be supplied (Yilbas *et al.,* 2003). During drying two processes, take place simultaneously such as heat is transferred to the product from the heating medium (air) and mass transfer of moisture from the interior of the product to its surface and from the surface to the surrounding air. The heat is transferred by conduction in the solid product and convection in the air. The water is moved to surface of the food by diffusion. This process induces chemical and physical changes in the material undergoing dehydration. These mainly originate from temperature increase, prolonged contact with air and removal of water.

There are two stages in a typical drying process: the first stage is the removal of surface moisture; the second stage is the removal of 'internal moisture' from within the solid material. Perry (2007) reported that drying rate periods could be categorized as: (Constant rate period, First falling rate period and second falling rate period). During the constant rate-drying period, the surface of the material is still wet and the rate of drying is governed by evaporation of free moisture from the product's surface or near surface areas. The falling-rate period of drying is controlled largely by the product and is dependent upon the movement of moisture within the material from the centre to the surface by liquid diffusion (Minkah, 2007). The drying process of agricultural material take place in the falling rate period (Falade and Abbo, 2007; Nguyen and Price, 2007; Saeed *et al.,* 2006; Singh *et al.,* 2008). This means that diffusion is the dominant physical mechanism governing moisture movement in the material (Akpinar *et al.,*

2003a; Doymaz, 2007). The rate of drying is dependent on the vapour pressure difference between the surface and the air. Drying air temperature, air velocity, shape and size of the drying particles can significantly affect the drying rate.

2.1.1 Importance of drying

Drying is one of the most common processes used to improve food stability, since it decreases considerably the water activity of the material, reduces microbiological activity and minimizes physical and chemical changes during its storage. It also, causes weight reduction, enhances aesthetic and sensory effects of food (Brennan, 2006). However, the main goal is to reduce moisture content to levels that halt or slow down the growth of spoilage microorganisms and incident of chemical reactions (Mujumdar and Law, 2010; Krokida and Marinos-Kouris, 2003) in order to extend the shelf-life of food (Doymaz, 2004, Oduro *et al*., 2007).

Maskan (2001) mentioned that high quality fast-dried foods have become necessary in the recent times leading to a renewed interest in drying operations. In addition, there is an increased demand for convenient foods including ready to eat and instant products, which are desired to contain the minimum quantities of additives and preservatives.

2.1.2 Drying curve

Drying kinetics is generally assessed experimentally by measuring the weight of a drying sample as a function of time (Saeed *et al*., 2008). Drying curves may be represented in different ways; averaged moisture content versus time, drying rate versus time, or drying rate versus averaged moisture content (Coumans, 2000 cited in: Saeed *et al.*, 2008). Kane *et al*. (2009) reported that drying time decreased as drying temperature was increased from 40 to 70 °C and drying air flow rate was increased from 0.028 - 0.056 m^2/s. The drying air conditions have an important influence on the

rate of these curves. It is apparent that drying rate decreases continuously with the moisture content. Meanwhile, rate of drying increases with the increase of air-drying temperature.

Drying curves are used to show the influence of the factors, which affect the rate of drying, example: temperature, air velocity, particle size and thickness. Typically, the moisture content (M) falls from the initial value (Mo) with drying time (t). As drying progresses, the drying rate falls further and tends to zero as the moisture content approaches the equilibrium value (Me).

2.1.3 Drying methods

Drying in earlier times was done primarily in the open sun. Now many types of sophisticated equipments and methods are used to dehydrate foods. Thus, the most commonly used drying methods include sun drying, convectional air drying, solar drying and osmotic drying (Krokida and Maroulis, 2001a). Despite its reliance on climatic conditions, solar drying is gradually becoming a more popular method of drying agricultural crop in tropical countries.

Solar energy is economical procedure for drying agricultural products in developing countries like Ghana where the intensity of solar radiation is high and sunshine duration is long. Meanwhile, the methods and the variables of drying influence both the quality and physicochemical characteristics of the dried products (Krokida and Maroulis, 1997).

2.1.3.1 Open Sun drying (Sun drying)

In the tropics, the traditional method for crop drying is open sun drying. Open sun drying usually involves the spreading in thin layers of crops such as paddy, coconuts, coffee, shrimp, cocoa and fish on concrete floors, large trays, and galvanized sheets or

simply on pitched roadsides until the crop is sufficiently dried (Arinze,1987). This type of drying is frequently the only commercially used and viable method in which agricultural products are dried in developing countries. In Ghana, food samples that are usually dried by direct exposure to the sun include cocoa beans, cereals, legumes, leafy vegetables, cassava, yam, fish and shrimps.

Sun drying is the most widely practiced agricultural operation in the world (Fellow, 2000; Doymaz, 2004). It is simple and inexpensive. Notwithstanding the positive impact of drying on shelf life, Sharma *et al.* (2009) reported several limitations associated with traditional sun drying. During periods of intermittent and particularly during continuous rainfall, crop drying is not possible and the risks of crop losses are high. Sun drying is slow and weather dependent compared to other alternative drying systems. Crop quality may be affected significantly due to direct contact with UV-radiation, contamination by dust, dirt, stones and insects, while direct crop losses from theft and livestock consumption can be high. Meanwhile, long exposure to the drying temperatures of open air-drying has an adverse effect on colour, rehydration ratio, texture, nutrient content and other characteristics of the dried product (Fellow 2000, Hofsetz *et al*., 2008).

In recent time, consumer demands have increased for processed products to keep more of their original characteristics, while bacterial and fungal contamination must be prevented and therefore this type of drying is not appropriate from food hygiene and food safety point of view. Therefore, any means by which samples are dried effectively, quickly and hygienically at a cheaper cost to make them available during the lean season is highly necessary. Solar dryers may be a good substitute to these problems.

2.1.3.2 Solar drying

In solar drying, solar-energy is used either as the sole source of the required heat or as a supplemental source. The airflow into the dryer can be generated by either natural or forced convection. The heating procedure could involve the passage of preheated air through the product or by directly exposing the product to solar radiation or a combination of both (Ekechukwu and Norton, 1998).

Solar drying has some advantages over other drying methods if dryer is correctly designed. Solar drying is cheap compared to other advanced methods of drying since it mainly relies on energy from the sun, requires low or no electric power and the dryers are relatively cheap and easy to construct. This makes it suitable for use in rural areas with limited electrification and frequent load shedding. Solar dryers are useful in areas where fuel or electricity is expensive, sunshine is plentiful but air humidity is high. Moreover, they are as useful as a means of heating air for artificial dryers to reduce fuel cost (Fellows, 2000). They give faster drying rates by heating the air above ambient, which causes the air to move faster through the product. The product is completely protected from rain, dust, insects and animals. Faster drying rates reduces the risk of spoilage and improves quality.

2.1.3.3 Types of solar dryers

2.1.3.3 1 Direct solar dryers.

In direct radiation drying, part of the solar radiation may penetrate the insolation material and be absorbed within the product itself, thereby generating heat in the interior of the product as well as at its surface, and thereby enhancing heat transfer (Basunia and Abe, 2001). In these types of dryers the material to be dried are placed in a transparent enclosure of glass or plastic. The drier chamber is usually painted black

to absorb the maximum heat. Due to direct exposure to the sun, it predisposes the food to ultraviolet light, which affect nutrient such as vitamins. During drying, there is a tendency of the food to form dry surface layers (case hardening) which are impervious to subsequent moisture transfer, if the drying rate is very rapid. To avoid this effect, the heat transfer and evaporation rates must be closely controlled to guarantee optimum drying rates.

Some comparative research of solar and open air dryers on the nutritional content of some food material and performance have gone on in recent times. Bala *et al*. (2003) compared solar tunnel dryer with sun drying and reported that proximate analysis indicated good quality dried pineapple sliced using solar tunnel dryer compare to sun (open air) drying. Bala and Mondol (2001) reported that fish dried in the solar tunnel dryer was completely protected and the dried fish was better in quality. Plate 2.1 and 2.2 show examples of direct solar dryers. In Plate. 2.1 there is a transparent material (polyethylene) at the top and sides, which allow direct solar radiation to the crop. The structure is made of wood and supported on posts. There are two parallel dryers with a gap at the central part for easy movement by the operator.

Plate 2.1 Marquee Solar Dryer Source: Minka (1996)

Plate: 2.2 Solar tunnel dryer
Source: Tarihi (2008)

Plate 2.2 is a solar tunnel dryer, which has 10m^2 base area and 2.23 m height is used for large scale drying of tomato. The dryer was oriented in an east-west direction to make the incident solar radiation more efficient on the solar tunnel dryer. Tunnel was covered with polyethylene plastic film material.

2.2.1.3.3 Indirect Solar Dryers

In an indirect solar system, the output air from a collector system (inclined or horizontal) which is placed either on top or by the side of the dryer system is channeled into the drying chamber by natural means or by forced convection.

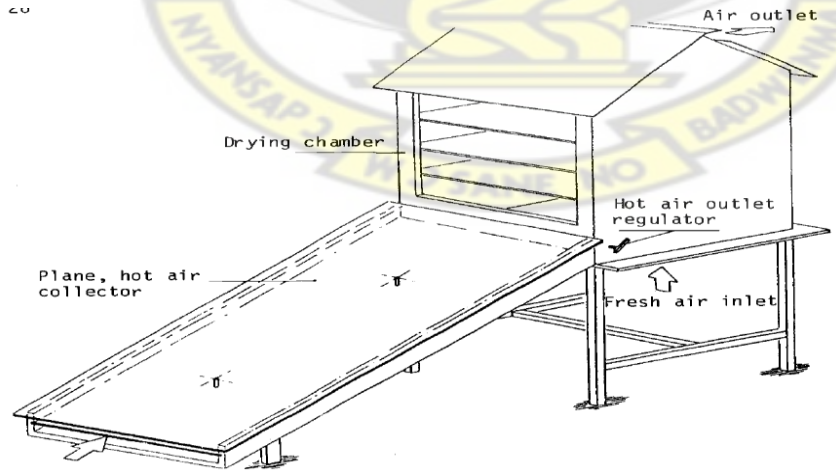

Plate 2.3 Indirect solar cabinet dryer
Source*: http://climatetechwiki.org/technology/jiqweb-edf*

Some comparative research works have gone on in recent times. Yaldiz and Ertekin (2001) compared open air and solar drying of pumpkin, green pepper; stuffed pepper, green bean, and onion in thin layers. They reported that the drying time was between 30.29 - 90.43 hours in solar drying as compared to open sun drying 48.59 and 121.81 hours for different vegetables.

Lotfalian *et al*. (2010) investigated the performance of two solar collectors dryers on drying of lemon and orange fruits using a passive and indirect dryer and results showed that the tendency towards buying solar dried lemons and oranges is 5.6 and 4.2 times, respectively, higher than traditionally dried fruits. This implied therefore that solar dried fruits have higher marketing value than open air-dried ones. However, solar drying is not a full solution as alternative to open air-drying since the sun is available between 6-8 hours in the day in Ghana (Dickson and Benneh, 1988). Solar adsorption drying system (SADS) is a new method of drying whose performance on agricultural products has not yet been investigated. Djaeni *et al*. (2009) developed recently at Wageningen University Research Center, a system for adsorption drying, where by air passes over adsorbent (Zeolite) for dehumidification. The temperature of the air is increased by the release of adsorption heat by converting water vapour to liquid. With this technology, the drying capacity of air is enhanced and drying during the night without additional heating becomes possible. Although energy is required to regenerate the adsorbent, adsorption drying is much more energy efficient than conventional drying systems (Atuonwu *et al*., 2011). By combining the best of solar and adsorption drying systems, agricultural products can be dried continuously day and night with low effect on product quality. Information on the effect of solar and adsorption drying on the drying kinetics and quality of yam is not available.

In the present study, an attempt is being made to compare the effects of three drying methods (SADS, SD and OSD) on the nutritional and organoleptic properties of yam. Information on yam is therefore necessary.

2.2 Botanical and Agronomical Characteristics of Yam

Yam, *Dioscorea species* belongs to family, *Dioscoreaceae*. Yams are annual or perennial tuber-bearing and climbing plants with over 600 species in which only few are cultivated for food and medicine (ITTA, 2006). Three most popular species in West Africa are; *Dioscorea rotundata* (White yam), *Dioscorea cayensis* (Yellow yam) and *Dioscorea alata* (Water yam) (Coursey, 1967). Other cultivated species in West and Central Africa include *Dioscorea bulbifera (*Potato yam*), Dioscorea dumetorun* (Bitter yam), *Dioscorea esculanta* (Lesser yam). Many wild yam species exist and may contain toxic or bioactive chemicals, while some are cultivated for pharmaceutical purposes (Coursey, 1967). Yams vary in appearance both between and within species, however all yams have common growth habit of thin, twinning vines and a shallow wide radiator root system, both of which die and removed each year. All economically important species are tuberous, producing one or more underground tubers. The flesh of yam is white, ivory, yellow or purple while the skin may either be white, pink or brownish black depending on the variety. Their shape is long, cylindrical and tapering while their exterior texture is rough and scaly. Yams have a very starchy and slippery texture and when cooked, it will become either creamy or firm, depending on the variety. The major constituent of the tuber is water, carbohydrate and other non-carbohydrate components. The stage of maturity, method of storage and species may also affect the tuber composition (Asiedu, 1986).

Dioscorea is pantropical genus and different species have independently domesticated on each continent (Coursey, 1967). Hahn *et al.* (1987) reported that some species of yam originated from Africa.

Dioscorea alata (greater yam or water yam) is the most wide spread species. It was thought to originate in southern Asia, but recent genetic studies have identified Melanesia as its centre of origin, and this region remains its centre of diversity (Lebot, 2009).

It is believed to have been among several Asian crops introduced to Madagascar by Austronesians some 2,000 years ago, and from there spread into mainland East Africa (Lebot, 2009). It is not clear whether *D. alata* was established in West Africa before European contact, but it has since come to rival African species both there and in the Caribbean. *D. alata* is also known for its high nutritional content, with crude protein content of 7.4 %, starch content of 75-84 %, and vitamin C content ranging from 13.0 to 24.7 mg/100 g (Osagie, 1992). Some examples of cultivated species in Ghana include; *Matches* and *Akaba.*

White yam (*Dioscorea rotundata*) which originated from Africa is the most widely grown and preferred yam species in Ghana, especially the *Pona* cultivar for both the domestic and export market. Other popular cultivars include *Dente, Lilii, Muchumuduu* and *Serwaa.* They are usually planted in February and April, and harvesting occurring in October (MiDA, 2009). Figure 2.3 shows a picture of white yam plants intercropped with cassava and maize. White yam (*Dioscorea rotundata*) is adaptable to well-drained, rich, loamy soil.

Plate. 2.4 A picture of Yam plants intercropped with maize.
Source:Osunde (2008).

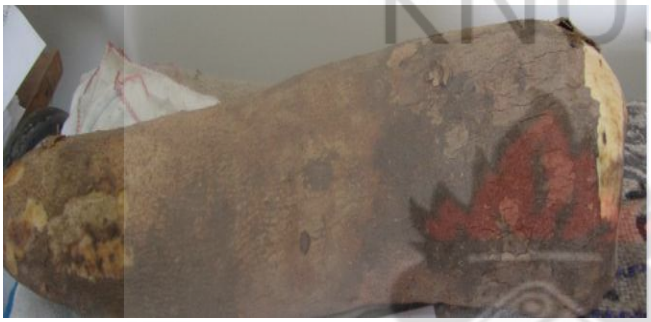

Plate 2.5 Fresh white yam tuber

Plate 2.5 shows a picture of white yam. The tuber is cylindrical with rough skin and dark brown colour. Their shape is long, cylindrical and tapering, while their exterior texture is rough and scaly.

2.3 Nutritional Value of Yam

Yam is considered the most nutritious of tropical root crops (Wanasundera and Ravindra, 1994). Bradbury and Holloway (1998) reported that yam contains approximately four times as much protein as cassava. Yam is the only root crop that exceeds rice in protein content to digestible energy. The amino acid composition of yam protein is rich in sulphur-containing amino acid (Cysteine and Methionine). Bhandari *et al*. (2003) and Splittstesse *et al*. (1973) reported that the overall rating for essential amino acids in yam is relatively higher and superior to sweet potato.

Yam is also a good source of vitamins and minerals. Osagie (1992) reported vitamin C contents 5-10 mg/100 g in *D. alata*. Bradbury and Singh (1986), reported that total ascorbic acid content of yam tubers is 50 % greater than that of cassava. Values ranging from (200-2100 µg)/100 g (fresh weight basis) has been reported for various species. Ascorbic acid is important for the normal function of the nerves and muscles. Adepoju (2012) reported mineral content as: sodium 350 mg/100 g, potassium 470 mg /100 g, calcium 68 mg /100 g, iron 4.1 mg/100 g, phosphorus 163 mg/100 g for *D. rotundata*. Yam has a moisture content of about 70 % when harvested (Fioreze and Morini, 2000). Soil nutrient, type of soil, moisture content and maturity of the crop can affect the mineral content of the yam.

Table 2.1 shows nutritional contents of yam species (*Dioscorea spp*.) per 100/ g fresh edible tuber portion. The moisture content ranged from 50-80 % and 65-78.6 % of *D. rotundata* and *D. alata* respectively. The fibre values (1.4-3.8 %) were higher in *D. alata* than *D. rotundata* (1.0-1.7 %). Meanwhile the iron content (5.5-11.6 mg/100 g) of *D. alata* was higher compared to that of D. *rotundata* (7-5.2 mg /100 g).

Table 2.1 Nutrient contents of yam species (*Dioscorea spp*.) per 100 g fresh edible tuber portion.

Nutrient (g/100)/ Variety	***D. alata***	***D.rotundata***
% Moisture	65-78.5	50.0-80.0
% Carbohydrate	22-31	15-23
% Protein	1.1-3.1	1.1-2.3
% Crude fat	0.1-0.6	0.05-0.1
% Fibre	1.4-3.8	1.0-1.7
% Ash	0.7-2.6	0.7-2.6
Phosphorus (mg/100)	28-52	17-61
Calcium (mg/100)	28-38	12-69
Iron(mg/100)	5.5-11.6	0.7-5.2

Source: Coursey (1967); Eka (1985); Brabury and Holloway (1988); Osagie (1992); Asiedu et al. (1997); and Adepoju (2012).

2.4 Uses of yam

Yam tubers have several uses currently and still have more potential uses in future. In the producing countries, yam is mainly use as food. Yam has other uses apart from food.

2.4.1 Food uses of yam

Fresh yam can be eaten fried, boiled, or roasted like potatoes (Wanasundera and Ravindran 1994). Different people prepare yam differently. *Fufu* is prepared from cassava in combination with plantain or cocoyam but in yam producing zones or during scarcity of plantain and cocoyam, *Fufu* is prepared from boiled yam and cassava. It is a popular food mostly eaten with soup in Ghana.

In Benin and Western parts of Nigeria, yam tubers are processed into slightly fermented flour called e*lubo* for a product called *amala*. To prepare *elubo*, yam tubers are peeled, sliced, and parboiled. The slices are left in the water, well covered, for about 24 h to ferment slightly. They are drained, dried and market throughout the year. Dried tuber slices are usually purchased on the market, crushed or pounded in a traditional mortar with pestle and milled into flour. *Elubo* is usually mixed with four parts of boiling water to give a smooth thick paste called *amala* (Akissoe *et al.*, 2001) which is eaten with soup. *Amala* is eaten by the Yoruba of Western Nigerian (Osagie, 1992; Onwueme and Charles, 1994; Orkwor, 1998).

Boiled yam is also a popular and easy to prepare food in the production areas. The tubers are first peeled, sliced and cooked in a pot with water. It is eaten with vegetable or tomato stew, beans and or soup. In Ghana, boiled yam can be mashed with palm oil into a smooth semi-solid paste known as *eto* by the Akans (Adepoju, 2012). It can also be fried in vegetable oil after slicing. Roasted yam used to be eaten mostly by farmers

on the field but it has now become a popular street food or fast food in most urban centres of the growing regions (Orkwor, 1998). In Ghana, it is usually eaten with a piece of salted and roasted fish or meat with pepper.

2.4.2 Industrial uses

Yam tubers can be processed into yam chips and pellets, which are milled to produce yam flour. Mestres *et al*. (2002) reported that there has been an increase in production and marketing of yam chips in Nigeria, Benin, and Togo. In the industry, yam chips can be milled and used for various food products for example biscuit and weaning food. Attempts to manufacture fried yam chips, similar to French fried potatoes have been reported from Puerto Rico and the potential for its production on a commercial level has been highlighted (Abass *et al.,* 2003). Yam tubers have also been processed into starch or into poultry and livestock feed just as cassava (Opara, 1999). Yam starch is used in production of all-purpose adhesives. Producers of cartons, packaging companies, leather and shoes use the adhesives for their products. Recently, several beneficial properties of yams were reported, and the extracts of yam showed antioxidant activity and possessed scavenging properties against free radicals (Farombi *et al.,* 2000).

2.5 Production and Storage

2.5.1 Production

The West African yam belt produced about 90 % of the worldwide production, which amounted to 48.7 million metric tonnes. Nigeria alone produces 75 % of the West African output. Nigeria is the leading producer of yam with 34 million tonnes followed Ghana (3.9 million tonnes); Cote D'ivoire (3.1 million tonnes) and Benin (2.1 million tonnes) (IITA, 2009). West and Central Africa account for about 94 % of the

world's productions (FAO, 2005). Scott *et al*. (2000) reported that sub- Saharan Africa is expected to produce 98.1 % of the total world production of yam in Africa by 2020. From 1995-2000 total world production increased from 32.7 million tonnes to 37.5 million tonnes. From 1975 to 1990, the total area cultivated increased by 38.8 % globally, with corresponding increase in the total production by 45.8 %. Researchers have reported that West India, the second most important yam-producing region is to produce over 250,000 tonnes of yam. Approximately 5 % of this is exported resulting in annual export earning of over $ 15 million (Mitchell *et al*., 1989; Wheatley, 2000)

2.5.2 Production of Yam in Major West African producing countries

Yam production in Ghana increased from 3.3 million tonnes in 2000 to 5.7 million tonnes in 2010. However, in 2003 and 2004, Ghana's yam production decreased to 3.8 million tonnes (MoFA, 2011). The decrease in production may be due to poor rainfall and poor environmental factors. Ivory Coast was second largest producer until 1999, when Ghana became second producer and has maintained this position till date.

2.6 Storage of Yam

Three main conditions are necessary for successful yam storage; aeration, reduction of temperature and regular inspection of produce. Notwithstanding cultivar difference, fresh yam tubers can be successfully stored in ambient and refrigerated conditions. The recommended storage temperature is in the range 12-16 ^{0}C. Optimum conditions of 15 or 16 ^{0}C at 70 -80 % Relative humidity (RH) or 70 % RH have been recommended for cured tuber (Martin, 1984; McGregor, 1987). Farmers have several traditional storage structures. The method used depends on the climatic conditions, the building material available and the purpose of the yam tubers in storage (FAO, 1990).The principal traditional yam storage structure in the major producing areas is the yam barn. Barns

are usually located in shaded areas and constructed to facilitate adequate ventilation. Other traditional storage methods include underground structures, leaving the tubers in the ground until required, putting harvested yams in ashes and covering with soil; with or without grass mulch until required for use (Opara, 1999). Yams can be stored using modern storage methods that include the low temperature or controlled atmosphere conditions, irradiation and chemicals. These methods are known to suppress sprouting of yams for longer storage.

2.7 Yam export in Ghana

Ghana is the world's largest exporter of yams. According to Ghana Export Promotion Council (2009), Ghana exports approximately 21,000 metric tons of yams annually, a number that has been increasing over the last decade. The compound annual growth rate of yam exports between 2000 and 2008 is 6.6 %.

The United Kingdom imports nearly half of Ghana's yam exports. Europe represents the largest foreign market for Ghanaian yam, with the Netherlands, Italy and Germany also importing significant quantities. The United States is currently importing 18 % of exports. In African countries, Niger imports the largest quantity of yam from Ghana. Not included in official export numbers are the large quantities of yam that are transported and sold in nearby countries, including Burkina Faso and Mali that consume but do not produce yam (GEPC, 2009).

2.8 Effects of drying on nutrient content of food

During drying, food loses its moisture content, which results in increasing the concentration of nutrients in the remaining mass. Vitamin C is temperature sensitive and deteriorates during drying. Thus, low and moderate temperatures are necessary for drying to prevent the loss of vitamin C. Furthermore, the changes in quality depend on

the local time, varying moisture content and temperatures in the product rather than the average moisture content.

Giovanelli *et al*. (2002) reported losses of ascorbic acid during the production of dried tomato halves and tomato pulp using high temperatures. Zanoni *et al*. (1998) found out that the loss of ascorbic acid was dependent on the drying temperature used and the moisture content in the final product as tomatoes dried at 80 ^{0}C contained 10 % ascorbic acid while at 110 ^{0}C it contained none.

According to Karel (1985), the effect of drying on protein is expressed as a decrease in the digestibility and biological value of the protein. Heating does not generally change the total dietary fibre content (Jones *et al.*, 1990), however, heat treatment cause insoluble dietary fibre content to increase as a result of the complexing of its components with protein and amino acids (Matalas *et al*., 2001). Agunbiade *et al.* (2006), studied the effect of dehydration on the physicochemical properties of chips produced from plantain and banana and reported that there was reduction in some proximate composition after dehydration. Crude protein was decreased from 15.41 to 7.21 % for banana and 13.21 to 6.30 % for plantain; crude fibre 3.00 to1.36 % and 2.60 to1.58 % ash content; 13.40 to 2.42 % and 8.80 to 2.91 % for banana and plantain respectively. However, an appreciable increase was found for carbohydrate: 61.74 to 82.29 % and 74.99 to 86.40 % and fat content 6.40 to 6.81 % and 2.59 to 2.82 % for banana and plantain respectively.

Agoreyo *et al*. (2011) reported calcium values of 42.3, 38.50 and 39.60 mg/100 g for fresh, sun and solar dried white yam respectively. Adepoju, (2012) reported that, processing yam into various products resulted in highly significant reduction in mineral content of the products compared with the raw sample. However, preparing

yam into porridge resulted in significant increase in calcium, phosphorus and zinc content of the product compared to raw sample. Calcium 68.0, 82.0, 61.0, 27.0, 29.0, 31.0, 97.0 and 92.0 mg/100 g respectively raw yam, roasted yam, fried yam, boiled yam, pounded yam with hot water.

2.9 Food colour

The most common technique to assess the food colour is by colorimeter. The surface colour can be represented in several colour scales. Three coordinates usually define it. The L*, a* and b* scale is recognized to show a better discrimination between small colour differences in the darker region of the colour space, providing good discrimination for saturated colours. Three-dimensional L*, a* and b* can be used in Minolta chromameter. The L* is the lightness coefficient, ranging from 0 (black) to 100 (white) on a vertical axis. a* represents the purple red (positive a* value) and blue-green (negative a* value) on horizontal axis. Second horizontal axis is b*, which represents yellow (positive b* value) and blue (negative b* value) as reported by (McGuire, 1992). The a* and b* are the two chromatic components with range, -120 to 120.

2.9.1 Effects of drying on colour and texture

Colour is the human perception of light waves reflected from the surface of any material. It is one of the first noticeable characteristics of food in early periods of dehydration. Krokida *et al*. (2000) investigated the effect of drying method on colour of dehydrated products and found out that the drying method used for dehydration significantly affected the colour parameters. Browning of fresh fruits and vegetables reduced the quality and often it is the limiting factor for shelf life and marketability of the dried products (Bolin and Huxsoll, 1991).

Olorunda (1990) reported that an increase in drying time and temperature resulted in tissue darkening. Sacilik *et al*. (2006) reported on thin layer solar tunnel dried tomato slice colour values; L, a and a/b varied from 33.8 to 37.44, 23.54 to 27.2 and 1.44 to 1.51 respectively. Corresponding values for samples of open sun drying varied from 30.54 to 34.90, 20.20 to 24.87 and 1.49 to 1.60 respectively. They concluded that the tomato slices dried under solar tunnel drier retained better colour than open sun dried due to the exposure of the tomato slices to solar radiations for a longer drying time.

2.10 Water activity

Water activity is the main factor of numerous important food-processing operations, such as microbial growth, toxin formation, enzymatic and non-enzymatic reactions (Leung, 1986). Water activity (a_w) is defined as the ratio of vapour pressure of water (P) in a food to the saturated vapour pressure of water (Ps) at the same temperature (Kaminski and Kudra, 2000).

The concept of water activity is of particular importance in determining product quality and safety. Water activity influences colour, odour, flavour, texture and shelf-life of many products. It predicts safety and stability with respect to microbial growth, chemical and biochemical reaction rates, and physical properties. It is reported that almost all-microbial activity is inhibited below a_w = 0.6, most fungi are inhibited below a_w = 0.7, most yeasts are inhibited below a_w = 0.8 and most bacteria below a_w = 0.9 (Fellows, 2000). The interaction of a_w with temperature, pH, oxygen and carbon dioxide, or chemical preservatives has an important effect on the inhibition of microbial growth (Fellows, 2000).

The water activity must be measured at constant temperature to compare the results. Akanbi *et al*. (2006) found out that the water vapour sorption isotherm of dehydrated

tomato slices in water activity (a_w) range of 0.08-0.85 at three temperature levels, 25, 30 and 40 ^{0}C.

2.11 Drying Characteristics

2.11.1 Effective moisture diffusivity

Moisture diffusivity is an important transport property needed in calculations and modelling of food drying, moisture adsorption/desorption during storage or dehydration. When different mechanisms occur, and it is difficult to separate individual mechanism, rate of moisture movement is described by an effective diffusivity, irrespective of which mechanism is involved in moisture movement (Okos *et al*., 1992).

Several researchers have presented various numerical models for moisture migration considering diffusion as the primary transport mechanism. In general, effective moisture diffusivity increases with increase in temperature. In general, moisture diffusivity in food ranges from 10^{-9}-10^{-11}.

Torres *et al. (*2012) reported that effective diffusivity (D_{eff}) has direct associations with temperature, and they are independent of geometry and the type of varieties of yam. Among the temperature ranged from 40 to 70 ^{0}C evaluated moisture diffusivities varied from 1.70 x 10^{-9} to 6.84 x 10^{-10} m^2/s and 1.33 x 10^{-9} to 6.30 x 10^{-10} m^2/s for the *D. alata* 9506-21 and 9506-27, respectively. Table 2.2 shows effective moisture diffusivity of two varieties of *D. alata* at various temperatures and geometry as reported by Torres *et al.* (2012).

Table 2.2 Moisture diffusivity (m^2/s) of *D. alata* for two varieties (9509-21 and 9506-27) of two geometries (circular and square)

Temperature (^0C)	Variety/geometry			
	9506-21		9506-27	
	Circular	Square	Circular	Square
70	1.7×10^{-9}	1.51×10^{-9}	1.33×10^{-9}	1.15×10^{-9}
55	1.15×10^{-9}	1.17×10^{-9}	1.17×10^{-9}	1.04×10^{-9}
40	7.03×10^{-9}	6.70×10^{-9}	6.70×10^{-9}	6.30×10^{-10}

Source; Torres et al. (2011)

Table 2.2 shows effective moisture diffusivity of two yam varieties of *D.alata* at different temperatures and geometry. Effective moisture diffusivity ranged from 7.03×10^{-9}-1.7×10^{-9} m^2/s and 6.70×10^{-9} - 1.51×10^{-9} m^2/s at temperatures 40-70 ^0C respectively using circular and square shape of the same variety (9506-21). In addition, 9506-27 had effective moisture diffusivity ranged from 6.30×10^{-10}- 1.15×10^{-9} m^2/s at temperatures of 40- 70 ^0C respectively.

According the table, increase of air temperature increase the effective water diffusivity but variety and geometry do not influence it.

Effective water diffusivity in both isothermal and non-isothermal models followed Fick's law with temperature, which increases linearly with initial moisture content (Gaston *et al*., 2004).

The solution of Fick's model for moisture diffusion in thin layer drying is as follows.

$$MR = \frac{M_t - M_C}{M_0 - M_C} = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\ exp\left[\frac{-(2n+1)^2\pi^2\ D_{eff}\,t}{4L^2}\right] \quad (1)$$

Where:

D_{eff} = the effective moisture diffusivity (m^2s^{-1})

L = is the half thickness of slice in (m)

t = is the drying time in (s) and n=0, 1. 2, …, ∞

2.11.2 Moisture content

Moisture content is the amount of moisture in a product. Moisture content is expressed as a percentage (%) either on a wet basis or a dry basis during drying, the moisture content of the product is decreased and water loss during drying is usually accompanied by shrinkage. The dry matter weight of the crop is expected to remain unchanged during drying.

The two ways of expressing moisture content are related by (Ekechukwu and Norton, 1998).

$$MC_{wb} = \frac{W_{tw}}{W_{tw} + Wt_{dm}} \times 100 \quad (2)$$

$$MC_{wb} = \frac{W_{tw}}{Wt_{dm}} \times 100 \quad (3)$$

Where

MC_{wb} = moisture content on a wet basis (%)

M db = Moisture content dry basis (%)

Wt w = weight of water

dm= weight of dry matter

2.12.3 Moisture Ratio (MR)

Moisture ratio is the ratio of the moisture content (kg/kg dry matter) at any given time to the initial moisture content (kg/kg dry matter) (Both relative to the equilibrium moisture content). It can be calculated as in equation 4 as reported by (O¨zbek and Dadali, 2007).

$$MR = \frac{Mt - Me}{Mi - Me} \quad (4)$$

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

Three cultivars of *D. rotundata* viz; (*Pona, Dente*, and *Lilli*) and one cultivar of *D. alata* (*Matches*) were used for this study. Yam samples were obtained from farmers in Ejura in the Ashanti region of Ghana in collaboration with Crop Research Institute at Fumesua. These varieties and cultivars were chosen because they are most important among food yams in Ghana and are preferred by consumers. The *D. rotundata* cultivars were cultivated in December 2011 and harvested in August 2012. The *D. alata* cultivar was planted in April 2011 and harvested in January 2012.

3.1.1 Measurement and data collection of yam

Hundred (100) tubers of selected yam cultivars of *D. rotundata* variety were picked at random and its dimensions (Length, distance and diameter) were measured using a tape measure. Radius and circumference were calculated based on the diameters.

3.1.2 Sampling for laboratory analysis and drying experiment

Four groups of twenty- four (24) healthy tubers from four cultivars were selected at random from the farm. Three tubers from each group were selected at random into three (3) separate sacks for laboratory analysis. Five tubers from these groups were also selected for drying experiment.

3.2 Sample preparation prior to drying

Homogenous yam tubers of average weight of 2.5 Kg were cleaned with napkins to remove all dust. The average dimensions (length, weight and diameter) of each tuber were taken before the start of the experiment. The yam tubers were hand peeled and

sliced with the aid of a stainless kitchen knife into a square shaped of dimension 3×3 cm and thickness 1 cm.

3.2.1 Drying process

Drying experiments were conducted during the periods of October 2012 to November 2012 in Department of Agricultural Engineering, KNUST in Ghana. The experimental dryer used for this study is Solar Adsorption Dryer System (SADS) and Solar dryer (SD). Plate 3.1 shows a picture of the SADS. The dryer consists of solar collector for day drying, adsorbent system for night drying and a collector system for regenerating the saturated adsorbent used during the night drying.

The concept of the SADS is that as air blows over the absorber plate (black coated aluminum) which receives radiation from the sun, the air heats up from the inlet section along the collector length to the outlet section. The heated air is channeled through a drying chamber by the help of fan for day drying. Dehumidified air is channeled into the dryer for night drying. The saturated adsorbent is recharged in the day for re-use by the collector with lengthier absorber plate. The drying has two cabinets of four trays (i.e. two trays at each cabinet).

Three different drying methods were used. This includes; Open sun drying (OSD), Solar drying system (SD) and Solar Adsorption Drying System (SADS). Open sun and Solar drying systems were carried out during day starting from 9.am to 5.pm. Solar adsorption drying is a combination of day and night continuous drying. Night drying starts from 5.pm to 12.a.m. The dryer was allowed to run for 30 minutes to reach the set drying air temperature conditions before loading the samples in each day. One hundred and twenty (120 g) each of yam cut (3x3x1 cm) with initial moisture content between 61-71 % depending on the cultivar were loaded on each tray in two

replicates. At the end of each of day drying, yam samples dried using SADS, SD and OSD were packed in airtight polyethylene bags and stored at room temperature. Sample meant for adsorbent drying continued at night until 10pm.This process was repeated during subsequent days and nights until desired moisture content (5 - 8 %) was reached.

Analytical balance (Model PA-2120; sensitivity 0.01g from Ohaus Co., Pine Brook NJ, USA) was used to weigh the moisture loss in the samples. The data were recorded manually every 30 mins for the first two hours and one hour for the rest of drying. Thermocouple was used for air temperatures determinations during drying processes.

The moisture contents were expressed on dry basis, (Saeed *et al.*, 2006). Moreover, the weight was converted to a more useful form, i.e., the dimensionless moisture ratio (MR) expression for calculation of moisture diffusivity (Falade and Abbo, 2007).

Plate 3.1 Solar Adsorption Dryer System.

3.3 Drying characteristics

3.3.1 Moisture ratio (MR) = $\frac{Mt - Me}{Mi - Me}$

Where;

M_i=Initial moisture content on dry basis (%)

M_e= is equilibrium moisture content on dry basis (%)

t = drying time, in min

M (t) = is dry basis moisture content at time

3.3.2 Effective diffusion

Assuming constant diffusivity, uni-dimensional moisture movement, constant temperature and negligible external resistance an analytical solution for linear diffusion in an infinite slab of thickness L as given by Crank (1975).

$$\frac{\overline{X} - X_e}{X_o - X_e} = \frac{8}{\pi^2} \sum_{n=1}^{\infty} \frac{1}{(2n-1)^2} \exp\left[-\frac{t(2n-1)^2 \pi^2 D_{eff}}{4L^2} \right] \quad (5)$$

Where $\overline{X}$, X_e and X_o are the average, initial and equilibrium moisture contents (g/g d.b) of the sample respectively at time t for a given a_w and D_{eff} is the constant effective diffusivity. L and t represent half the thickness of the slab (drying from both sides) and the drying time (s) respectively. Only the first term of the above equation can be used for long drying times.

$$MR = \frac{8}{\pi^2} \exp\left[-\frac{t\pi^2 D_{eff}}{4L^2} \right] \quad (6)$$

The slope is determined by plotting ln (MR) against time given a negative slope

$$Slope = \left[-\frac{\pi^2 D_{eff}}{4L^2} \right]. \quad (7)$$

In general, those calculated of the coefficients diffusive starting from the experimental data, they presented a good adjustment to Arrhenius equation

3.4 Chemical analysis

3.4.1 Proximate composition determination

3.4.1.1 Moisture content

Two grams (2.0 g) of each sample accurately weighed with, chemical balance (Model UB-302 IFS, England) to a previously cleaned, dried and weighed glass crucible. The crucible with its content was put into a drying oven (Gallenkamp, model OV 880, London, England) at 105^0 C for 6 hours to constant weight. The sample was then cooled in a desiccator and weighed. The process was repeated until a constant weight was obtained. The loss in weight expressed as a percentage gave the percent moisture content using the formula reported in (Appendix A). (A.O.A.C. No. 945.38) (A.O.A.C, 2005)

3.4.1.2 Ash

Two grams (2.0 g) each of oven dried milled samples were weighed with a balance (Model UB- 302 IFS, England) into dried and pre-weighed porcelain crucibles. The sample was each charred on hot plate until water and other volatile constituents were eliminated in the form of black fumes. The samples were then ashed by placing them in pre-heated muffle furnace (Gallenkamp, model OV 880, London ,England) at 600 ^{0}C for 6 hours. The crucibles with ash contents were cooled in a desiccator, weighed and the percentage ash was calculated. (A.O.A.C. No. 936.07) (A.O.A.C, 2005).

3.4.1.3 Crude Protein content

Two grams (2.0 g) of the sample was weighed with a balance (Model UB- 302 IFS, England) into a digestion flask and 0.5 g of selenium catalyst was added. Twenty-five milliliters (25 ml) of concentrated H_2SO_4 was added and the flask was shaken to mix the contents. The flask was then placed on a digestion burner for 8 hr and heated until

the solution turned green and clear. The sample solution was then transferred into a 100 ml volumetric flask and made up to the mark with distilled water.

Twenty-five milliliters (25 ml) of 2 % boric acid was pipetted into a 250 ml conical flask and 2 drops of mixed indicators (20 ml of bromocresol green and 4 ml of methyl red) solution were added followed by 15 ml of 40 % NaOH solution. Ten milliliters (10 ml) of digested sample solution was then introduced into a Kjedahl flask. The condenser tip of the distillation apparatus was then dipped into boric acid contained in the conical flask. The ammonia in the sample solution was then distilled into the boric acid until it changed completely into bluish- green. The distillate was then titrated with 0.1M HCl solutions until it became colourless. The percent total nitrogen and crude protein were calculated using the formula in Appendix A. (A.O.A.C. No.2001.11) (A.O.A.C, 2005). The percentage protein was obtained by multiplying the percentage nitrogen by the appropriate conversion factor of 6.25.

3.4.1.4 Crude Fat Content

Two grams (2 g) each of samples were weighed directly into the extraction thimble, plugged with glass wool, and placed in an extraction tube. A clean dry 250 ml Soxhlet flask was weighed, filled with 200 ml of petroleum ether (BP. 40-60 ^{0}C), and the set up refluxed for three hours. The extract was disconnected, and the thimble lifted and drained. The apparatus was reconnected and the distillation continued, using the siphon

to reclaim the ether. After refluxing, the flask was removed to a steam bath for evaporation of final few milliliters of ether and then dried in an oven at 60 ^{0}C overnight. The flask was cooled in a desiccator and weighed. The fat obtained was expressed as a percentage of the weight of the sample taken. (A.O.A.C. No. 2003.05) (A.O.A.C, 2005).

3.4.1.5 Crude fibre content

The defatted sample (from crude fat determination) was transferred into 750 ml Erlenmeyer flask and 0.5 g of asbestos was added. Two hundred (200) ml of boiling 1.25 % H_2S0_4 was added and the flask was immediately set on a hot plate and a condenser set to it. The content was brought to boil within 1 minute and the sample was digested for 30 minutes. At the end of the 30 minutes, the flask was removed and the content was filtered through a linen cloth in a funnel and subsequently washed with boiling water until the washings were no longer acidic. The sample was washed back into the flask with 200 ml boiling 1.25 % NaOH solution. The condenser was again connected to the flask and the content of the flask was boiled for 30 minutes. It was then filtered through the linen cloth and thoroughly washed with boiling water until the boiling was no longer alkaline. The residue was transferred to a clean crucible with a spatula and the remaining particles washed off with 15 ml ethanol into the crucible. The crucible with its content was then dried in an oven (Gallenkamp, Model OV 880, England) overnight, cooled in a desiccator, and weighed. The crucible with its content was ignited in a furnace (Muffle furnace size 2, England) at 600 ^{0}C for 30 minutes, cooled and reweighed. The loss in weight gave the crude fibre content and was expressed as a percentage of the initial weight of the sample using the method of A.O.A.C. 920.86 (A.O.A.C, 2005). The calculation is shown in appendix A.

3.4.1.6 Carbohydrate content

Total percentage carbohydrate was determined by the difference method. Available carbohydrate content was calculated by difference [(100- total of A)] where A is moisture + crude fat + ash + crude fibre + crude protein (A.O.A.C. No. 986.25) (A.O.A.C., 2005).

3.5 Mineral Determination

3.5.1 Sample preparation

Two grams of each dried sample were weighed accurately and ashed in muffle furnace (muffle furnace size 2, England) preheated to 600 ^{0}C for 2 hours. 2 ml of HCl was poured on ashed sample to dissolve sample. Distilled water was used to wash left over ash in the crucible and poured in volumetric flask. This was made up to 50 ml mark using distilled water prior to analysis.

3.5.2 Calcium determination

Calcium was determined by O- Cresolphthalein complexone method in which calcium form a complex with a buffer medium of O- Cresolphthalein complexone (CPC) to form a deep violet colour. A stock solution of 100 mg/L was prepard from $CaCO_3$ by dissolving in 10 % HCl and six serial standard prepared from stock.

Colour Development Reagents

The Colour Development Reagent was prepared by adding 20 ml of 2-amino-2-methyl-1-propanol (buffer) to 30 mg of CPC in 1L of solution+80 ml of ethanediol. Hundred milligrams (100 mg) of 8- hydroxyquinone was added.

Procedure

2.5 ml of CDR was added to 0.2 ml of each the serial standard and the sample and incubated at room temperature for 20 minutes. The absorbance of each sample was determined with a UV spectrophometer (UNICAM 929 AA Spectrophometer, Gloucester, UK) at 570 nm. A standard calibration curve was plotted for absorbance (y) against concentration (x) to calculate the unknown concentration. (Norbert,1986).

3.5.3 Phosphorus

Phosphorus was determined by Ascorbic Acid-Molybdate method using spectotrophotometer. One hundred milligram per litre (100 mg/l) of phosphate was prepared and six serial standards were prepared from the stock at 5,10,15,20 mg/l respectively.

***Colour development reagent* (CDR)**

Mix colour development reagent was prepared with 50 ml of 2.5M H_2SO_4+5 ml PAT (Potassium Antimonyl Tatrate) + 30 ml of AM (Ammonium Molybdate) and 15 ml AA (Ascorbic Acid). All the reagents were mix until a colour was developed.

Procedure

2.5 ml of CDR was added to 0.25 ml of each serial and each sample, and incubated for 20 minutes. The absorbance was read at 770nm using UV spectrophometer (UNICAM, 929 AA Spectrophometer, Gloucester, UK). A calibration curve was plotted for absorbance (y) against concentration (x) of which phosphorus in the sample was calculated. (Greenberg *et al*.,1992).

3.5.4 Iron determination

Standard stock of 100 mg/l Ammonium- Iron II sulphate solution was also prepared as a stock solution. Five serial standard of 1,2,3,5 and 8 respectively were prepared from stock solution.

Reagent preparation.

Colour reagent was prepared by adding 5 % hydroxylamine hydrogen chloride to 0.5 % of 1, 10-phenanthroline.

Procedure

One milliliter (1.0 ml) of hydroxylamine hydrogen chloride was added to 0.2 ml of each of serial /sample and 1.0 ml of 1, 10- phenanthroline was added to the mixture and incubated for 20 minutes. The absorbance was read at 520nm using UV spectrophometer (UNICAM 929 AA Spectrophometer, Gloucester, UK). Calibration curve was plotted for absorbance (y) against concentration (x). From the equation of the graph the contration of sample was calculated. (AOAC, 2005).

3.6 Ascorbic acid determination

Sample preparation

One gram each of sample was soaked in 4 % oxalic acid for ten minutes and it was ground using a pestle and mortar. The contents were filtered and the volume was made up to 100 ml with oxalic acid. Protein were precipitated with 10 % trichloroacetic acid and centrifuged.

Procedure

Hundred (75) µL of DNPH (2 g of dinitrophynl hydrazine, 230 mg thiourea and 270 mg $CuSO_4$ in 100 ml 5M H_2SO_4) was added to 500 µL protein-free supernatant

sample. The sample was incubated at 37 ^{0}C for 3 h. 0.5 ml of H_2SO_4 (sulphuric acid) of 65 % (v/v) was added to the medium and the absorbency was recorded at 520 nm using UV spectrophometer (UNICAM 929 AA Spectrophometer, Gloucester, UK).

Calibration curve was plotted for absorbance (y) against concentration (x). From the equation of the graph the concentration of sample was calculated. (Benderitter *et al*., 1998).

3.7 Instrumental determination of colour

The colour of fresh and dried yam slices was determined in terms of the tristimulus colour values L*, a* and b* using Minolta Chroma meter, CR-300 (Minolta Co. Ltd., Osaka, Japan). Where, L* indicates lightness or darkness of the material. Where L* = 0 is completely black and L* = 100 is completely bright. The a*is the colour coordinate in red-green axis. Positive (+ve) a* value redness and negative (-ve) for greenness. b*is the colour coordinate in yellow-blue axis. Positive (+ve) for yellowness and negative (-ve), blueness. The colour of the yam slices were measured after calibrating the instrument with white tile (L* = 93.3 a* 0.32 and b* 0.33). Yam slices were put into a transparent petri dish and the measuring head of the meter was carefully placed on three different locations on the petri dish. The measurements were determined in triplicates and mean and standard deviations determined.

3.8 Determination of water activity

The water activity of fresh and dried yam was measured at room temperature (29.5 ± 1 °C) using a water activity meter (Aqua Lab, Model Series 3TE, Washington

USA). The water activity metre was calibrated using 0.5 mol/kg NaCl salt at room temperature of 25 ^{0}C. Three measurements were taken for each cultivar and average values were determined.

3.9 Sensory evaluation

3.9.1 Recruitment

Twenty member (20) trained **panelists** were used for the sensory evaluation. The selection was based on willingness to participate. Recruited panelist ability to recognize the basic taste (sweet, bitter, sour and salt) was tested.

3.9.2 Preparation of dried food products

The traditional method of *amala* preparation was adopted with little modification.

The dried yam chips were milled into flour. Ninety grams of the flour was poured into 300 ml of boiling water on fire and stirred continuously with a wooden spoon until a thick consistent paste was obtained (Baah, 2009).

Colour, taste, texture, appearance and overall acceptability were the attributes that were scored during sensory evaluation; the ability to describe and use the attributes in scoring samples was tested using standard methods (such as difference test, descriptive test and ranking test). This was done until all panelists were conversant with the quality attributes and the sensory test procedure to be used. Panelists were requested to assess each coded sample, using a 9-point Hedonic scale. On this scale, 9 = Like extremely; 8= Like very much; 7= Like moderately; 6 = Like slightly ;5= Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2= Dislike very much; 1 = Dislike extremely.

3.10 Experimental design and statistical analysis.

A completely randomized design was adopted for the study. All means were reported in two replications. (MATLAB) and Microsoft excels 2007 were used to show the graphical representation. Minitab (version 16) was software used for statistical Analysis. One way Analysis of variance (ANOVA) used to determine differences in

proximate composition, mineral content, sensory evaluation. Fischer's Least Significant was performed for post multiple comparisons to separate the means.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Proximate composition of fresh yam

Table 4: 1 shows the proximate composition of fresh yam.

Table: 4.1 Proximate composition of fresh yam sample (%)

Variety	Moisture	Ash	Crude protein	Crude fibre	Crude fat	CHO
D.rotundata						
Dente	67.35±0.01^{b}	2.44±0.01^{b}	5.14±0.01^{c}	1.34±0.01^{b}	0.25±0.01^{a}	23.74±0.37^{c}
Lilii	65.18±0.01^{c}	2.99±0.01^{a}	4.76±0.03^{d}	1.49±0.01^{a}	0.23±0.01^{a}	25.68±0.01^{b}
Pona	60.77±0.01^{d}	1.97±0.14^{c}	5.27±0.14^{b}	0.98±0.01^{c}	0.25±0.01^{a}	30.99±0.01^{a}
D.alata						
Matches	71.04±0.01^{a}	2.40±0.02^{b}	5.85±0.01^{a}	1.37±0.01^{b}	0.25±0.01^{a}	19.72±0.01^{d}

Values are Means ± standard deviation from duplicate analyses. Those with the same superscripts in the same column are not significantly different at P>0.05

4.1.1 Moisture content

In this study, the moisture content of fresh yam was found to be 60.77, 65.18, 71.04, 67 .35 % for *Pona*, *Lilii*, *Dente (D.rotundata)* and *Matches (D.alata)* respectively with *Dente* recording the highest among the white yam and *Pona* the least. Significant differences (P<0.05) were obtained in the moisture content of the yam cultivars investigated due to varietal differences. In this research, *D.alata* (*Matches*) had the highest moisture content of 71.04 %.

This value was higher than the values reported in literature by Adegunwa *et al*. (2011) and Polycarp *et al*. (2012) for water yam (*D. alata*) who obtained 62.76 % and 64.88 % respectively. Baah, (2009) have reported similar ranges of 66.2 – 80.9 % for *D. alata* values in literature. In addition, various researchers (Coursey, 1967; Eka, 1985;

Brabury and Holloway, 1988; Osagie, 1992; Asiedu *et al*., 1997; Opara, 1999 and Agoreyo *et al*., 2011) for *D. rotundat*a and *D.alata* respectively have reported comparable ranges of 50 % - 80 % and 65-78.6 %. The moisture content of any sample is an index of its keeping quality and thus an indicator of the shelf life. The lower the moisture contents the longer the longevity making *Pona* a cultivar that can be stored for a longer period.

4.1.2 Ash content

The ash content of fresh sample of the test cultivars ranged from 1.9 - 2.99 % with *D.rotundata* (*Lilii)* recording the highest and *(Pona)* the lowest. Though significant difference ($p<0.05$) existed between cultivars generally, differences between *D.rotundata* (*Dente)* and *D.alata* (*Matches)* were not significant ($p>0.05$) in terms of ash content. Some researchers (Agoreyo *et al.*, 2011: Aghor - Egbe Treache, 1995) reported ranges of 1.10 - 1.7 % for *D. rotundata* which is lower than that obtained in this work. Others reported a range of 0.7-2.1 % and 0.7- 2.6 % for *D.alata* and *D. rotundata* respectively (Coursey, 1967; Eka, 1985; Brabury and Holloway, 1988; Osagie, 1992; Asiedu *et al.*, 1997 and Opara, 1999). However, the value of 2.40 % obtained for *D.alata* (*Matches)* are lower than a value of 5.2 % reported by Baah, (2009), for *D. alata*. Ash content is an indication of mineral status of food product and it depends on maturity or soil type and can be because of contamination.

4.1.3 Crude protein

The crude protein content of fresh *D. rotundata* cultivars ranged between 4.76 % for *Lilii* and 5.27 % for *Pona* compared to a value of 4.42 % reported by Treche *et al.* (1994) and 7 % obtained by Shoeninger *et al*. (2001) for white yam. However, the protein content of *D. alata* cultivar (*Matches*) was 5.85 % falling below a value of 6.08 % reported by Polycarp *et al*. (2012) and 8 % by Shoeninger *et al*. (2000) for the

Matches cultivar. Baah, (2009) reported a range of 4.3 - 8.7 % for *D. alata*, while, Osagie (1992) found a range of 1.4 - 3.5 % for the same cultivar. There were significant difference ($p<0.05$) among test cultivars.

4.1.4 Crude fibre

The crude fibre content among the test *D. rotundata* cultivars ranged from 0.98 % - 1.49 % with *Pona* recording the least and *Lilii* highest. A range of 1.4 - 3.8 % had been reported in literature by Coursey (1967), Eka (1985); Brabury and Holloway (1988); Osagie (1992): Asiedu *e*t *al*. (1997) and Opara *et al.* (2009). Agbor- Egbe (1995) reported a range of 0.1- 0.92 %. Differences between current work and literature values may be because of soil nutrient and maturity.

4.1.5 Crude fat and carbohydrate (CHO) content

The crude fat content was between 0.23 – 0.25 %. However, there was no significant ($p>0.05$) difference between crude fat content of test cultivars. Shoeninger *et al.* (2000) had previously reported similar result for yams. Carbohydrate contents ranged from 19.72 - 30.99 % with *D. rotundata* (*Pona)* recording the highest content and the *D. alata* sample (*Matches*) recorded the least. Among the *D. rotundata* samples, *Dente* had the least carbohydrate content of 23.74 %. There was significant difference ($p<0.05$) between carbohydrate content of test cultivars.

4.2 Preliminary work

The information on dimensions of the yam is necessary in the determination of the number of cuts that could be derived from each tuber of yam with specific range of dimension selected. In addition, the distribution pattern of the moisture in the yam is necessary in determination pattern before drying. Tables 4.2 A- shows the average range of selected cultivars of fresh white yam (*D. rotundata*).

Table: 4.2-A Average dimensions of the selected cultivars of fresh white yam (*Dioscerea rotundata)*

Name of cultivar	Weight (kg)	Length (cm)	Circumference (cm)	Radius (cm)
Pona	2.3-5.2	37.3-62.3	29.2- 43.7	4.64-6.95
Lilii	3.0-17.9	38-72.3	23.2-10.3	3.69- 4.1
Muchumudu	2.7-5.9	37.3-56.8	31.4-53.2	4.99 -8.47
Laribakor	1.8-3.5	40.0-55.0	22.0-41.7	3.5- 6.63
Dente	2.7-5.9	37.1-53	33.4 -45.9	5.32-10.34

The weight ranged from1.8-3.5 kg to 3.0- 17.9 kg in *Laribako* and *Lilli* respectively. In general, *Laribakor* had the least range of weight (1.8-3.5 kg) and *Lilii* had the highest range from 3.0 to 17.9 kg. The analysis show high variation in the weight of white of yam.

The length ranges from 37.3-56 cm in *Muchumuduu* to 38-72.3 cm *in Lilii* respectively. The radius ranges from 3.5-6.63 cm *Laribakor* to 5.32-10.34 cm in *Dente.* The circumference ranged from 22.0-53.2 cm for *Laribako* and 31.4-53.2 cm *Muchumuduu* respectively. *Laribakor* had the least circumference compared to other cultivars used for this investigation

Table 4.2 B shows the average mean dimension of the cultivars used for the study. The average weight of yam ranged from 2.31 kg to 7.86 kg in *Laribako* and *Lilii* respectively.The high standard deviation showed indicate variation in weight in the same cultivar. The average length ranged from 44.28 cm to 52.37 cm in *Dente* and *Lilii* respectively. *Lilii* had the highest circumference and radius of 47.76 cm and 7.61 cm respectively.

Table 4.2 B Mean dimension of the cultivars of fresh white yam (*D. rotundata*)

Name of cultivar	Weight (kg)	Length (cm)	Circumference (cm)	Radius (cm)
Pona	3.70±0.98	49.55±5.39	32.62±6.15	5.19±0.47
Lilli	7.86±4.23	52.37±7.50	47.76± 7.08	7.61±1.13
Muchumuduu	3.70±0.98	49.75±4.95	36.08± 4.52	5.74± 0.91
Laribako	2.31±0.278	44.76±4.82	33.77± 5.11	5.37±0.89
Dente	3.59±0.64	44.28±2.54	44.41±7.09	7.10±1.13

4.3 Mositure distribution in fresh white yam.

Drying require reducing the moisture content in order to prevent post-harvest losses. The knowledge of the moisture distribution pattern in the tuber is therefore necessary to inform the experimenter as well as the food industrialist for moisture analysis and the energy content necessary for drying respectively.

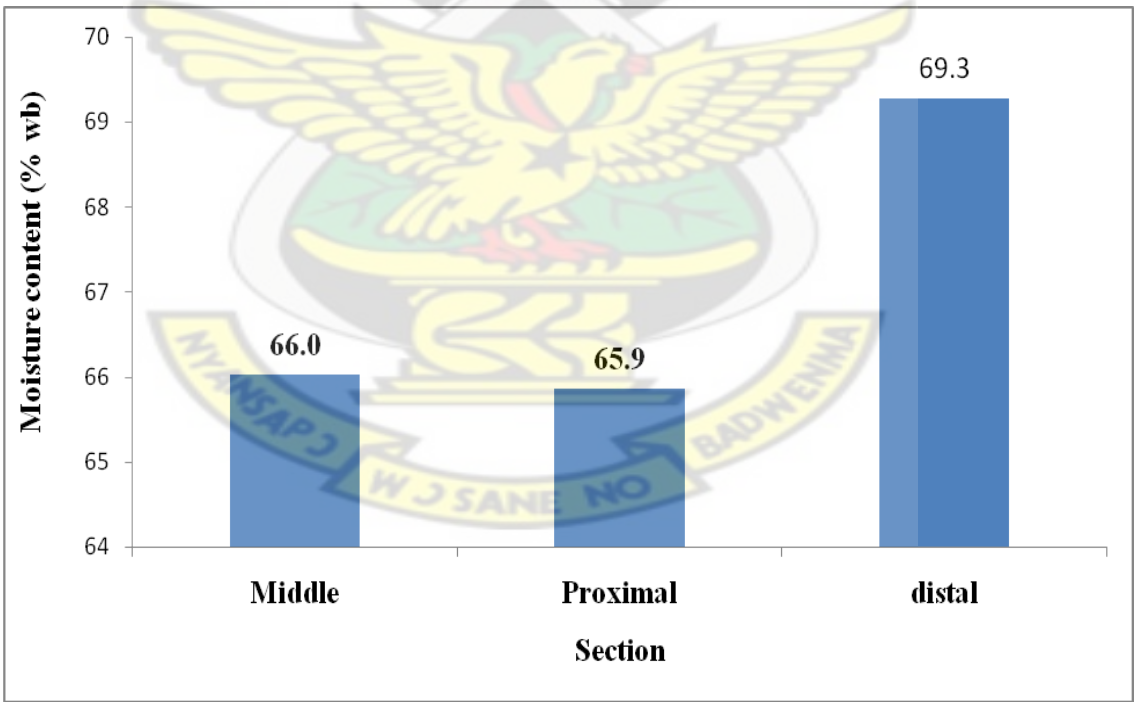

Fig: 4:1 Average Moisture content distribution in five cultivars of white yam (D.rotundata).

The moisture content of proximal part (PP), median part (MP) and distal part (DP) of five cultivars *Pona, Muchumuduu, Dente, Laribako* and *Lilii* cultivars of yam belonging respectively to *Dioscorea rotundata* are summarised in figure 4.1. The moisture content of yam tuber at different parts varied meaningfully from distal part to other parts of yam

In this study, moisture content distribution was higher in the distal part compared to the proximal and middle part. Figure 4.1 shows the moisture content distribution of various parts of fresh white yam (*D.rotundata*)..

The study indicated that there was no signicant difference in moisture content between the middle and the proximal region of yam, however, the distal region is significantly higher than proximal and middle portions. Kouakou *et al. (*2010), reported moisture content was different at different parts of the yam tuber.

4.4 Drying behavior of yam at different drying methods

4.4.1 Varietal effect of yam on drying behavior

Different varieties of yam have different structural formation. Therefore, it is expected that they will have different drying rates when subjected to the same drying conditions. In addition, different drying methods will have varying energy outputs and usage and thus impact on a sample differently. In view of these, it is expected that structural differences and different drying methods will affect nutrient content and heat sensitive components differently. Figures 4.2 A-C show the impact of the drying methods on the drying behavior of three cultivars of *D. rotundata* variety. From this figure, the results indicated that throughout the different drying methods *Lilii* dried faster, followed by *Pona* and the *Dente.* The present findings show that the granule size of the *Dente* was smaller than that of both *Pona* and *Lilii.* However, for the SD system in this work,

there were no significant differences in the drying behavior of the *Pona* and *Lilii* cultivars (see Figure 4.2 B).

Figure 4.3a-c shows the drying behavior of each cultivar subjected to SADS, SD and OSD drying methods. In all the cultivars, the SADS, which is the combination of adsorption and solar drying, removed the free water faster than the SD system, which was only solar drying. It could be realized that the OSD was less effective in terms of moisture removal. For instance, while it took 4 days to dry various cultivars of yam to between 0.024-0.14 kg/kg db and 0.06-0.16 kg/kg db moisture content with SADS and SD respectively, it took 9 days to dry to between 0.098-0.24 db moisture content with OSD. SADS method involves low temperature and low humidity, so it is expected that impact on the heat sensitive components will be mild.

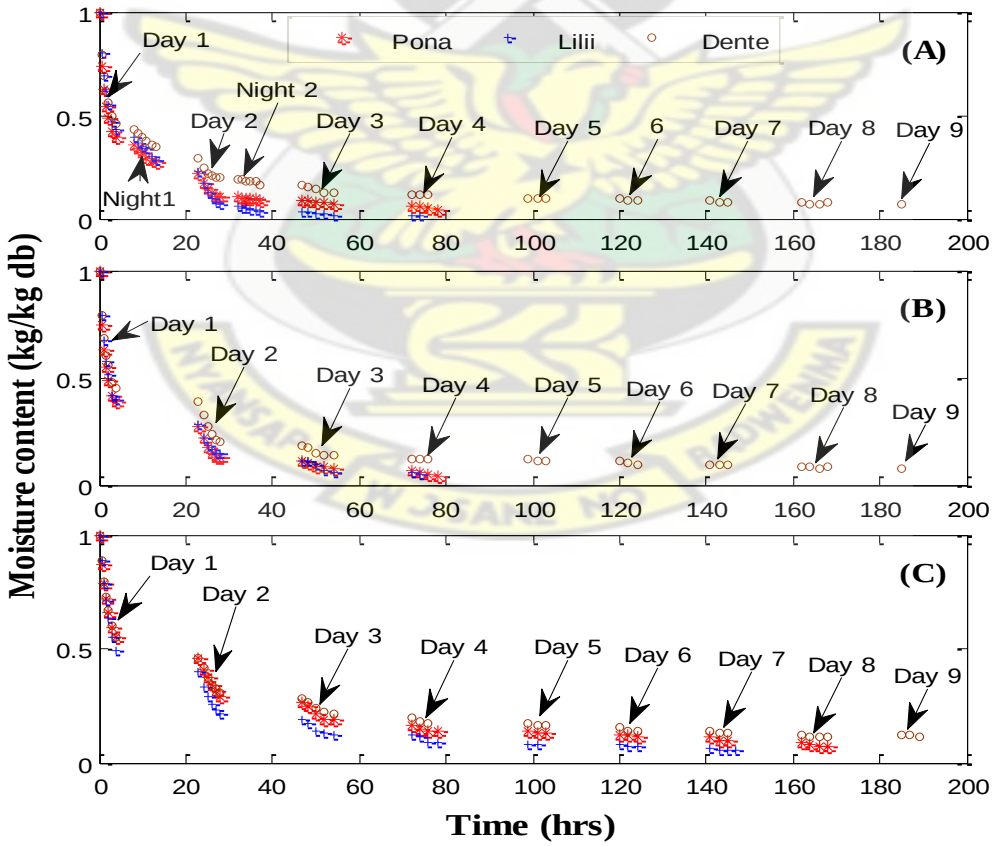

Figure 4.2 Same drying methods: SADS (A), SD (B) and OSD (C) on different cultivars of D. rotundata

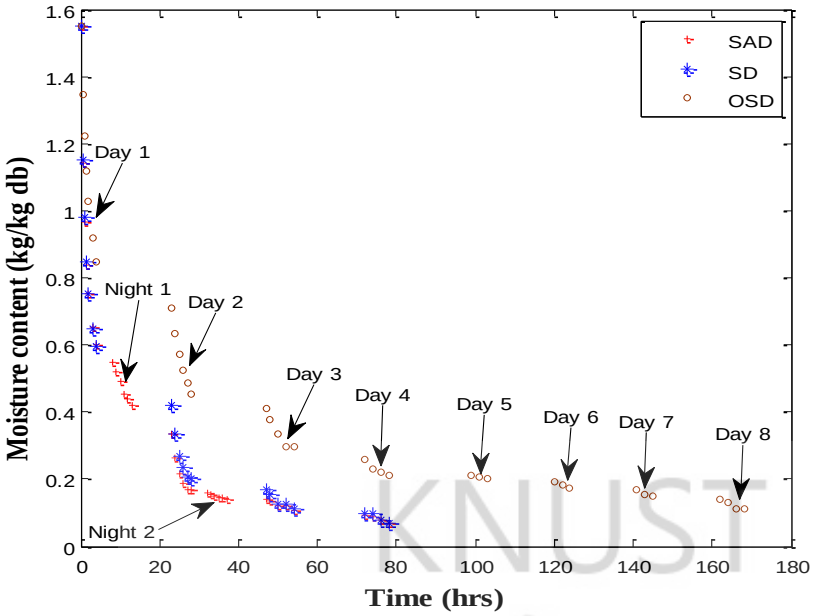

Figure 4.3a Effect of drying methods on drying behaviour of Pona.

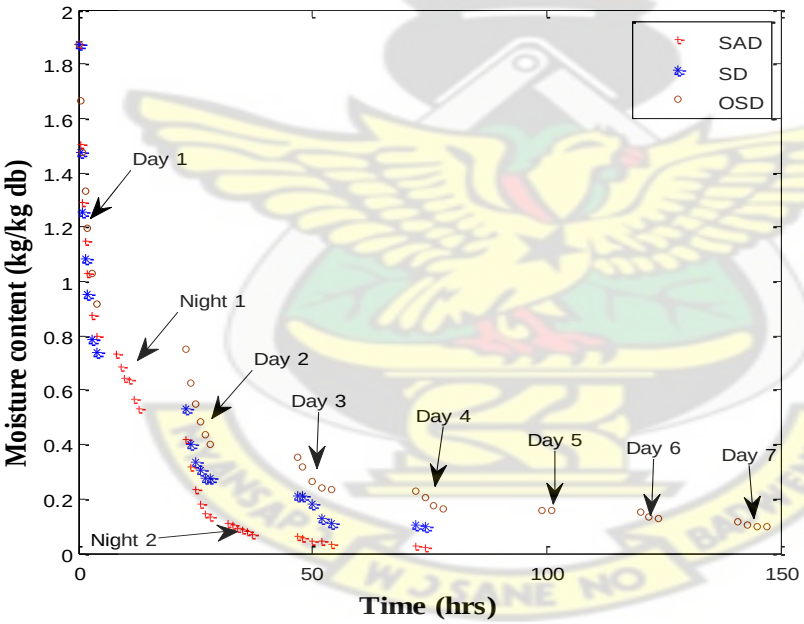

Figure 4.3b Effect of drying methods on drying behaviour of Lilii.

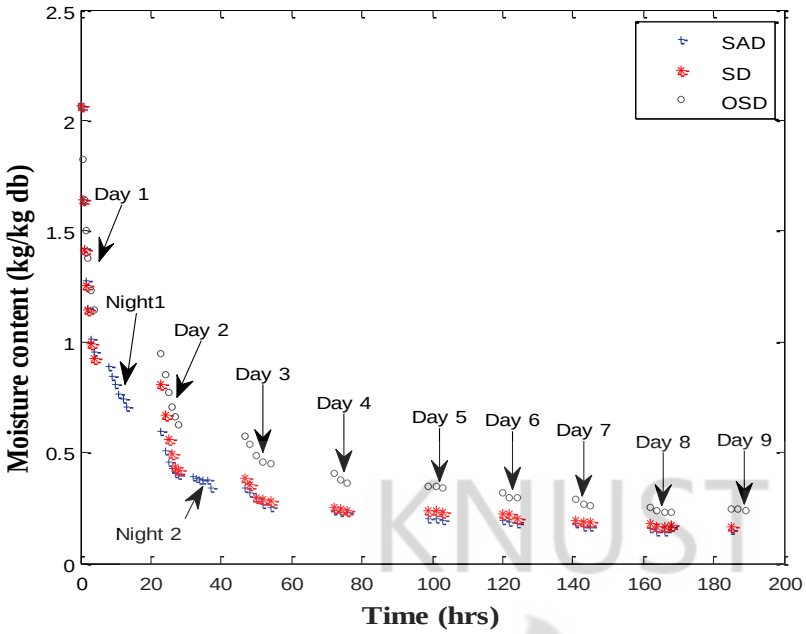

Figure 4.3c Effect of drying methods on drying behaviour of Dente

4.4.2 Effective moisture diffusivity

Diffusion method was used in the study of the transfer of mass of agricultural products For the case of the *D. alata* and *D. rotundata* the integrated equation of the second law of Fick was used (Eq. 6) for long time drying.

Table 4.3 Effective moisture diffusivity (m^2/s) of four yam cultivars using various drying methods.

		Drying methods		
Variety/ Cultivar		**SADS**	**SD**	**OSD**
D.rotundata	*Pona*	2.03×10^{-10}	4.12×10^{-10}	2.03×10^{-10}
	Lilii	4.05×10^{-10}	5.06×10^{-10}	4.05×10^{-10}
	Dente	6.08×10^{-11}	4.05×10^{-11}	4.05×10^{-11}
D. alata	*Matches*	4.15×10^{-10}	4.15×10^{-10}	3.03×10^{-10}

Effective moisture diffusivity of three yam cultivars (Pona, Dente, Lilii) D. rotundata and one cultivar(Matches) D. alata using the various methods of drying.

The values of effective moisture diffusivity (D_{eff}) of yam slices were calculated using Eq. (8, 9). Moisture diffusivity (D_{eff}) varied from 2.03×10^{-10} SADPO to 6.08×10^{-11} m^2/s SADDE. These values are within the general range 10^{-9} to 10^{-11} m^2/s for drying of

food (Maskan *et al*., 2002). These values can be compared to 8.7×10^{-10} to 12.51×10^{-10} m^2/s reported by Koua *et al*. (2013) for thin layer drying of yam slice at 35- 45^0 C. In this study, *Dente* had the highest diffusivity from 4.05×10^{-11} to 6.08×10^{-11} m^2/s in SADS, SD and OSD respectively.

The effective diffusivity (D_{eff}) presents a direct relation with the temperature. Torres *et al*. (2012) reported a ranged of 7.03×10^{-9}-1.7×10^{-9} m^2/s and 6.70×10^{-9} - 1.51×10^{-9} m^2/s at temperatures 40-70 ^{0}C respectively using circular and square shape of the same variety (9506-21). In the present study, drying method did not affect the effective moisture diffusivity but the type of the cultivar. *Dente* had the lowest rate of moisture diffusivity among the tests cultivars.

4.5 Proximate composition of dried yam

The result obtained from the proximate analysis of the dried samples using various methods is as shown in Table 4.4. It was observed that moisture content levels of the samples using various drying methods were all below 10 % (db) which is within the acceptable range for well packaged dehydrated yam product (Okaka and Okechukwu, 1993). Higher ranges were reported by Agoreyo *et al.* (2011) as 6.8 – 13 % and Jimo *et al.* (2007) as 12. 30 - 15.4 % for *D. rotundata* yam flours. The ranged is still lower than the ranged 8.4-10.7 % found by Ukpabi *et al.* (2007) for sun dried chips from *D. alata* cultivars. It was observed that all the three methods were able to remove moisture but Solar drying (SD) and Solar adsorption drying had highest water removal compared to open Sun drying (OSD). There were significant differences ($p<0.05$) in moisture content among various drying methods however, there was no significant differences between SADPO and SDPO and SADLI and SDLI. Reduction in moisture content as observed in this study will reduce perishability and therefore extend the shelf-life of yam as food crop and make it available throughout the year.

Ash content ranged between 2.55-3.60 %. These were relatively higher than what was reported by Olajumoke *et al.,* (2012) for white guinea yam. There were significant differences ($p<0.05$) in ash content among various cultivars however, differences between *Pona* and *Lilii* were not significant for all the methods. The drying methods did not significantly affect the ash content.

Table: 4. 4 Proximate composition of dried yam samples using three methods (SADS, SD and OSD %)

Method parameter	Moisture	Ash	Protein	Crude Fibre	Crude fat	CHO
SADPO	5.21±0.01^{f}	3.60±0.14^{a}	3.81±0.08^{d}	1.05±0.03^{d}	0.62±0.02^{ab}	85.84±1.46^{a}
SADLI	5.75±0.09^{d}	3.40±0.14^{a}	3.19±0.01^{e}	2.55±0.10^{a}	0.56±0.01^{ab}	83.12±0.01^{a}
SADDE	5.16±0.14^{de}	2.85±0.01^{b}	3.94±0.01^{cd}	2.05±0.01^{c}	0.56±0.01^{ab}	85.44±1.26^{a}
SADMA	5.74±0.04^{ef}	2.64±0.14^{bc}	4.77±0.01^{a}	2.31±0.01^{ab}	0.56±0.01^{ab}	83.96±0.01
SDPO	5.15±0.07^{f}	3.52±0.01^{a}	3.91±0.01^{cd}	1.04±0.01^{d}	0.64±0.01^{ab}	85.05±1.48^{a}
SDLI	5.80±0.14^{d}	3.60±0.14^{a}	3.38±0.01^{e}	2.54±0.01^{a}	0.56±0.01^{ab}	83.34±0.93^{a}
SDDE	5.20±0.14^{f}	3.00±0.01^{b}	3.94±0.01^{cd}	2.05±0.07^{c}	0.50±0.01^{b}	85.87±0.03^{a}
SDMA	5.78±0.04^{ef}	2.65±0.14^{bc}	4.75±0.03^{a}	2.34±0.01^{ab}	0.52±0.03^{b}	82.48±0.01^{a}
OSDPO	7.00±0.14^{bc}	3.52±0.01^{a}	4.32±0.01^{b}	1.05±0.01^{d}	0.58±0.01^{ab}	83.20±0.96^{a}
OSDLI	6.78±0.03^{c}	3.60±0.14^{a}	3.82±0.01^{d}	2.56±0.14^{a}	0.52±0.09^{b}	83.07±1.32^{a}
OSDDE	7.26±0.09^{b}	2.95±0.01^{b}	4.38± 0.16^{b}	2.13±0.04^{bc}	0.56±0.01^{ab}	85.87±0.03^{a}
OSDMA	8.00±0.14^{a}	2.55±0.01^{c}	4.10±0.03^{c}	2.35±0.03^{ab}	0.50±0.01^{b}	82.36±0.01^{a}

Values are Means ± standard deviation from triplicate analyses. Those with the same superscripts in the same column are not significantly different at P>0.05.

In this study, the protein levels obtained in the fresh sample as shown in Table 4.1 (4.76 - 5.85 %) in general were relatively higher than dried yam (3.19 - 4.10 %). Similar observations of reduction in protein were reported in literature. Agoreyo *et al.* (2011) found a drop from 4.50 to 2.75 % respectively for fresh and solar dried yam. Agunbiade *et al*. (2006) mentioned a decrease in banana after solar drying from 15.41 to 7.20 % and 13.21 to 6.30 % in banana and plantain respectively. In all the methods and concerning the *D. rotundata* samples the *Dente* recorded higher protein values. In terms of the drying methods, the OSD dried samples recorded relatively higher crude protein values after drying, followed by SD and then SADS in that order. There were

significant differences in protein content between drying methods. The decreased in protein content on the application of heat can be attributed to protein forming complexes with tannins and therefore decreasing its availability (Enonfon-Akpan and Umoh, 2004). Similar results had been be recorded by Agoreyo *et al*. (2011) for *D. rotundata* using various drying methods.

There was an increased in crude fibre and crude fat in all drying methods compared to the fresh sample. Crude fibre increased from 0.98 - 1.37 % for fresh samples in Table 4.1 to 1.04 - 2.56 % for dried samples for various drying methods. There existed significant differences among the crude fibre content of the yam cultivars but not the drying methods. Crude fat was less than one (0.50 – 0.64 %) for all the drying methods representing an increase of 117 – 156 % from the fresh crude fat content to the dried sample. The increased obtained in this study could be as a results of increase in concentration by the removal of moisture (Hassan *et al*., 2007).

4.6 Mineral and vitamin C content of fresh and dried yam cuts

Retention of nutrient in a processed food is an important component of food research. Knowledge of the final nutrient content helps to evaluate the processing method and its effect on the quality of the final product that ends in the hands of the consumer. In view of this, some mineral components were determined to ascertain the extent of increase or reduction and to make recommendation for improvement in the processing scheme.

The mineral content of the fresh and dried yam samples are presented in Figures 4.4a-c. In Figure: 4.4a the results obtained shows significant differences between the phosphorus content of the fresh sample. The highest phosphorus content in the fresh sample was found in *Lilii* (159 mg/100 g) while the least was found in *Matches* (123

mg/100 g). A significant increase in phosphorus content were obtained for all drying methods with SADS dried sample recording the highest content except *Pona* where the SD dried sample had the highest. Meanwhile the OSD dried sample recorded the least phosphorus content among all the drying methods and for all the cultivars. Previous studies done by Polycarp *et al.* (2012) recorded a value of 158 mg/100 g for dried *Pona*, which compared well with the SADS and SD dried *Pona.* However, what was obtained for *Matches* (239 mg/100 g) in their findings was about two times more than what was obtained in this research. The phosphorus content of all cultivars in this work were all lower than that reported by Huang *et al.* (2007) for *D. alata.*

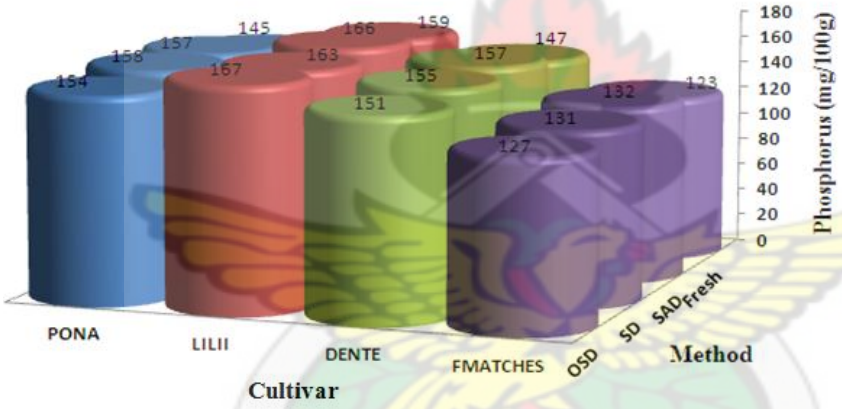

Figure 4.4a Different drying methods on the phosphorus content of various yam cultivars.

Calcium content for fresh and dried yam samples is presented in Figure 4.4b. It is observed that the *Lilii* again recorded the highest calcium content for all the fresh samples. Here the drying methods caused a decrease in the calcium content with the SADS dried samples recording the highest calcium content of all the cultivars. OSD dried samples again recorded the lowest calcium content of all the cultivars. In this research the calcium content in the fresh sample ranged between 44.2 and 63.8 mg/100g with *Lilii* comparing favourably with Huang *et al.* (2007) at a growth age of 225 days for yam cultivars of TN1 and TN2. This ranged is higher than those recorded

by Bell and Favier (1981) in yam whole tubers of D. *dumetorom* with range 41.8 - 52.4 mg/100 g. Agoreyo *et al*. (2011) reported calcium values of 42.3, 38.50 and 39.60 mg/100g for fresh, sun and solar dried white yam respectively. These results compared favorably with the SADS and SD dried cultivars but relatively higher than the OSD dried cultivars (Figure 4.4). Significant differences ($p<0.05$) were observed in between calcium content of yam cultivars and methods Table 4.5.

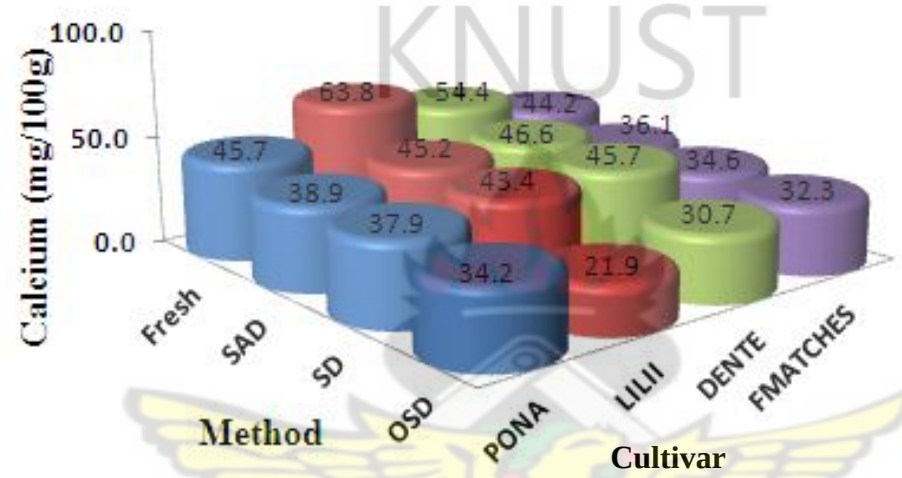

Figure 4.4b Different drying methods on the calcium content of various yam varieties

The iron content of the fresh and dried samples are presented in Figure 4.4 c. it was observed that for the fresh yam samples, Iron content of *Pona* and *Matches* were higher and similar compared to that of *Lilii* and *Dente*, meanwhile drying method did not have any observable effect on the the cultivars. The drying methods had some effect on the iron content with OSD dried sample recording the least iron content. The iron content of the fresh samples ranged between 2.0 mg/100 g in *Dente* to 3.5 mg/100 g *Pona* and *Matches.* Comparative ranged of 0.7 to 5.2 mg/100 g has been reported by Osagie (1992). Olaofe and Sanni (1988) reported range of 12.4-16.5 mg/100 g while Afoakwa and Sefa-Dede (2002) reported a range of 8.89-10.0 g/100 g for white and

yellow yams from *D. dumetorum*. These were higher than what was obtained in this present work.

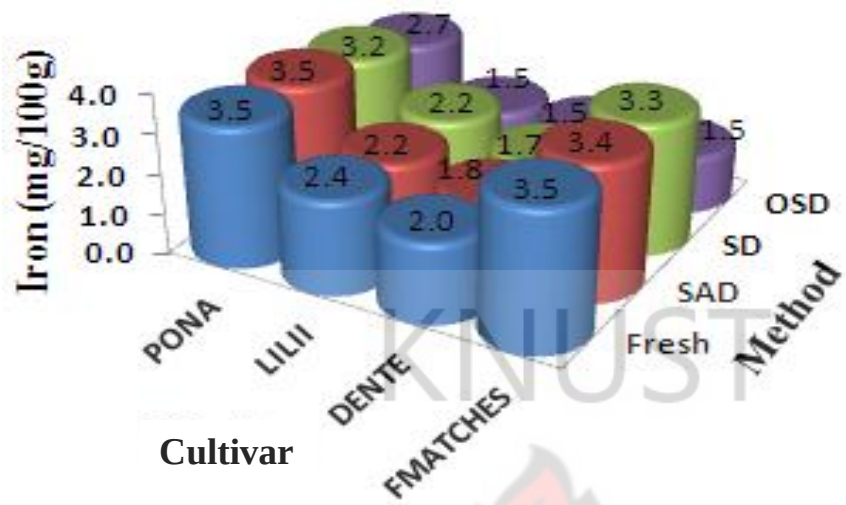

Figure 4.4c Different drying methods on the iron content of various yam cultivars.

Vitamin C content of the fresh and dried samples is presented in Figure 4.5. In this figure, it is observed that all the drying methods significantly affected the vitamin C content. Fresh *Dente* recorded the highest vitamin C content (19.8 mg/100 g) followed by *Pona* (17.4 mg/100 g) while *Lilii* and *Matches* recorded the least of 9.3 % each. Comparable ranged of 4 to 18 mg/100 g has been reported in yam (Osagie, 1992). From this research it obvious that the time of exposure to the drying methods ultimately has significant effect on vitamin C. The SD dried samples rather retained more vitamin C than the SADS dried samples since the exposure time of the SADS samples were longer though it was expected that night drying involved in low temperature and low humidity. Afoakwa and Sefa-Dede (2001) presented vitamin C content of 23.27 and 28.31 mg/100 g for fresh white and yellow yams respectively from *D. dumetorum* variety. Meanwhile, Udensi *et al.* (2008) reported a range of 16.7-28.4 mg/100 g for fresh water yam (*Dioscorea alata*).

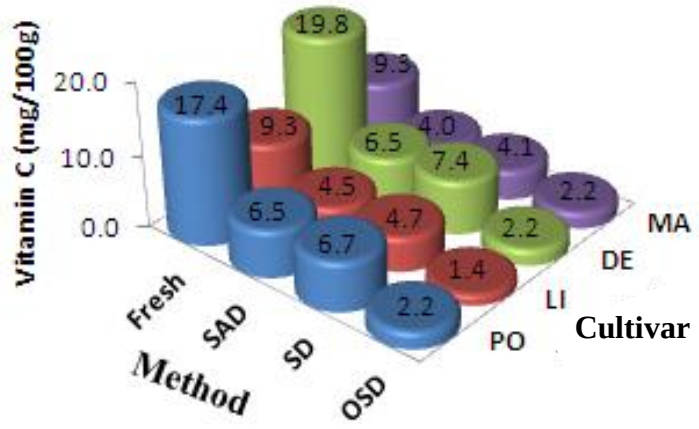

Figure 4.5 Different drying methods on the vitamin C content of various yam cultivars.

4.7 Effect of drying methods and yam cultivars on some minerals and vitamin C

It could be observed from figure 4.5 that though drying methods had siginificant ($p<0.05$) effect on the phosphorus, calcium, iron and vitamin C content in each cultivar; *Pona* (Po), *Lilii* (Li), *Dente* (De), and *Matches* (Ma), the differences in SADS and SD dried samples were generally not significant ($p>0.05$) compared to the content in the fresh sample and OSD dried samples.

With regards to cultival effect on the mineral and vitamin C content for each drying method (see Figure 4.5), it could be observed that there was no specific trend of variability. However, for various drying methods diffences in mineral or vitamin C did not significantly differ.

Vitamin C: There existed significant differences ($p<0.05$) of vitamin C in all cultivars for the fresh yam samples and for all drying methods. For SADS dried samples, vitamin C content between *Pona* and *Dente* as well as between *Lilii* and *Matches* were not significantly different, however, in the SD dried samples significant diffences existed between *Pona* and *Dente* except between *Lilii* and *Matches*. Meanwhile in the

OSD dried samples, no significant differences existed between *Pona*, *Dente* and *Matches* except *Lilii*.

Phosphorus: The results obtained shows that significant differences existed in the phosphorus content of all the fresh and OSD dried yam samples. Phosphorus content in *Pona* and *Dente* were not significantly different ($p>0.05$) except *Lilii* and *Matches* dried in the SADS and SD systems.

Calcium: Calcium content of different foods is important since this macronutrient plays critical roles in skeletal development, neuromuscular function etc. with its deficiency resulting in muscle spasms, cramps and eventually osteoporosis (Andre *et al*., 2007).

In the fresh sample no significant difference ($p>0.05$) existed between *Pona* and *Matches*. Meanwhile in the SADS and SD dried samples significant differences of phosphorus did not exist between *Pona* and *Matches* as well between *Lilii* and *Dente* cultivars. Meanwhile in the OSD system phosphorus content in *Pona*, *Dente* and *Matches* were not significantly different.

Iron: In the fresh yam sample, differences in iron content in *Pona* and *Matches* as well between *Lilii* and *Dente* were not sigificant ($p>0.05$). In the SADS and SD dried yam samples, significant differences in iron content occurred between *Pona* and matches as well as between *Lilii* and *Dente*. On the other hand, in the OSD dried samples, iron content in *Lilii*, *Dente* and *Matches* were not significantly different, except *Pona.*

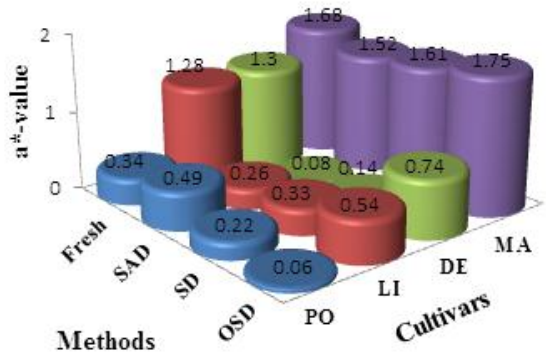

Figure 4.6a Different drying methods on the colour (a) of yam.*

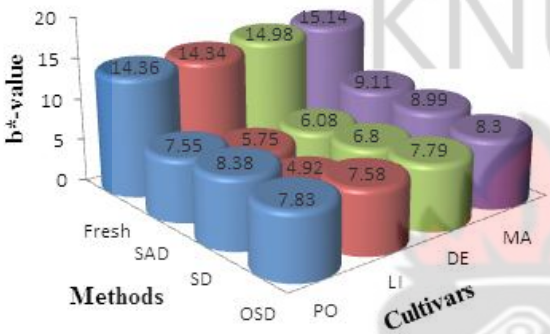

Figure 4.6b Different drying methods on the colour (b) of yam*

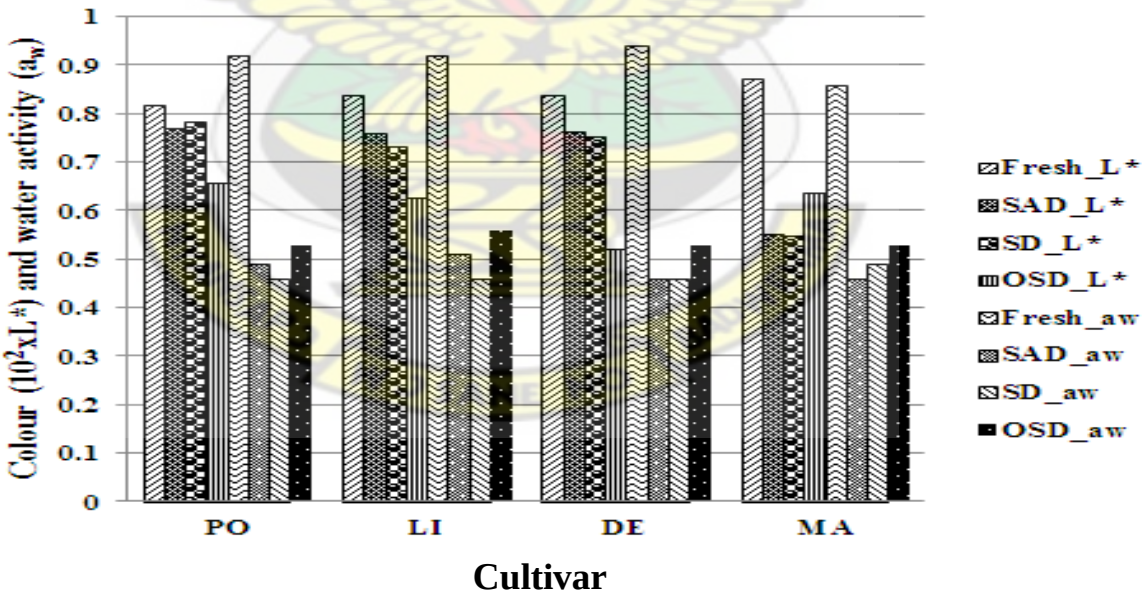

*Figure 4.6c Different drying methods on colour (L*value) and water activity of yam.*

4.8 Effect of drying method and yam cultivar on colour and water activity of fresh and dried yam cut.

The data on surface colour of yam was recorded using the L*a*b* colour space and are presented in Fig 4.6a-c L* is the luminance or lightness component, which ranges from 0 to 100, and parameters a* (from green to red) and b* (from blue to yellow) are the two chromatic components, with range -120 to 120.

In the current study, the L* values for fresh yam ranged between 81.83 *Pona* to 87.13 *Matches; a** values 0.34 *Pona* to 1.68 *Matches* and b* values +14.34 *Lilii* to +15.14 *Matches*. It is generally observed that the higher the L* values the lower the a* and b* values. The water activity values for the fresh samples range between 0.86 *Matches* to 0.94 *Dente*.

The effect of drying methods and type of cultivar on the colour value and water activity are presented in Fig. 4a-c. The L* values of the dried sample for the various methods ranged between 52 and 78 while the water activity values ranged between 0.46 and 0.56 with the OSD dried samples recording higher water activities. It is observed by Fellows, (2000) that almost all microbial activity is inhibited below a_w = 0.6.

It was observed that the drying methods had significant effect ($p<0.05$) on the extent of colour degradation with OSD having the highest effect on colour due to long and direct exposure of the samples to ultraviolet radiation. While the percentage decrease in white colour (L*) from the fresh to dried state for samples dried in SADS and SD sample ranged between 6.1 - 36.6 % and 4.2 - 37.0 % respectively, that of OSD dried samples ranged between 19.6 – 40.2 %. The water activity on the other hand reduced between 39-51 % for all drying methods and yam cultivars with the OSD dried yam

cultivars recording higher water activity. This implies that the equilibrium moisture content of the OSD dried samples were relatively higher leading to lower L* values.

The colour of the cultivar, *Matches* were slightly reddish than the other cultivars (see Figure: 4.6c). It is evident in this research that *Matches* had the least lightness (L*) value (see Figure: 4.6c). Ukpabi *et al*. (2007) observed a change in colour from fleshy cream to brown after drying yam chips. This significantly ($p<0.05$) varied amongst cultivars and drying methods. Compared to the range -120 and 120, all a* values were relatively not significant. Meanwhile, the drying methods significantly ($p<0.05$) affected the a* values. From Figure 4.a it is observed that the fresh samples were slightly yellowish than the dried samples and the difference between the b* values of the fresh yam cultivars of range (+14.32 to +15.21) were not significant ($p>0.05$). Between 43 to 71 % percent of the b* value was however reduced after drying. The change in colour could be due to enzymatic browning (Okaka and Okaka, 2001). These changes in colour and their variability with cultivars may be attributed to differences in phenolic compound as reported by Aserota *et al*. (1992).

4.9 Sensory evaluation of *amala*

Amala is a starchy viscous flour paste produced by reconstituting fermented yam flour (*Elubo)* mostly consumed in West Africa. It is a popular food among the people of Nigeria, Benin and Togo (Akissoe *et al*., 2006). It is reported in literature that a good *amala* should be soft, smooth, non sticky and firm. In addition, the colour should be light to dark brown. (Akissoe *et al*., 2001 and Hounhouigan *et al*., 2003)

On the 9-point hedonic scale used in this work, a score of 1 represented dislike extremely and 9 represented like extremely. In this study, significant difference ($P<0.05$) was found in the colour using solar dried and sun dried cooked *amala*

samples of the same cultivar except OSDMA and SDMA which the drying method had no significant effect on the colour of *amala*. Generally, *amala* prepared from the *Matches* (*D.alata*) was rated better in terms of its brown colour. This may be due to high content of phenolic compounds in the *D.alata* species as reported by Asemota *et al*. (1992) and Muzac-Tucker *et al.* (1993).

Plate 4.1a-b shows the differences in the colour of *amala* from different drying methods. Although the *amala* was prepared from the same cultivar *Lilii*, there was a difference in the colour due to differences in the drying methods. The Open Sun dried *amala* from *Lilii* was deep brown compared to the light brown from the solar dried method. The differences in methods could be attributed oxidative browning.

Plate 4.1a Amala from open sundried Lilii

Plate 4.1b Amala from solar dried Lilii

The presence of protein and sugar could also be responsible for the observed differences in brown colour of *amala* from different cultivars. Differences in protein contents in the various cultivars could be accounted for variation in the brownish colourations plate (4.2a-b). Farombi *et al.* (2000) reported that Amino acids and proteins when heated can react non enzymatically with sugars forming brown-coloured compounds commonly called Maillard reaction. Ascorbic acid oxidation which is a

type of non enzymatic reaction that results in browning during processing could also account for differences in brown colour (Onimawo and Akubor, 2005).

Plate 4.2a Amala from solar dried Pona

Plate 4.2b Amala from solar dried Dente

Notwithstanding different yam cultivars used for the *amala* preparation, there was no significant difference (P>0.05) in taste however, the panellists on the other hand, seemed to have rated the *amala* samples from SDPO and SDLI cultivars higher , the *amala* samples made from *Dente* were rated lower by the test panellists in terms of taste (Figure 4.7). Also, drying method had no effect on texture, which in this case consists of elasticity, consistency, stickiness and hardness. The panellists on the other hand, seemed to have rated the *amala* samples from *Pona* highly (in combined scoring for texture, which in this case consists of elasticity, consistency, stickiness and hardness). Otegbayo *et al*. (2001) reported that boiled yam from *Pona*; a cultivar of *D. rotundata* was rated superior to other cultivars in cooking quality attributes due to its sweet taste, softness and mealy texture after cooking.

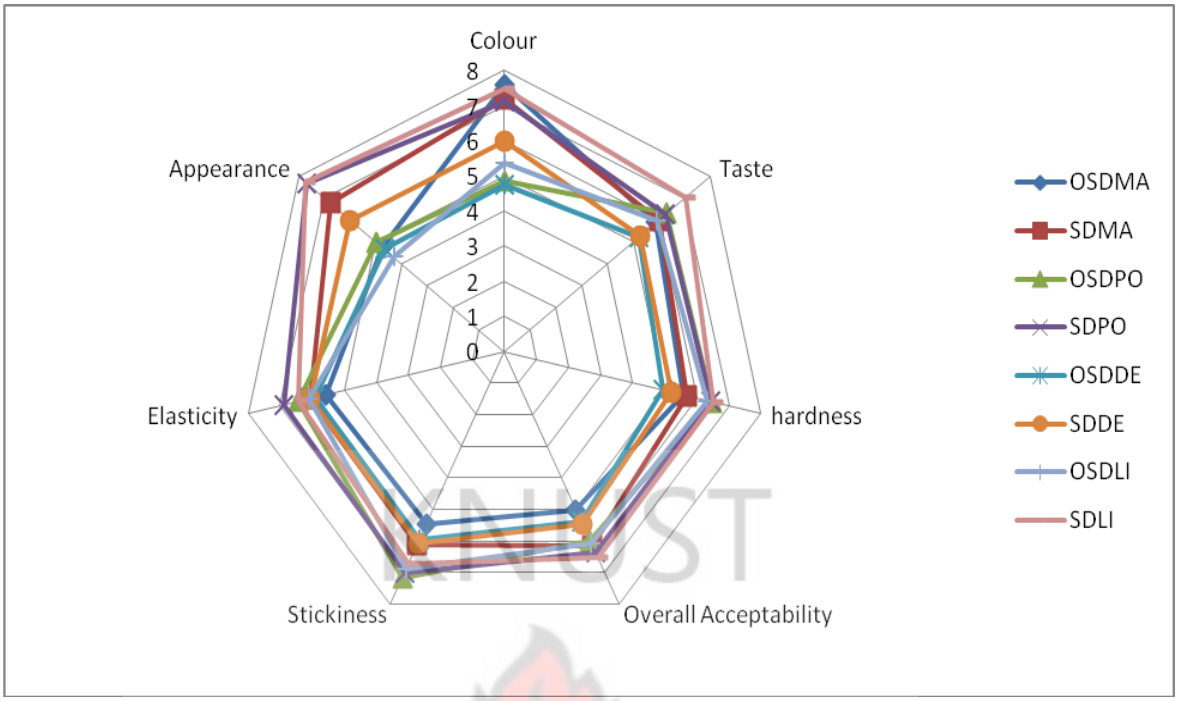

Figure: 4.7 Show the sensory of amala prepared from cultivars – Matches (D.alata); Pona, Dente and Lilii (D. rotundata) with drying methods OSD and SD

Although white yam is preferred in literature in the preparation of *amala* for the people of Yoruba, the water yam also had high acceptance score in this present study.

Acceptance scores for the products including the water yam did not indicate significant difference. The high acceptance score by the panelist makes the tested cultivars good for production of *amala.* Based on the present study, food technologists and processors may explore the possibility using yam (*D.rotundata* and *D.alata)* for development *amala* in Ghana to increase its usage in other to reduced post harvest loss in the country.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

- Drying methods (SADS, SD and OSD) and cultivar have strong effects on the rate of moisture removal. The OSD method and Dente cultivar had the least rate of moisture removal. There were decrease in protein, calcium and vitamin C contents of dried samples, using all the drying methods whiles fat, ash and phosphorus were increased. Apart from temperature, the time of exposure to the heating medium has significant effect on heat sensitive nutrients such as vitamin C.

- It was established that the drying methods had significant effect ($p<0.05$) on the extent of colour degradation with OSD having the highest effect on colour. In general, SADS and SD yielded better products in terms of colour (lightness) and water activity compared to OSD method, which gave somewhat brownish products. Dente had the lowest rate of moisture removal and diffusivity among the tests cultivars.

- The study has shown both D. *alata and rotundata* should be promoted for products such as *amala*, particularly in countries like Ghana and other yam producing areas where *amala* is not a common product, to increase utilization. Though, the colour of *amala* from OSD were rated higher by the panelist, *amala* from SD method had the higher overall acceptability.

5.2 Recommendation.

- Further studies on shelf-life must be carried out on the flour to determine the keeping quality.
- A comparative study must be carried out by researchers to compare adsorption drying alone with solar and open sun drying on nutritional and sensory parameters of yam.
- Further studies must be conducted on the physico-chemical properties of *amala* samples by researchers that might have accounted for the observed sensory differences amongst the experimental cultivars.
- Although, *D. rotundata* is a preferred variety in Ghana, it has been shown from this study that *D. alata* possesses distinct nutritional qualities (such high protein) that can be promoted to solve the problem of malnutrition in Ghana while the food industry can exploit it for food product development.

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Appendix A: Formulae Used in Calculation

A1. Moisture content

$$\% \text{ Moisture} = \frac{(\text{weight of wet sample} - \text{weight of dry sample}) \times 100\ \%}{\text{weight of wet sample}}$$

A2. Ash determination

$$\% \text{ Ash} = \frac{(\text{weight of crucible and ash residue} - \text{weight of empty crucible}) \times 100\ \%}{\text{weight of sample}}$$

A3. Crude fat determination

$$\% \text{ Crude fat} = \frac{(\text{weight of flask and fat residue} - \text{weight of dry empty flask}) \times 100\ \%}{\text{weight of sample}}$$

A4. Crude protein determination

$$\% \text{ Total nitrogen} = \frac{100\ (S_T - S_b) \times 0.1 \times 0.01401 \times 100\ \%}{\text{weight of sample} \times 10}$$

Where S_T = volume (ml) of HCl used in the sample titration

Where S_b = volume (ml) of HCl used in the blank titration

% Crude protein = % nitrogen × 6.25

A5. Crude fibre determination

$$\% \text{ Crude fibre} = \frac{(\text{weight of crucible and sample before ignition} - \text{weight of crucible and ash}) \times 100\ \%}{\text{weight of sample}}$$

A.6 Carbohydrate determination

% Carbohydrate = 100- (% moisture + % ash + % protein + % fat + % fibre)

Appendix B: Minerals, (Phosphorus, Calcium and Iron) and Vitamin C Content of Fresh and Dried Yam Sample (mg/100 g)

METHOD/CULTIVAR	VIT C	P	Ca	Fe
FPO	17.40±0.12^{b}	144.55±0.02^{f}	45.65±0.01^{c}	3.50±0.01^{a}
FLI	9.30±0.10^{c}	159.04±1.45^{bc}	63.80±0.02^{a}	2.35±0.02^{cd}
FDE	19.84±.0.11^{a}	146.80±0.01^{ef}	54.35±0.01^{b}	2.00±0.00^{de}
FMA	9.28±0.10^{c}	123.10±0.01^{i}	44.19±0.02^{c}	3.491±0.01^{a}
SADPO	6.47±0.01^{e}	156.62±0.05^{c}	38.85±0.01^{d}	3.50±0.01^{a}
SADLI	4.50±0.01^{fg}	165.82±0.01^{a}	45.15±0.01^{c}	2.15±0.01^{de}
SADDE	6.50±0.01^{e}	156.85±0.05^{c}	46.60±0.01^{c}	1.81±0.00^{ef}
SADMA	4.01±0.01^{fg}	132.12±0.41^{g}	36.24±0.02^{def}	3.40±0.02^{a}
SDPO	6.70±0.10^{e}	157.82±0.73^{bc}	37.85±0.01^{de}	3.21±0.01^{a}
SDLI	4.70±0.01^{fg}	162.96±0.88^{ab}	43.35±0.01^{c}	2.20±0.00^{de}
SDDE	7.37±0.01^{d}	155.15±0.05^{cd}	45.65±0.01^{c}	1.70±0.01^{ef}
SDMA	4.13±0.01^{fg}	130.78±2.36^{g}	34.60±0.01^{def}	3.31±0.01^{ab}
OSDPO	2.20±0.23^{h}	153.89±2.32^{cd}	34.20±0.01^{ef}	2.70±0.01^{bc}
OSDLI	1.43±0.15^{i}	166.69±1.69^{a}	21.90±0.00^{g}	1.45±0.01^{f}
OSDDE	2.15±0.15^{h}	150.63±1.94^{de}	30.65±0.01^{f}	1.45±0.01^{f}
OSDMA	2.23±0.23^{h}	127.21±0.79^{gh}	32.25±0.00^{f}	1.45±0.01^{f}

Values are Means ± standard deviation from duplicate analyses. Those with the same superscripts in the same column are not significantly different at P < 0.05.

Appendix C Colour and water activity for both fresh and dried yam.

METHOD	L*	a*	b*	Water activity
FPO	81.83±0.15^{e}	-0.34±0.01^{de}	+14.36±0.06^{a}	0.92±0.1^{ab}
FLI	83.69±0.001^{b}	-1.28±0.01^{b}	+14.34±0.01^{a}	0.92±0.1^{ab}
FDE	83.68±0.01^{b}	-1.300±0.01^{b}	+14.98±0.01^{a}	0.94±0.00^{a}
FMA	87.13±0.02^{a}	-1.68±0.01^{a}	+15.14±0.01^{a}	0.86±0.03^{b}
SADPO	76.87±0.06^{ef}	-0.49±0.02^{d}	+7.55±0.01^{cde}	0.49±0.01^{def}
SADLI	76.01±0.63^{ef}	-0.26±0.03^{ef}	+5.75±0.38^{gh}	0.51±0.01^{cdef}
SADDE	76.22±0.09^{fg}	-0.08±0.04^{fg}	+6.08±0.30^{fg}	0.46± 0.01^{efg}
SADMA	56.98±1.40^{h}	-1.59±0.14^{a}	+8.99±0.16^{b}	0.49±0.01^{def}
SDPO	78.41±0.29^{efg}	-0.22±0.01^{efg}	+8.38±0.05^{bc}	0.46± 0.01^{efg}
SDLI	73.30±0.13^{e}	-0.33±0.15^{de}	+4.92±0.40^{h}	0.46± 0.01^{efg}
SDDE	75.32±0.25^{fg}	-0.14±0.06^{fg}	+6.80±0.15^{ef}	0.46± 0.01^{efg}
SDMA	54.86±1.40^{h}	-1.61±0.14^{a}	+8.99±0.16^{b}	0.49±0.01^{def}
OSDPO	65.79±0.45^{g}	-0.06±0.01^{g}	+7.83±0.18^{cd}	0.53±0.01^{cde}
OSDLI	62.67±0.53^{e}	-0.35±0.14^{de}	+7.58±0.01^{d}	0.56±0.01^{cd}
OSDDE	62.49±0.29^{c}	-0.74±0.05^{c}	+7.79±0.66^{cd}	0.53±0.01cde
OSDMA	52.14±0.01	-1.75±0.02^{a}	+8.3±0.18^{cd}	0.53±0.01cde

Appendix: D Questionnaire for Sensory Evaluation of *Amala*

Acceptability Test

Name…… Age……

Date……..

Instructions:

You have provided with cook yam flour paste (*amala*) from different cultivars of yam, (*Dioscorea spp*). Please assess them based on the quality attributes listed below in order in which the samples have been presented. Please use the scale below for rating.

NB: The samples have not been placed in any special order.

Scale

Like extremely 9

Like very much 8

Like moderately..... 7

Like slightly 6

Neither like nor dislike..... 5

Dislike slightly..... 4

Dislike moderately..... 3

Dislike very much..... 2

Dislike extremely..... 1

SAMPLE CODE/ATTRIBUTE	Colour	Taste	Consistency	Stickiness	Elasticity	Hardness	Appearance	Overall acceptability
M001								
M002								
P003								
P004								
D005								
D006								
L007								
L008								

Comment:.....

.....

Appendix E: some pictures in the thesis

E1:Section of panelist evaluating *amala* at sensory laboratory

E2:Determination of water activity in Food Research Laboratory`

E3:SAMPLES OF YAM CULTIVARS (*D. alata and D .rotundata*) USED.

Appendix F: Sensory Evaluation of *amala* Prepared from Cultivars *Matches* (*D.alata*); *Pona*, *Dente* and *Lilii* (*D. rotundata*) with Drying Methods OSD and SD

Attributes	Drying methods							
	OSDMA	**SDMA**	**OSDPO**	**SDPO**	**OSDDE**	**SDDE**	**OSDLI**	**SDLI**
Colour	7.58±0.96^{a}	7.21±1.18^{a}	4.84±1.86^{b}	7.11±2.00^{ac}	4.74±2.42^{b}	6.00±1.67^{cd}	5.37±2.39^{bd}	7.47±0.90^{a}
Taste	5.89±1.70^{a}	6.00±1.60^{a}	6.32±1.53^{ab}	6.26±2.05^{abd}	5.21±1.47^{ac}	5.26±1.19^{acd}	5.95±2.12^{ac}	7.05±1.22^{b}
Hardness	5.58±2.01^{a}	5.68±2.03^{a}	6.47±1.81^{a}	6.42±1.64^{a}	4.95±1.68^{ab}	5.21±2.07^{abc}	6.32±1.73^{ac}	6.53±1.47^{ac}
Stickiness	5.47±1.33^{ae}	6.11±1.50^{ae}	7.16±1.45^{b}	7.00±1.42^{bc}	5.95±1.26^{e}	6.05±0.70^{ae}	6.89±1.51^{bd}	6.74±0.96^{ab}
Elasticity	5.58±1.26^{a}	6.05±0.99^{ab}	6.42±1.21^{bc}	6.89±1.05^{cd}	5.89±1.58^{ab}	6.05±1.08^{ab}	6.11±0.94^{ab}	6.42±1.28^{bd}
Appearance	4.74±0.90^{a}	6.79±0.91^{bd}	5.00±1.35^{a}	7.68±1.20^{bc}	4.68±0.88^{a}	6.00±0.97^{d}	4.32±0.74^{a}	7.74±1.02^{c}
Overall Acceptability	5.00±1.45^{a}	6.16±1.36^{a}	6.00±1.83^{a}	6.37±0.89^{a}	5.37±1.34^{a}	5.47±1.41^{a}	6.05±1.80^{a}	6.53±0.87^{a}

Values in table are represented as mean ± standard deviation. Values in the same row with the same superscript letters are not significantly different at 95% confidence level or 5% significance level