Drying Characteristics, Physicochemical and Functional Properties of Yam (*Dioscorea spp.*) Flours: Influence of Air Drying Temperature

A THESIS

BY

MD. RAHMAT ALI

Registration No. 1605212

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DEPARTMENT OF FOOD PROCESSING AND PRESERVATION

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200

JUNE, 2017

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ABSTRACT

This study investigated the effect of air drying temperature on drying characteristics, chemical composition and functional properties of yam flours. Prior to drying, peeled yam tuber was blanched in boiling water containing 2% NaCl and 1% citric acid and drying was conducted in a cabinet hot air dryer at 50°C, 60°C, 70°C and 80°C. The time required for the lowering the moisture content of yam slices from initial 74.44 % (wb) to a constant moisture content (9.34 to 11.33 %) was varied between 420 to 730 min, depending on the temperature used and drying took place entirely in the falling rate period. Drying led to a significant ($P < 0.05$) reduction in the moisture (9.34 to 11.33 %) and total phenolic content (9.68 to 10.74 mgGAE/100g) of yam flours, whereas the protein (4.24 to 5.42 %), ash (4.64 to 5.99 %), fat (0.45 to 0.95 %), fiber (0.75 to 1.33 %), total carbohydrate (77.41 to 79.23 %) and total starch content (56.46 to 65.57 %) increased significantly ($P < 0.05$) compared to fresh yam. Both chromatic parameters (L, a, b, h, C and whiteness index) and browning index were affected by drying temperatures, which contributed to the discoloring of some yam flour sample. Moreover, the functional properties of yam flours in terms of bulk density (0.84 - 1.15 g/ml), swelling power (2.10 - 2.63), water absorption index (132 - 176%), water solubility index (13.59 – 27.16%), iodine affinity of starch (196.66 - 353.33 ppm) and starch gelatinization point (77.67 - 85.31°C) was found to be varied significantly ($P < 0.05$). The results of this study concluded that flours obtained from yam tubers by drying in cabinet dryer at various temperatures gave excellent overall nutritional quality and functional properties. These flours could be used to make a higher quality product that is more attractive to product developers and consumers.

TABLE OF CONTENTS

ACKNOWLEDGEMENT...i

ABSTRACT..ii

TABLE OF CONTENTS iii

LIST OF TABLES..vi

LIST OF FIGURES..vii

CHAPTER I 1

INTRODUCTION..1

CHAPTER II..4

REVIEW OF LITERATURE...4

2.1 Origin and Distribution of *Dioscorea*..4

2.2 Nutritional Value of Yams...5

2.3 Health Benefit of Yam...6

2.4 Use of Yam..7

2.5 Effect of Thermal Treatment..7

2.6 Literature Related to Yam Flour...8

CHAPTER III 14

MATERIALS AND METHODS...14

3.1 Collection and Preparation Sample...14

3.2 Drying Experiment..14

3.3 Drying Characteristics..15

3.4 Quality Evaluation of Yam Flour..15

3.4.1 Proximate Composition..15

3.4.1.1 Determination of Moisture Content...15

3.4.1.2 Determination of Protein Content..16

3.4.1.3 Determination of Fat Content..17

3.4.1.4 Determination of Ash Content...17

3.4.1.5 Determination of Fiber Content 18
3.4.1.6 Determination of Total Carbohydrate 18
3.5 Determination of Starch Content 18
3.6 Determination of Total Phenol Content 19
3.7 Colour Parameters 19
3.8 Browning Index 20
3.9 Evaluation of Functional Properties 20
3.9.1 Determination of Bulk Density 20
3.9.2 Water Absorption Capacity (WAC) and Water Solubility Index (WSI) 21
3.9.3 Determination of Iodine Affinity of Starch 21
3.9.4 Determination of Swelling Power 22
3.9.5 Gelatinization point determination 22
3.10 Statistical analysis 22
CHAPTER IV 23
RESULTS AND DISCUSSION 23
4.1 Drying Characteristics of Yam Slices 23
4.2 Chemical Composition of Yam Flours 26
4.2.1 Moisture Content 27
4.2.2 Protein Content 27
4.2.3 Fat Content 27
4.2.4 Ash Content 29
4.2.5 Fiber Content 29
4.2.6 Carbohydrate Content 29
4.3 Total Starch Content 30
4.4 Total Phenolic Content 30
4.5 Color Attributes of Yam Flours 30
4.6 Browning Index of Yam Flours 32

4.7 Functional Properties of Yam Flours 32
4.7.1 Bulk Density 32
4.7.2 Swelling Power 33
4.7.3 Water Absorption Capacity 33
4.7.4 Water Solubility Index 35
4.7.5 Iodine Affinity of Starch 35
4.7.6 Starch Gelatinization Point 35
CHAPTER V 37
SUMMARY AND CONCLUSION 37
REFERENCES 39
APPENDICS 53

LIST OF TABLES

Table 2.1. Proximate composition of Yam (Sanful et al., 2013). 6

Table 4.1. Effect of air drying temperature on the chemical composition of yam flours……….. 28

Table 4.2. Effect of air drying temperature on the color attributes and browning power of yam flours…… 31

Table 4.3. Effect of air drying temperatures on the functional properties of yam flours……….. 34

LIST OF FIGURES

Figure 4.1. Effects of air drying temperature on the drying curve of yam slices dried at different temperature. 23

Figure 4.2. Effects of air drying temperature on the moisture ratio of yam slices dried at different temperature. 24

Figure 4.3. Drying rate curves showing the rate of moisture removal during drying of yam slices at different temperature. 25

CHAPTER I

INTRODUCTION

Yams (Dioscorea spp.) are the fourth major root crop in the world after cassava, potatoes and sweet potatoes (Akinoso & Olatoye, 2013). It belongs to the genus *Dioscorea* of the family Dioscoreaceae, which has about 600 species of which *D. alata, D. cayenensis,* and *D. rotundata*, has the greatest economic importance. Yams are wide spread and are one of the major staple foods in many tropical countries (Akanbi et al., 1996; Omonigho & Ikenebomeh, 2000). It is an important source of carbohydrate for many people of the sub-Sahara region, especially in the yam zone of West Africa (Akissoe *et al*., 2003). Yam is comprised of approximately 75% to 84% starch, 6% to 8% crude protein and 1.2% to 1.8% crude fiber (Wanasundera & Ravindran, 1994).

Recently, several beneficial properties of yams were reported in the literature. Among various functional components, the most interesting are phenolic compounds, including anthocyanins (Shoyama et al., 1990; Yoshida et al., 1991) and catechins (Ozo et al., 1984). Yam extracts showed significant antioxidative activity (Bhandari & Kawabata, 2004; Chen et al., 2008), which can reduce blood sugar (Undie & Akubue, 1986) and blood lipid level (Araghiniknam et al., 1996), inhibit microbial activity (Kelmanson et al., 2000), anti-mutagenic (Miyazawa et al., 1996) and anti-allergic activities (Tewtrakul & Itharat, 2006). This statement also suggests that consumption of fresh yam tubers has potential health benefits for human beings. Traditionally, yams can be used as herbal medicines to prevent the diseases of diarrhoea and diabetes (Hsu et al., 1984; Yen, 1992).

Fresh yams are difficult to store because of its high moisture content (e.g. above 70 %) when harvested (Afoakwa & Sefa-Dedeh, 2001) and susceptible to deterioration especially when bruised (Fioreze & Morini, 2000), which accounted a post-harvest loss of yam to be about 30 % (Alhassan, 1994). Drying as a matter of fact, has been reported as a suitable alternative for post-harvest management especially in non-developed countries, where exist poorly established low-temperature distribution and handling facilities (Sagar & Kumar, 2010). Because yams are regarded as health foods and not staple foods in Oriental countries, it is feasible to develop a stable form of yam products to fulfil the health food market (Hsu et al., 2003). Since flours can be easily stored for long period of time and conveniently used in manufacturing formulated foods or capsules for consumption, dried yam flour is worth developing (Akissoe et al., 2001).

The qualities (flavor, taste, color and nutrients) of resulting products are determined by the drying methods and conditions used. In practice, air drying (sun drying) has been traditionally used in the processing of yams for storage after-harvesting. This technique has the advantages of simplicity and low capital investments, but it also has some disadvantages e.g., it is a time-consuming, weather dependent, labour intensive process, and yams are potentially exposed to possible environmental contamination (Arslan & Özcan, 2010). In recent years, many studies have been undertaken to discover the alternative to the natural drying process, which should lead to shortening the drying length, controlling pests and maintaining a better appearance and quality yams flours (Jiang et al., 2013). Hot air drying is one of the most commonly used methods, has relatively low production costs and has the added advantage of very often producing good quality products (Singh et al., 2006; Njintang et al., 2007). However, the quality of some of the flours so produced leaves a lot to be desired by the local consumers and food industry, especially with respect to their functional properties which are important quality indicators of the final product (Kaur & Singh, 2007).

The flesh of the yam species used is usually white, but the colour of the processed flour ranges from creamy white to dark brown (Akissoe et al., 2003). The discoloration phenomenon has been attributed to enzymatic browning, due to the action of polyphenol oxidase (Almentros & Del Rosatio, 1985), the production of polyphenols and derived products (Osagie & Opoku, 1984), thermal drying and direct contact with air and light (Wiriya et al., 2009). For this reason, different pretreatment methods (chemical, thermal and physical) have been employed (Falade et al., 2007; Akyildiz et al., 2004; Dewanto *et al*., 2002) to abate these problems. These pretreatments will in no doubt affect the drying characteristics, during drying of yam slices. Blanching is a short and mild heat treatment prior to the main process for the purpose of enzymes inactivation, modifying texture, preserving color, flavor and nutritional value and removing trapped air (Akissoe et al., 2006; Leng et al., 2011). Hot water and steam are the most commonly used heating media for blanching in the industry (Akissoe et al., 2006; Corcuera *et al*., 2004).

Although considerable amounts of food materials are dried artificially in heated mechanical air-drying systems (Das *et al*., 2001; Doymaz, 2004a, 2004b; Maskan, 2001; Senadeera et al., 2003), there is little information on the influence of the pretreatments and drying air temperature on the drying characteristics, physicochemical and functional properties of yam tubers.

Objectives of the Research

Therefore, the information so far accumulated, the present research has been planned to fulfil the following objectives:

I. To investigate the effects of pretreatments and air drying temperature on the drying characteristics of yam tuber.

II. To evaluate the physicochemical and functional properties of yam flours as a result of pretreatments and drying air temperature.

CHAPTER II

REVIEW OF LITERATURE

2.1 Origin and Distribution of *Dioscorea*

The yam is a perennial plant with long trailing vines. The yams are members of the genus *Dioscorea* in the section, Enantiophyllum. *Dioscorea* is the largest genus of the family Dioscoreaceae, containing between three and six hundred species (Vernier et al., 1998). Only a few species of yams are cultivated as food crops. The most important species of *Dioscorea* include *D. rotundata, D. alata, D. cayenensis, D. dumetorum, D. esculenta and D. bulbifera.* Yams grow best in deep, well-drained soils with a rainfall of 1000- 3000 mm in the absence of frost. Grown commercially as far north as southern Japan, altitude similar to South Georgia's. Normally grows for 8-10 months, and then goes dormant for 3-4 months, with aerial stems dying back during dormancy. Said to survive winters in France if planted deep enough (Coursey 1973). Fertile seeds rarely produced; spread by aerial tubers and fragments of underground tuber (Coursey, 1973). *Dioscorea alata,* called "water yam", "winged yam" and "purple yam", is the species most widely spread throughout the world and in Africa is second only to white yam in popularity (Mignouna et al., 2004). White Guinea yam and water yam are the most important food yams in terms of cultivation and utilization (IITA, 2010). The tubers mature in 6- 10 months and when stored remain dormant for 3-6 months depending on species and cultivar. *Dioscorea ala/a* may be grown up to an altitude of about 2000 m (Bourke 1982). The tubers from the greater yam *(D. alata)* may grow to be very large, up to 3 m long and 60 kg in weight, whereas those of the lesser yam *(D. esculen/a)* are more numerous (5 - 20), much smaller and are less fibrous than the larger tubers of other species. Exploiting alternative sources of starch would lessen the burden of its importation. *Dioscorea* family or yam tuber consists of about 600 species which are around 50-60 species cultivated or food and medicine. *D. esculenta* that have productivity of 60-70 ton/ ha, but these tubers have not yet been used intensively. Vigorously twining herbaceous vine, from massive underground tuber. Stems to 10 m (30 ft) or more in length, freely branching above; internodes square in cross section, with corners compressed into "wings," these often red-purple tinged. Aerial tubers (bulbils) formed in leaf axils (not as freely as in *D. bulbifera*), elongate, to 10 cm (4 in) x 3 cm (1.2 in), with rough, bumpy surfaces. Leaves long petioled, opposite (often with only 1 leaf persistent); blades to 20 cm (8 in) or more long, narrowly heart shaped, with basal lobes often angular. Flowers small, occasional, male and female arising from leaf axils on separate plants (i.e., a dioecious species), male flowers in panicles to 30 cm (1 ft) long, female flowers in smaller spikes. Fruit a 3-parted capsule; seeds winged.

2.2 Nutritional Value of Yams

Yam is grown and cultivated for its energy-rich tuber. Yam is an excellent source of starch, which provides calorific energy (Coursey, 1973). It also provides protein three times more superior than the one of cassava and sweet potato (Bourret-Cortadellas, 1973). Apart from food, yams are also sources of pharmaceutical compounds like saponins and sapogenins, which are precursors of cortisone (a hormone from the adrenal gland used medically in the treatment of arthritis and some allergies) (Higdon et al., 2001).

Yams generally have high moisture content; the dry matter is composed mainly of starch, vitamins, sugars and minerals. Nutrient content varies with species and cooking procedures. Yams may also contain small quantities of polyphenolic compounds (e.g. tannins), alkaloids (e.g. dioscorine), steroid derivatives (e.g. diosgenin), calcium oxalate crystals and phytic acid. Yam tuber is essentially a starchy food with its principal nutritional function being the supply of calories to the body (Onwueme, 1978).

In addition to micronutrients, it is important to assess the antioxidant activity of foods since it tells the extent to which they are able to nullify the effects of free radicals. Free radicals are independently existing atoms or molecules that have one or more unpaired electrons and are thought to play key roles in initiation of many inflammatory and metabolic diseases (Williams *et al*., 2006).

Yam (*Discorea rotundata*) is a good source of carbohydrates, vitamins and minerals (G. Osuji, 1990), as well as some essential amino acids. Afoakwa and Sefa-Dedeh (2001) reported that *D. dumetorum* is the most nutritious of the commonly consumed yam species, with fairly high protein content and a well-balanced amino acid.

Agbor-Egbe and Treche (1995) reported a starch content of 15-38% (fresh/wet weight) and 70-80% (dry weight basis) in yams from Cameroon. Yam is composed mainly of starch, with some proteins, lipids, vitamins and minerals (Lasztity *et al.,* 1998). *D. rotundata* is reported to have about 85% on dry weight basis (Treche and Agbor-Egbe, 1996), *D.*

dumetorum is reported to have about 75% (Bell and Favier 1981; Eka 1985; Afoakwa and Sefa-Dedeh 2001), *D. alata* has about 65-80% while D. bulbifera contain about 43-70% (Baah, 2009; Shanthakumari *et al.,* 2008). Their protein, fat and ash content is low with only 3-11%, 0.05-2.5% and 3–9% respectively on dry weight basis have been identified (Treche and Agbor-Egbe, 1996; Afoakwa and Sefa-Dedeh, 2001; Shanthakumari *et al.,* 2008).

Yams generally have a considerably higher protein than the 1.2–1.8% on dry weight basis reported for cassava (Charles *et al*., 2005). Although regarded mainly as a source of carbohydrate, some species of yam are nearly as rich in protein as rice and maize (Dansi et al., 1999). Yam is of higher nutritional value than some other root and tuber crops such as cassava. Its protein content is about 3 to 5% as compared to 1 to 2% in cassava (Charles et al., 2005). *Dioscorea rotundata* has been reported to be rich in vitamin C, dietary fibre, vitamin B_6, potassium, manganese and low in saturated fat and sodium (Kay, 1987). The fat levels of *D. rotundata* varieties has been reported to range from 0.1 to 0.9g/100g while the starch levels range from 72.4 to 80.9g/100g (A Bell, 1980).

Table 2.2 Proximate composition of Yam (Sanful et al., 2013).

Parameters	**Amount (%)**
Moisture	61.55 to 71.09 (Wet basis)
Ash	2.8 to 5.57
Fat	1.95 to 3.29
Protein	5.32 to 7.27
Fat	0.73 to 0.97
Carbohydrate	11.86o 25.78

2.3 Health Benefit of Yam

In a study that evaluated the anti-obesity role of diosgenin-rich *Dioscorea nipponica* Makino, a related species to *Dioscorea villosa*, (Kwon et al., 2003). Yam tubers contribute to anti-diabetic effects in experimental models (Basch et al., 2003). Recent studies have indicated that diosgenin in *Dioscorea* species have a biological effects including anti-inflammatory, antitumor, estrogenic, hypocholesterolemic, and immunomodulatory activities (Huang, 2010). The vitamin A in yams has other functions, such as maintaining healthy mucous membranes and skin, heightening night vision, supporting healthy bone development, and providing protection from lung and mouth cancers. Yam is particularly useful for menopausal women. It contains an enzyme that provides a natural alternative to hormonal replacement in women who have reached menopause. The dietary fibre present in Yam reduces constipation and decreases bad cholesterol. It contains good amount of potassium which aids in healthy digestion and stimulates smooth muscle contraction in the stomach for proper bowel habits. Yams contain complex carbohydrates and fibre which gradually slow the rate at which sugars are released and absorbed in the mainstream. Being high in fibre, yam keeps you full without putting on those extra kilos. Yams are also a good source of manganese, a mineral that aids carbohydrates metabolism and is very important for energy production and antioxidant defenses. The vitamins present in yam mediate various metabolic functions in the body. Carotenes are very essential to convert Vitamin A in the body. Vitamin A maintains healthy mucous membranes and skin. It also improves vision. Vitamin C in yam plays an important role in anti-ageing, improves immunity, wound healing and bone growth.

2.4 Use of Yam

Yams are consumed as staple food. For domestic purposes, yam is also useful for feeding livestock especially the peel, for industrial starch, manufacture of gums and adhesives and in textile industry for finishing cloth and printing fabrics with paste made from starch and dye. It is also used in the paper industry during pulping (Ihekoronye and Ngoddy, 1985). Traditional foods derivable from yam tubers include chips, fufu, amala and pounded yam. Yams are not among the most common sources of industrial starch, which are mostly imported at a cost.

2.5 Effect of Thermal Treatment

Root crops are not easily digested in their natural state and should be cooked before they are eaten. Cooking improves their digestibility, promotes palatability and improves their keeping quality as well as making the roots safer to eat. However, cooking may affect the nutritional composition and phyto-constituents in food.

Peeling and frying are the processes that best preserve the chief nutrients in yams while grilling and preparation of 'biscuit' from yam flour result in largest losses of nutrient (Bell, 1980). Discoloration phenomenon on fresh tubers has long been known to be associated with enzymatic activity, e.g., due to the action of polyphenoloxidases and peroxidases. These enzymes are inactivated by blanching (Akissoe *et al*., 2002). However, blanching reduces nutritional value of foods due to nutritions leach out or degrades by heating (Corcuera *et al*., 2004). Starch properties may also be altered by heating (Kouassi *et al*., 2010).

Drying methods and the physicochemical changes that occur in tissues during drying affect the quality of the dehydrated products. More specifically, the method used for drying affects properties such as colour, texture, density, porosity and sorption characteristics of materials (Krokida et al., 1998). High quality, convenient products are obtained efficiently at a fast rate and at competitive costs by several methods of drying. Hot air drying is one of the most frequently used operations for food dehydration. It is a method in which heated air is blown over food materials with the aid of fan(s) to remove most of the moisture from the food material. The drying of wet materials induces a number of physico-chemical changes in the product, often reflected by colour.

2.6 Literature Related to Yam Flour

A study was conducted by Adepoju and Thomas (2012) to determine the effects of processing methods on nutrient retention and possible contribution of some diets prepared from yam to nutrient intake of consumers. They reported that Raw yam was very low in crude protein (2.3 g), lipid (0.8 g), and fibre (1.4 g) moderate in ash (3.4 g), iron (4.1 mg) and zinc (5.6 mg), high in carbohydrates (33.3 g), energy (369.6 kcal), sodium (580 mg) and potassium (470 mg) /100 g edible portion. Roasting and frying brought significant improvement on crude protein, lipid and energy content of the products ($p<0.05$). Boiling yam caused significant reduction in all nutrient content except fibre, while boiling and pounding yam significantly improved its crude lipid, ash and energy content ($p<0.05$). they also reported that diets from yam can serve as good source of energy and minerals, and their 100 g portion can contribute between 12.4 to 20.9% gross energy, 11.0 to 46.0% iron and 17.3 to 48.7% zinc to recommended dietary allowances (RDAs) of consumers.

Chen et al. (2016) investigated the effects of drying processes on starch-related physicochemical properties, bio-active components and antioxidant properties of yam flours. The effects of five different drying processes, air drying, sulphur fumigation drying, hot air drying, freeze drying and microwave drying for yams in terms of starch-related properties and antioxidant activity were studied. They found that samples obtained by hot air drying and sulphur fumigation drying were observed to have the highest comprehensive principal component values. Based on their results, hot air drying would be a better method for yam drying than the more traditional sulphur fumigation drying.

Bhandari and Kawabata (2004) conducted a study to assess the antinutritional factors and bioavailability of calcium and zinc in wild yam (Dioscorea spp.) tubers of Nepal. They reported that The ranges of antinutrient contents were found to be: oxalates (Ox) 67–197 mg/100 g fresh weight (FW), phytate (Phy) 184–363 mg/100 g dry matter (DM), cyanogens 3.2–6.0 mg of HCN/kg FW, trypsin inhibitor activity 4.1–20.9 mg of pure trypsin inhibited/g DM, and a -amylase inhibitory activity 78-147 IU/g DM. The ranges of Ox:Ca, Phy:Zn, Ca:Phy and [Ca] [Phy]/[Zn] molar ratios for yam tubers studied were: 1.1–2.2, 10.4–32.3, 5.0–14.1 and 0.27–1.9, respectively. The molar ratios indicated that the bioavailability of Ca and Zn in these tubers could be low. The results tend to imply that the Nepalese wild yams may present a health-hazard potential, which in turn demands proper processing before consumption to eliminate the effects of the antinutrients.

Nine staple foods were assessed for minerals, antioxidants and some bioactive constituents by Dilworth et al., (2012). The study found that iron and zinc concentrations were highest in dasheen samples; yellow yam and dasheen recorded highest calcium values; while the highest copper concentrations were recorded in potato and water yam samples. Water yam and dasheen samples recorded significantly higher antioxidant activities compared to other samples (95.83 ± 0.21 and 93.41 ± 0.60% DPPH inhibition respectively).

Polycarp et al. (2012) carried out a study on “Characterization of chemical composition and anti-nutritional factors in seven species within the Ghanaian yam (Dioscorea) germplasm”. They reported that the moisture content of the fresh tubers ranged between 58.18 to 77.79%. The varieties had low fat (<1.0%), protein (4.0-6.5%) and fibre (1.25-3.47%) with high carbohydrate (77.5-87.3%) and energy (1451.2-1574.7 kJ/100g). The most predominant minerals were potassium (475-1475 mg/100g), phosphorus (158-294.5 mg/100g) and sodium (62.5-102.5 mg/100g). All the studied varieties had low levels of oxalates, tannins and phytates (<15 mg/100g) and could all be safely recommended for food processing applications.

The impact of cooking on the proximate composition and anti-nutritional factors of water yam was investigated by Ezeocha and Ojimelukwe (2012). They informed that the crude protein contents (10.27%), ash (2.93%) and lipid (0.15%) were significantly ($p<0.05$) lowered in the boiled tubers while the carbohydrate (76.57%) significantly ($p<0.05$) increased in the boiled tubers. The antinutrients; alkaloids (2.77%), saponins (2.71%), flavonoids (1.38%) and tannins (0.21%) significantly ($p<0.05$) reduced in the boiled tubers. It was concluded that boiling had both positive and negative effect on water yam. They recommended that a cooking time of between 30 and 60 min at 100°C was suitable for D. alata.

Sakthidevi and Mohan (2013) conducted a study for total phenolic, flavonoid contents and in vitro antioxidant activity of *Dioscorea alata* tuber. The results showed that the total phenolics and flavonoids in methanol extract were found to be 0.68 g 100 g-1 and 1.21 g 100 g-1 respectively. The methanol extract of tuber showed potent hydroxyl, superoxide, ABTs radical cation scavenging activities. Ethanol extract of tuber showed strong DPPH radical scavenging activity. The maximum inhibitory concentration (IC50) in all models viz., DPPH, hydroxyl, superoxide and ABTs radical cation scavenging activity of tuber of *Dioscorea alata* were found to be 27.16, 26.12, 30.65 and 25.53µg/mL respectively at 1µg/mL concentration.

Extraction of Diosgenin, a Bioactive Compound from Natural Source Dioscorea alata was done by Shah and Lele (2002). Diosgenin content of two Indian varieties viz., D. deltoidea and D. prazeri ranges from 0.32 - 1%.

Physicochemical and Bioactives Characteristics of Purple and Yellow Water Yam (Dioscorea alata) Tubers was evaluated by Harijono et al. (2013). Purple and yellow water yam contained 25.94 and 25.45% dioscorin from water soluble protein. The analysis of amino acid profile showed that the water soluble protein of water yam comprises of aspartate, glutamate, serine, histidine, glycine, arginine, alanine, tyrosine, valine, phenylalanine, ileusin, leucine, andlysine.

Oladeji et el. (2014) conducted a research on physicochemical and bioactive properties of selected white yam varieties adapted to riverine areas of Nigeria.

Afiukwa et al. (2013) compared the nutritional and antinutritional characteristics of two wild yam species (okpura and ighobe) from Abakaliki, Southeast Nigeria. The result showed that Protein was higher in Ighobe (3.37%) than okpura (2.21%). Carbohydrate was also higher in okpura (85.16%) than ighobe (78.71%). The crude fibre contents of okpura and Ighobe were 3.56% and 1.52% respectively. The fat contents of the two wild yam species were found to be 6.01% (okpura) and 13.03% (ighobe). Okpura was higher in K (145.33), Na (5.40), Mg (9.47) and Mn (0.032) while ighobe was higher in Ca (56.11) all in mg/100g. The concentrations of three anti-oxidant vitamins (A, C and E) and two B vitamins (Thiamine and Niacin) in the wild yam species were also determined. The obtained concentrations of the anti-oxidant vitamins were respectively 1.75 mg/100g in okpura and 1.54 mg/100g in ighobe, 0.99 mg/100g in okpura and 0.98 mg/100g in ighobe, and 3.93 IU/100g (2.632 mg/100g) in okpura and 2.50 IU/100g (1.674 mg/100g) in ighobe, while thiamine and niacin were respectively 0.11 mg/100g in okpura and 0.15 mg/100g in ighobe and 0.82 mg/100g in okpura and 0.98 mg/100g in ighobe. The concentrations of alkaloids, saponins, tannin, HCN and oxalate differed significantly between the yam species ($P<0.05$), while flavonoids, phenols and phytate did not show significant variations. The results of this study revealed that the wild yam species are good nutritionally, containing proximate components, minerals and vitamins in amounts comparable to cultivated species in Nigeria. However, they have high contents of phytochemicals most of which are anti-nutritional substances, but these are significantly reduced during cooking and cannot prevent their full utilization as food sources.

A study was conducted by Okwu and Ndu (2006) for the evaluation of the phytonutrients, minerals and vitamin contents of some varieties of yam. All the species studied were found to contain bioactive compounds comprising saponin (2.98 – 19.46 mg/100g), alkaloids (0.38 – 1.68 mg/100g), flavonoids (1.10 – 9.94 mg/100g), tannin (0.044 -0.09 mg/100g and phenols (0.0024 -0.005 mg/100g).

Sunful et al. (2013) conducted a research to find out the proximate and functional properties of five local varieties of aerial yam in Ghana. The results indicated that the moisture conten ranged from 61.55% to 71.09, ash content 2.8 to 5.57%, fat content 1.95 to 3.29, protein content 5.32 to 7.27%, fiber 0.73 to 0.97 % and carbohydrate from 11.86 to 25.78 %. The water binding capacity ranged from 280.54 to 323.13%, solubility from 20.28 to 24.35%, sweeling power from 6.37 to 8.81% and p^H from 6.06 to 6.52.

Amoo et al. (2014) conducted a study on physicochemical and pasting properties of starch extracted from four yam varieties. Results obtained showed significant differences ($p<0.05$)

in some physicochemical properties (moisture, ash, starch yield and pH). Moisture, ash, starch yield, pH, amylose, amylopectin, swelling power, solubility and water binding capacities ranged from 7.22 to 7.82%, 024 to 0.86%, 12.61 to 20.89%, 5.57 to 6.25, 27.48 to 31.55%, 68.45 to 72.52%, 10.57 to 12.48%, 8.52 to 9.32% and 175.25 to 182.69% respectively. Asobayere had the highest starch yield (20.89%) and may be exploited for starch production. There were significant differences ($p<0.05$) in the pasting properties. The pasting temperature ranged from 75.10 (Asobayere) to 77.30°C (Muchumudu). Peak temperature ranged from 81.7 (Asobayere) to 94.8°C (Muchumudu). Peak viscosity for Asobayere, Pona, Labreko and Muchumudu were 726, 614, 685 and 639 BU respectively. Final viscosity ranged from 385 (Pona) to 817 BU (Muchumudu). Values of 385 (Asobayere), 142 (Labreko), 293 (Pona) and 25 BU (Muchumudu) were observed for breakdown viscosity. Labreko had the highest value of 337 BU and Pona the lowest value of 79 BU for setback viscosity. Muchumudu may be used industrially in products that require high unit yield, low viscosity and paste stability at low temperatures. Asobayere and Labreko may be used for foods that require thick and cohesive paste such as fufu and pounded yam due to its high pasting viscosities. Yam starches can be exploited for diverse uses.

A preliminary Studies on the Development and Evaluation of Instant Pounded Yam from Dioscorea alata was done by Adeola et al. (2012). Results showed that instant poundo yam blanched for 10 min recorded higher sensory scores than the one blanched for 5 min and compared fairly well with the reference sample.

Harijono et al. (2013) studied the effect of blanching on properties of water yam flour. The results showed that the proximate composition of flours from the yellow cultivar was different from that of the purple cultivar. Steam blanching (97±2°C, 7 min) on the purple cultivar resulted in more significant reduction on yield and the Lightness (L) value. However, it had significant effect on some components of the flours such as protein, ash, amylose and fiber. Results of proximate composition showed crude fat yellow and purple water yam ranging from 0.4 to 0.55%, crude protein 5-8%, dietary fiber 16-26% and starch 41-76%. Starch granule size between 20-40 μm. Blanched yellow water yam flour has the highest water and oil absorption which is 2.02 and 1.18 g/g. Dioscorine and water soluble polysaccharides, bioactive components from Dioscorea, of purple water yam flour are larger than the yellow flour. Purple water yam flour is better to be proceed as a functional food because it has a high peak viscosity, more stable to heat and has greater content of bioactive compounds. Steam blanching decrease the yield of dioscorine and water soluble polysaccharide.

Olajumoke et al. (2012) conducted a study to evaluate the proximate and anti-nutrient composition of white Guinea yam diets consumed in Ibarapa, South West region of Nigeria. The yams were prepared as boiled yam (BY), Pounded Yam, Soup and Stew (PYSS), Boiled Yam and Stew (BYS) and Fried Yam and Stew (FYS) and Boiled yam with Rat Chow (BYPo). The soup was prepared using the tender leaves of okro (Abelmuschus esculentus) known locally as "Ilasa". The samples were homogenized, pelleted, dried in an air oven at 55oC for 24 hours, milled and analyzed in triplicates using standard procedures. Results of proximate composition showed crude protein ranging from 6.53±0.11%DM for boiled yam to 17.13±0.05% DM for PYSS, crude fat ranging from 1.00±0.03%DM for BY to 12.72±0.10% DM for FYS. Carbohydrate ranged from 41.86±0.15%DM for PYSS to 68.57±0.06%DM for BY. PYSS had significantly (P<0.0 5) higher protein level but lower carbohydrate and phytate levels. Boiled yam contained the highest hydrocyanic level at 0.19±0.02mg/100g. Phytate levels ranged from 1.91±0.03mg/100g for PYSS to 2.37±0.01mg/100g for FYS. There were significant increases in the levels of total and soluble oxalate in all the diets compared to the boiled yam. The results showed that the various processing methods adopted reduced the hydrocyanic and phytate levels.

CHAPTER III

MATERIALS AND METHODS

This study was conducted in the Laboratory of Food Processing and Preservation, Hajee Mohammad Danesh Science and Technology University, Dinajpur during the period of November, 2016 to June, 2017. In this chapter, the methodology used to prepare the yam flours and its chemical composition and functional properties were discussed.

3.1 Collection and Preparation Sample

Yam tubers were collected from the local market of Basherhat, Dinajpur, Bangladesh. They were thoroughly peeled and washed. Prior to drying, the yam tubers were cut into slices of about 5 mm thickness using a sharp knife. The yam slices were pretreated by blanching at 90 ± 1°C for 3-4 minutes in 2% NaCl + 1% Citric acid solution prior to drying. The initial moisture content of yam tubers was determined at 105^{o}C for 24 h in a hot air oven (AOAC, 2000).

3.2 Drying Experiment

Drying of yam tubers were performed in a cabinet hot-air dryer (Shanghai Experimental Apparatus Company Limited, 101C-3B) at temperatures of 50°C, 60°C, 70°C and 80°C with the air velocity of 1.5 ms^{-1}. The samples were put into the drying chamber after the target condition was steady for at least 1h. About 1000g of yam tuber slices were used in each run. Only single layer of yam slices was used in the drying process. The sample weight was continuously recorded at a time interval of 30 minutes throughout the whole drying period. The drying was stopped when two consecutive weight of the sample become constant. The drying experiments were repeated for triplicate and average moisture content was used to plot the drying characteristics curves for the temperature range studied with dimensionless moisture ratio against drying time. The dried samples were made into powder by a laboratory grinder (Jaipan CM/L-7360065, Japan) and packed in high density polyethylene pouch and stored at 4^{o}C until further used.

3.3 Drying Characteristics

The drying behaviours of yam slices was expressed in terms of drying curve, drying rate curve and dimensionless moisture ratio. The drying rate was calculated using the following equation (Abano et al., 2011; Doymaz, 2010).

$$DR = \frac{M_{t+dt} - M_t}{dt}$$

Where, M_{t+dt} is the moisture content (kg water per kg dry matter) at t +dt, and t is the drying time (min).

The drying curve was constructed by plotting the moisture content against drying time and the drying rate curves was obtained by plotting the drying rates against moisture content. The drying kinetics of yam slices were expressed in terms of empirical models where the experimental data obtained for the four different temperatures (50, 60, 70 and 80°C) were plotted in the form of dimensionless moisture ratio (MR) against drying time (expressed in min). According to Cheng et al. (2015), the MR is expressed as follows:

$$MR = \frac{M - M_e}{M_0 - M_e}$$

Where, M, M_0 and M_e represent the mean moisture content, the initial moisture content and the equilibrium moisture content, respectively.

3.4 Quality Evaluation of Yam Flour

3.4.1 Proximate Composition

3.4.1.1 Determination of Moisture Content

AOAC method 7.045 (2000) was used to determine the moisture content of yam flour. Sample (3gm) was weighed and taken in a clean, dry and pre-weighted petridish. Then the petridish with sample was transferred to oven and dried at 105°C for 24 hours. After that it was cooled at desiccator and weighed. Moisture content was calculated by following formula:

$$\% \text{ Moisture} = \frac{W_1 - W_2}{W} \times 100$$

Here,

W_1 = weight of sample with crucible

W_2= weight of dried sample with crucible

W = weight of sample

3.4.1.2 Determination of Protein Content

Preparation of Standard Curve

Stock solution of Bovine Serum Albumin **(**BSA) was prepared by adding 5 mg BSA to 1 ml distilled water. 500, 1000, 1500, 2000 and 4000 µl of stock solution was taken in 6 different falcon tubes to which distilled water was added to make the final volume of 5000 µl. Five millilitre of Bradford reagent was then added to each of the 6 falcon tubes and mix by vortex (KMC-1300V, Korea) for 4-5 minutes. In another falcon tube, 5000 µl of distilled water was taken for use as blank. The absorbance of the prepared solution was measured at 595 nm using spectrometer (T80 UV/VIS Spectrometer, PG Instruments LTD.) against the blank. The absorbance of the standards solution was plotted against their concentration (Appendix I). The best fit of the data to a straight line in the form of the equation "y = mx + c" was determined; where, y = absorbance at 595 nm and x = protein concentration (mg/ml).

Estimation of Protein

Protein content in the sample was measured spectrophotometrically according to Bradford method (Bradford, 1976) with little modification. 0.5g of sample was taken in a beaker and then 10 ml of distilled water was added to it. Then the sample was stirred with magnetic stirrer and filtered with a filter paper. Then 500 µl filtered samples was taken into a falcon tube and diluted to 4500µL with distilled water. Then 5 ml of Bradford reagent was added and mixed by vortex (KMC-1300V, Korea) for few minutes. The concentration of protein in the solution was determined from the absorbance at 595 nm (T60 U, PG instrument, United Kingdom) against the blank (containing same reagents without sample). Protein content was determined using the following formula by a comparison of the values obtained with the standard curve of BSA and the results were expressed as percentage.

$$\% \text{ Protein} = \frac{\text{X } (mg/ml) \times \text{Voume made (ml)}}{\text{Weight of sample (g)}} \times 100$$

3.4.1.3 Determination of Fat Content

To determine the fat content of yam flours, the AOAC method 7.045 (2000) was used with some modification. Sample (3g) was taken into the thimble. Then the thimble was attached to the Soxhlet apparatus which was attached with a round bottom flask containing 250 ml petroleum ether. The fat was extracted for 6 hours. After that petroleum ether was evaporated at 105ºC until the flask completely dried. Fat content was calculated by following formula:

$$\% \text{ Fat} = \frac{W_1 - W_2}{W} \times 100$$

Here,

W_1= weight of evaporated flask with fat

W_2= weight of empty flask

W= weight of sample

3.4.1.4 Determination of Ash Content

Total ash content of yam flour was measured by AOAC method 14.006 (2000). Sample (3gm) was weighed and transferred into a clean, dry and pre-weighted crucible. Then the crucible was kept into muffle furnace at 550ºC for 6 hours. Turn off muffle furnace and wait to open it until the temperature has dropped to at least 250° C, preferably lower. The door of muffle furnace was opened carefully and the ignited powder was cooled at desiccator and weighed. The ash content was calculated by the following formula:

$$\% \text{ Ash} = \frac{W_1 - W_2}{W} \times 100$$

Here,

W_1= weight of ash with crucible

W_2 = weight of empty crucible

W = weight of sample

3.4.1.5 Determination of Fiber Content

The sample was taken for crude fiber analysis by adopting the procedure mentioned in AOAC (2000). 5g sample was used to determine crude fiber of yam flour. Samples were boiled for 30 minutes in 200 ml of 1.25% H_2SO_4 and then filtered and washed. Then the sample was again boiled in 200 ml of 1.25% NaOH for 30 minutes and then filtered and washed. The resultant residue was dried at 110ºC for 2 hours and weighed. The dried residue was ignited at 550 ± 15ºC, cooled and reweighed. The crude fiber was calculated according to following expression:

$$\% \text{ Fiber} = \frac{\text{Loss in weight on ignition}}{\text{weight of sample}} \times 100$$

3.4.1.6 Determination of Total Carbohydrate

The total carbohydrate contents were determined by deference that is by deducting the mean values of other parameters that were determined from 100 (Amon et al., 2014). Therefore,

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

3.5 Determination of Starch Content

Starch was extracted by the method of Riley et al. (2006) with little modifications. The Freshly harvested yam tubers (100.0 g) were peeled and homogenized with 1 M NaCl (900.0 ml) solution using a multipurpose laboratory grinder (Jaipan CM/L-7360065, Japan). The mixture was filtered through triple layered cheesecloth and starch was washed using distilled water. The granules were allowed to settle and water decanted followed by centrifugation at 3,000 rpm for 10 min. Starch was allowed to air dry overnight at room temperature. The dried granules were crushed into fine powder using multipurpose laboratory grinder (Jaipan CM/L-7360065, Japan) and the amount of starch obtained was measured with an electronic balance. Same procedure was followed for yam flours.

3.6 Determination of Total Phenol Content

The total phenolic content of the sample was determined by Folin-Ciocalteau method (Heimler *et al*., 2006) with slight modification using gallic acid as a standard compound. The extracted solution was obtained using 1g sample mixed with 40 ml 100% methanol in separate glass beaker and stirred for 4-5 minutes. Then the mixtures were concentrated to 10 ml by heat using hotplate stirrer followed by adding 10ml of 100% methanol to concentrated samples solution. From these mixtures, aliquots of 1 ml of each sample were taken in glass test tubes to which 0.2 ml 10% Folin-Ciocalteau reagent was added. These mixtures were vortexed for 3 minutes. Then 0.8 ml of 7.5% Na_2CO_3 was added to the mixture and allowed to stand at dark place for 1-2 hours before measuring the absorbance at 760 nm using spectrometer (T80 UV/VIS Spectrometer, PG Instruments LTD.) against the blank (contained the same mixture solution without the sample extract). Standard gallic acid was used for constructing the standard curve. Concentration range of standard gallic acid was of 0.05, 0.10, 0.15, 0.20, 0.25 and 0.30 mg/ml. The regression line in relation to absorbance (y) and gallic acid content (x) was y = 0.208x + 0.143 at R^2 = 0.985 (Appendix II). The total phenolics were determined using the following formula by a comparison of the values obtained with the standard curve of gallic acid. The results were expressed as mg gallic acid/100g of sample.

$$\text{Total Phenol (mg Gallic acid/100g)} = \text{X (mg/ml)} \times \frac{\text{Volume made (ml)}}{\text{Sample taken (g)}} \times 100$$

3.7 Colour Parameters

The surface colour of yam flour was evaluated with a spectrophotometer (CM2500d, Konica, Minolta Optics Inc., Japan) based on the CIE L*a*b* colour space. Values of 'L*' represent brightness, 'a*' corresponds to the red-green colour gradient while 'b*' corresponds to the yellow-blue colour gradient. Each sample was randomly measured at 3 spots; means of measurements were reported. While the colour difference, ΔE, was calculated in relation to the control sample as follows (Romano et al., 2008):

$$\Delta E = [(L_o - L^*)^2 + (a_o - a^*)^2 + (b_o - b^*)^2]^{\frac{1}{2}}$$

Where L*, a*, and b* and L_o, a_o and b_o are the current and the initial Hunter L*a*b* coordinates, respectively.

The Hue angle (h) and Chroma (C) were calculated according to the formula as follows:

$$h = \tan^{-1}(\frac{b^*}{a^*})$$

$$C = \sqrt{b^{*2} + a^{*2}}$$

For Hue colour index, 0° or 360° represents red and 90°, 180° and 270° represent yellow, green and blue, respectively.

Whiteness index (WI) was calculated according to Hsu *et al.* (2003) as follows:

$$\text{Whiteness Index} = 100 - \sqrt{(100 - L^*)^2 + a^{*2} + b^{*2}}$$

Where: L^*, a^* and b^* were Hunter L^*, a^*, and b^* values.

3.8 Browning Index

Browning index was determined using the method described by Vega-Galvez et al. (2009) with little modification. One gram of dehydrated yam flour was extracted with 40 mL of distilled water and 10 ml of 10% trichloroacetic acid solution in a beaker. The extract was filtered through a Buchner funnel with Whatman No. 2 filter paper. After the solution stood for 2 h at room temperature, its concentration was determined from absorbance readings at 420 nm (T80 UV/VIS Spectrometer, PG Instruments LTD.).

3.9 Evaluation of Functional Properties

3.9.1 Determination of Bulk Density

Jinapong *et al.* (2008) method was used to determine bulk density of yam flours. 1 gm of sample (M) was weighed in a graduated cylinder. Gently tapped the base of the cylinder and read off the volume (V) of sample in ml. Determine bulk density according to the formula:

$$\text{Bulk Density (gm/ml)} = \frac{M}{V}$$

3.9.2 Water Absorption Capacity (WAC) and Water Solubility Index (WSI)

WAC and WSI were evaluated according to Amon *et al*. (2014) methods. Exactly 2.5 g of flour (M_o) were mixed with a 30 ml of distilled water in a centrifuge tube and shaken for 30 min in a KS10 agitator. The mixture was kept in a water-bath (37°C) for 30 min and centrifuged (Ditton LAB centrifuge, UK) at 5,000 rpm for 15 min. The resulting sediment (M_2) was weighed and then dried at 105°C to constant weight (M_1). The WAC was then calculated as follows:

$$\text{WAC } (\%) = \frac{\text{M}_2 - \text{M}_1}{\text{M}_1} \times 100$$

While the WSI was calculated using the following equation:

$$\text{WSI } (\%) = \frac{\text{M}_\text{o} - \text{M}_1}{\text{M}_\text{o}} \times 100$$

3.9.3 Determination of Iodine Affinity of Starch

The iodine affinity of starch was assayed according to method of Kawabata *et al*. (1984) with little modification. Three (3) gms of flour samples were introduced into 50 ml beakers and made up to 30 ml dispersions using distilled water. The dispersion was stirred occasionally within the first 30 min and then filtered through Whatman no.42 filter paper. A 10 ml aliquot of the filtrate was pipetted into a conical flask, phenolphthalein (four drops) was added, and the filtrate titrated with 0.1N I_2 solution to a bluish-black end-point. The starch cell damage (free starch content) was calculated using the titre value and expressed as iodine affinity of starch, IAS (ppm):

$$IAS\ (ppm) = \frac{V_D \times V_t \times N_a}{V_A \times M_s \times 1000} \times 10^6$$

Where,

V_D - Total volume of dispersion;

V_A - Volume of aliquot used for titration;

V_t - Titre value;

M_s - Mass (db) of flour used;

N_A - Normality of iodine solution used.

3.9.4 Determination of Swelling Power

Three (3) gram of each flour were transferred into clean, dry, graduated (50 ml) cylinders. The flour samples were gently levelled and the volumes noted. Distilled water (30 ml) was added to each sample; the cylinder was swirled and allowed to stand for 60 min while the change in volume (swelling) was recorded every 15 min. The swelling power of each flour sample was calculated as a multiple of the original volume as done by Iwuoha (2004).

3.9.5 Gelatinization point determination

In the determination of gelling temperature, the method of Narayana and Narasinya-Rao (1982) was adopted. The flour sample (10 g) was dispersed in distilled water in a 250-ml beaker and made up to 100 ml of flour suspension. A thermometer was clamped on a retort stand with its bulb submerged in the suspension, with a magnetic stirrer, and the system heated. The heating and stirring were continued until the suspension began to gel and the corresponding temperature was recorded.

3.10 Statistical analysis

Each experiment was repeated in triplicate. The obtained data were analyzed by SPSS (version 20.0). The results were expressed as mean ± standard error mean (SEM) of three replicates. One-way analysis of variance was performed using ANOVA procedures. Significant differences among the means were determined by Duncan's Multiple Range Test (DMRT) at the 95% confidence level. Microsoft office excel (2016) was used for plotting graphs.

CHAPTER IV

RESULTS AND DISCUSSION

The present study was conducted in the laboratories of Food Processing and Preservation and Food Engineering and Technology, HSTU, Dinajpur. The interest in the drying of yam slices and production of yam flour is to make it available throughout the year. This flour can be used as a thickener in soup, gravy, fabricated snacks, and bakery products. It can also serve as a substitute for cereal flours that would bring maximum benefit for the farmers and consumers at household and national level.

4.1 Drying Characteristics of Yam Slices

The moisture changing pattern during drying of yam slices as a consequences of various drying temperature at different time intervals is sketched in Fig. 4.1-4.3.

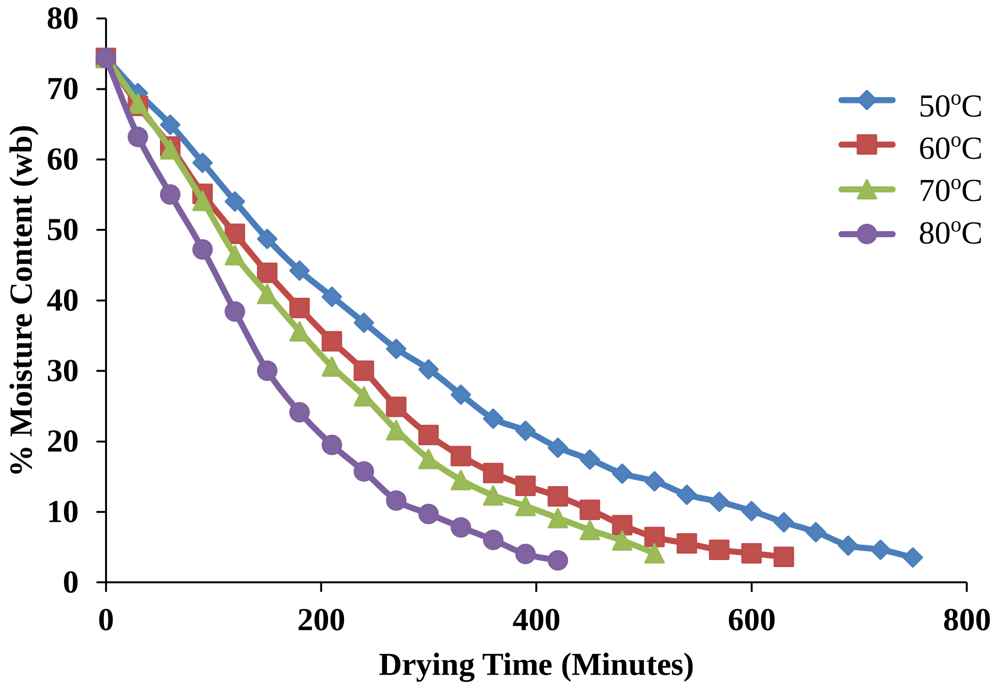

Figure 4.1. Effects of air drying temperature on the drying curve of yam slices dried at different temperature.

It is revealed in the Fig. 4.1 that initially the moisture decreased rapidly and afterwards slowed down and reached to the equilibrium moisture content. The time required for the lowering the moisture content of yam slices from initial 74.44 % (wb) to a constant moisture content was varied between 420 and 730 min, depending on the temperature used. For all sample, the maximum time required by yam slices dried at 50°C (750 min.) followed by 60 °C (630 min.), 70 °C (510 min.) and 80 (420 min.), which indicates that increase in drying temperature results in shorter drying time.

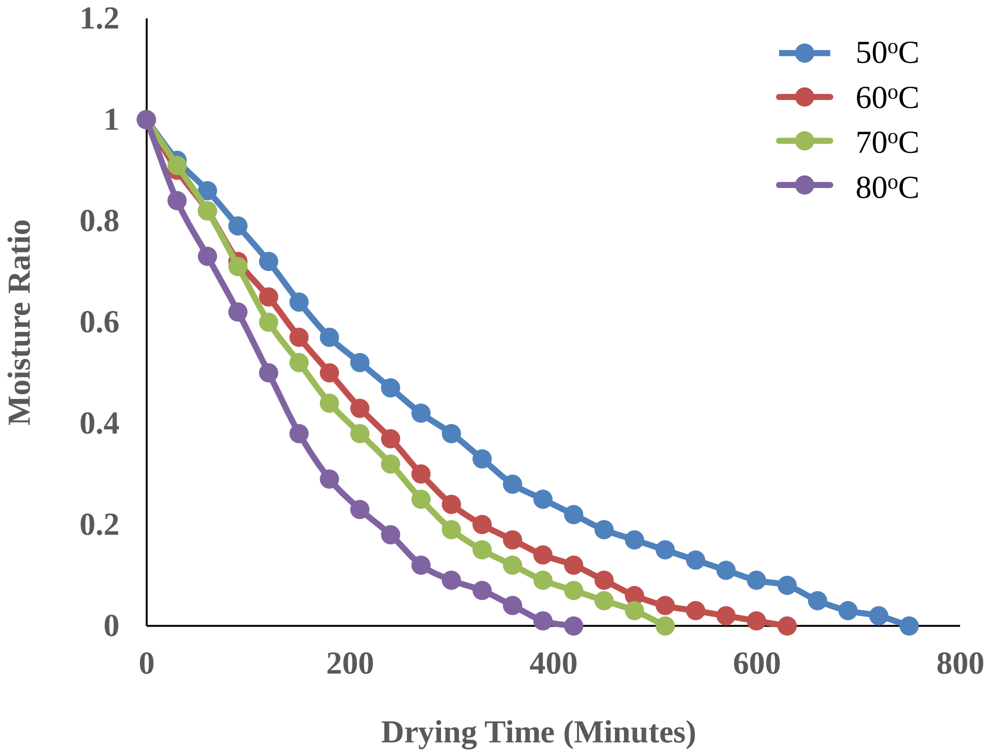

Figure 4.2. Effects of air drying temperature on the moisture ratio of yam slices dried at different temperature.

Figs. 4.2. show that the shape of the moisture ratio curves for all sample is similar to that obtained for other food materials indicating a rapid moisture removal from the product at the initial stage, which later decreased with increase in drying time. Thus the moisture ratio decreased continually with drying time. This continuous decrease in moisture ratio indicates that diffusion has governed the internal mass transfer. This is in agreement with the results of the study on chilli pepper (Tunde-Akintunde, 2011), figs (Piga *et al*., 2004), lettuce and cauliflower leaves (Lopez *et al*., 2000) and peach slices (Kingsly *et al*., 2005).

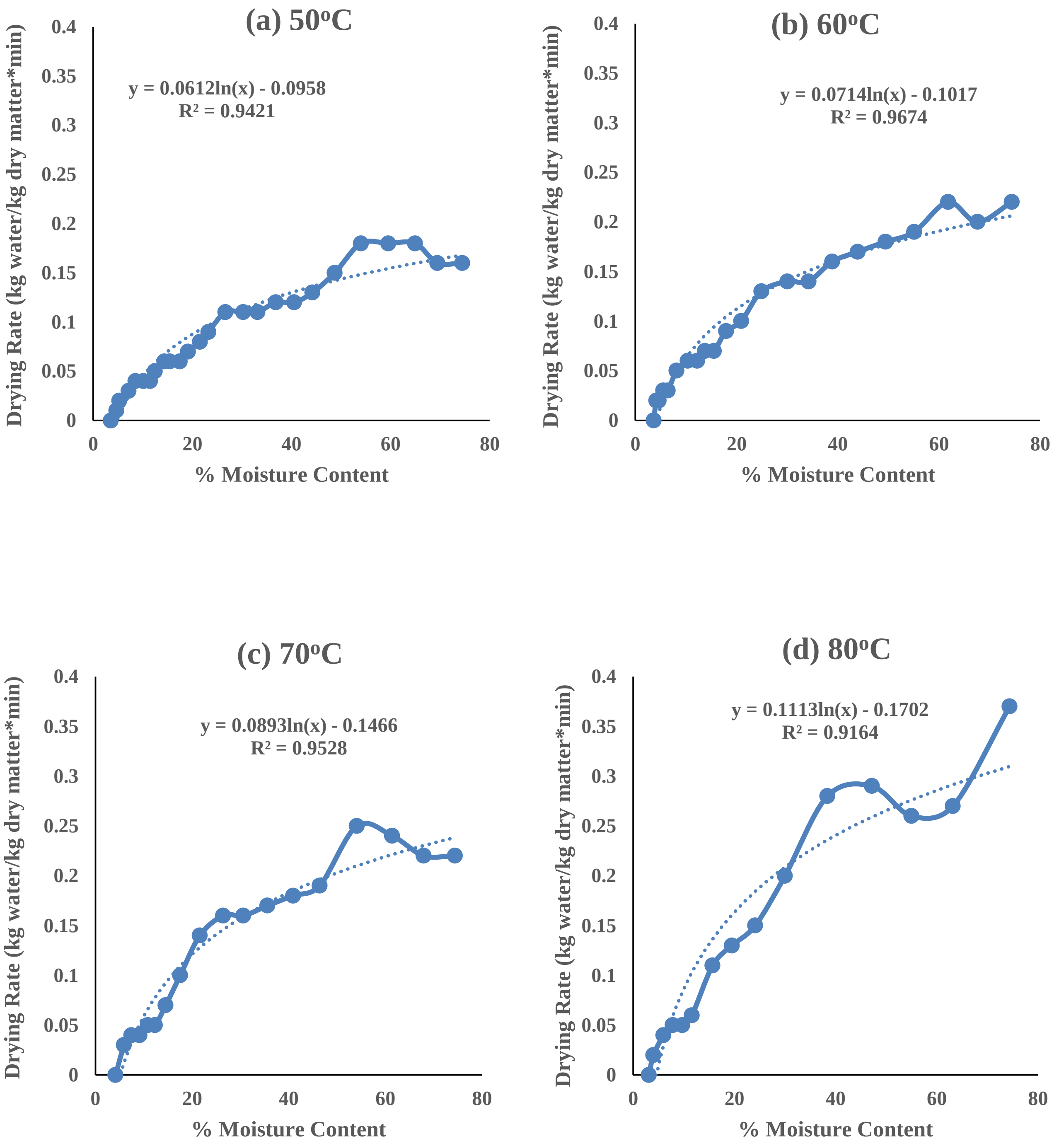

Figure 4.3 Drying rate curves showing the rate of moisture removal during drying of yam slices at different temperature.

Drying rate versus moisture content during drying of yam at different drying temperature is presented in Fig 4.3 (a) – (d). It is observed from the figures that drying rate of yam tuber was higher at higher moisture content and it decreased logarithmically as moisture content reduced (Fig. 4.3 (a) – (d)) during the drying process. At the initial stage of drying, the moisture content of yam was high and more moisture was evaporated from the outer surface and outer layers of yam. As the drying process proceeded, the moisture on the surface decreased and the evaporation zone moved from the surface into the inside of yam and less evaporation took place and hence drying rate reduced with the drying time as well as moisture content. Further, no constant-rate period has been observed during drying of yam slices while drying took place only in the falling-rate period. The following regression equations were developed for drying rate with the moisture content of yam slices.

For yam slices dried at 50ºC:

$$y = 0.0612 \ln(x) - 0.0958 \qquad (R^2 = 0.9421) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

For yam slices dried at 60ºC:

$$y = 0.0714 \ln(x) - 0.1017 \qquad (R^2 = 0.9674) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.2)$$

For yam slices dried at 70ºC:

$$y = 0.0893 \ln(x) - 0.1466 \qquad (R^2 = 0.9528) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.3)$$

For yam slices dried at 80ºC:

$$y = 0.1113 \ln(x) - 0.1702 \qquad (R^2 = 0.9164) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.4)$$

According to the regression equations, it is obvious that highest drying rate was observed during drying of yam slices at 80ºC (R^2 = 0.9164), followed by 70ºC (R^2 = 0.9528), 60ºC (R^2 = 0.9674) and 50ºC (R^2 = 0.9421), respectively. These results correspond to observations reported by Hossain and Bala (2007) and Banout *et al*. (2011) in the study focused on solar drying of red chilli.

4.2 Chemical Composition of Yam Flours

The result obtained from the chemical analysis of the hot air dried yam flours using various temperature is shown in Table 4.1.

4.2.1 Moisture Content

There were significant differences ($p < 0.05$) in moisture content among the samples. It was observed that moisture content levels of the yam samples using various drying temperature were ranged between 9.34 to 11.33% with 74.44% in fresh yam. All the samples had a moisture content below 13% which is the standard for dry food samples as described by (Prinyawiwatkul *et al*. 1997), the result of the moisture content is consistent with the previous reports of Jimoh and Olatidoye (2009) and Okaka and Okechukwu (1993). Higher ranges were also 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 range is higher than the range 8.4-10.7 % found by Ukpabi *et al*. (2007) for sun dried chips from D. alata cultivars. Reduction in moisture content as observed in this study will reduce perishability and therefore extend the shelf-life of yam as a food item and make it available throughout the year.

4.2.2 Protein Content

The protein content of yam flours was significantly different among the samples ($P \leq 0.05$) dried at the different temperature and ranged from 4.24 % to 5.42 %, whereas crude protein content of fresh yam tuber was 2.82 %. These values were lower than the reports of Hsu *et al*. (2003) who obtained 10-11% of crude protein using various drying method. 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 recorded by Agoreyo *et al*. (2011) for D. rotundata using various drying methods.

4.2.3 Fat Content

The fat content of yam flours obtained by drying at different air temperature is presented in Table 4.1. The fat content of yam flours was found to be ranged between 0.45 to 0.95 % which was significantly different from the air drying temperature. Among the samples, yam flours obtained at 80^{o}C was recorded to have maximum fat content (0.95%) followed by 70^{o}C, 50^{o}C, 60^{o}C. Low-fat contents obtained in the yams flours were in accordance with the previous study of Afoakwa & Sefa-Dedeh (2001).

Table 4.1. Effect of air drying temperature on the chemical composition of yam flours.

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fiber (%)	Carbohydrate (%)	Starch (%)	Total Phenol (mg GAE/100g)
Fresh Yam	74.46 ± .02a	2.82 ± 0.01e	0.73 ± .01b	1.51 ± 0.01e	0.42 ± 0.01e	20.06 ± 0.03e	37.23 ± 0.34	18.22 ± 11.62a
Yam flours obtained at:								
50ºC	11.33 ± .03b	4.24 ± 0.01d	0.52 ± .01d	4.97 ± 0.01c	1.33 ± 0.02b	77.63 ± 0.03c	65.57 ± 0.28a	9.81 ± 0.13c
60ºC	10.04 ± .10c	4.53 ± 0.01c	0.45 ± .01e	5.01 ± 0.01b	1.77 ± 0.01a	78.20 ± 0.04b	64.63 ± 0.29a	10.49 ± 0.11b
70ºC	9.61 ± .01d	4.86 ± 0.01b	0.61 ± .01c	4.64 ± 0.01d	0.75 ± 0.01d	79.23 ± 0.02a	60.44 ± 0.26b	10.74 ± 0.09b
80ºC	9.34 ± .15e	5.42 ± 0.01a	0.95 ± .01a	5.99 ± 0.01a	0.88 ± 0.01c	77.41 ± 0.01c	56.46 ± 0.25c	9.68 ± 0.06c

All values are mean ± SEM of three replicates.
Means followed by different lowercase letters in each column are significantly different among flour samples ($p < 0.05$).

4.2.4 Ash Content

Yams are reported to contain a relatively high level of minerals (Afoakwa & Sefa-Dedeh, 2001; Liu *et al*., 1995). From Table 4.1 it is seen that significant ($p < 0.05$) differences exists in the ash content of the yam samples. Fresh yam tuber contained 1.51 % of ash, whereas yam flours contained 4.64 – 5.99% of ash, which reflected the mineral contents of the yam tubes. These findings were found to be higher than that reported by Olajumoke *et al*., (2012) for white guinea yam. The drying methods significantly increase the ash content. Besides, the variation in ash content observed could be due to the varietal and environmental differences (Saniful *et al*., 2013).

4.2.5 Fiber Content

There was an increased in crude fibre in all yam flours dried at various temperature compared to the fresh yam. Table 4.1 showed that crude fibre of yam flour ranged from 0.75 - 1.33 %, whereas it was 0.42 % in fresh yam and were found to be significantly ($p < 0.05$) different among the flours obtained at different drying temperatures. The crude fiber obtained in this study is comparable to the findings of Hsu et al. (2003). This finding is important because crude fibre has a useful role in providing roughage that aids digestion and reduces the risks of cardiovascular diseases (Verma and Banerjee, 2010; Sharma et. al., 2011; Dhingra *et al*., 2011). Previously, it was reported that increase in fibre consumption might have contributed to the reduction in the incidence of certain diseases such as diabetes, coronary heart disease, colon cancer and various digestive disorders (Augustin *et al*., 1978). Fibre consumption also softens tools and lowers plasma cholesterol level in the body (Verma and Banerjee, 2010; Sharma *et al*., 2011; Dhingra et al., 2011).

4.2.6 Carbohydrate Content

The largest components in yam flours were carbohydrate. From Table 4.1, it is shown that total carbohydrate content of yam flours was ranged from 77.41 to 79.23 %, which was mainly contributed by starch in the yam tubers. Because many carbohydrate constituents besides starch might be found in yam and starch is not the primary bioactive ingredient in yam flours. In the proximate analysis, the total carbohydrate of yam was obtained by subtraction, i.e. 100 – (moisture + crude protein + crude fat + crude fibre + ash). So, compositional variation may be contributed to the differences in total carbohydrate content of yam samples.

4.3 Total Starch Content

The total starch content of yam flours obtained by different air drying temperature of yam tuber is shown in Table 4.1. A significant difference in starch content was observed between samples ($P \leq 0.05$) being highest in yam flours obtained by drying at 50ºC (65.57%) followed by 60ºC (64.63%), 70ºC (60.44%) and 80ºC (56.46%) whereas the fresh yam possessed 37.23 % of starch. Comparatively, high starch content was observed among the sample prepared by using different air drying temperature. These contents are more or less similar to the findings of previous researchers as such, Oladeji *et al*. (2014), Du Toit (2004) and Harijono *et al*. (2013) reported 39.9 to 75.7%, 63 to 72% and 41 to 76%, respectively.

4.4 Total Phenolic Content

The principal antioxidant constituents of natural products are phenolic compounds which composed of phenolic acids and flavonoids that are potent radical terminators (Shahidi & Wanasundara, 1992; Ghasemnezha *et al*., 2011). The total phenol contents were significantly different among the samples ($P \leq 0.05$). Our results showed that total phenolics content was found to be decreased in all air dried yam flours (ranged from 9.68 to 10.74 mg GAE/100g) compared to fresh yam (18.22 mg GAE/100g). Previous researchers reported that total phenolic content was found to decrease after drying (Amon *et al*., 2014; Wiriya *et al*., 2009; Arnnok *et al*., 2012).

4.5 Color Attributes of Yam Flours

The quality of dried products depends on its color, which reflects the consumer's acceptances and therefore the market price. The effects of air drying temperature on color attributes of all yam flour samples are shown in Table 4.2. The L (lightness) values ranged from 51.33 to 67.28, a (red /green) values ranged from 13.63 to 18.33 and the b (yellow /blue) 1.58 to 5.75, whereas these values for fresh yam was 69.24, 23.19 and 7.14, respectively. Table 4.2 revealed that maximum colour change (ΔE) was observed in yam flours dried at 60ºC (20.84) followed by 80ºC (14.01), 70 ºC (7.72) and 50 ºC (7.65) compared to fresh yam tuber. The hue angle (h) and chroma (C) specifies the purity of the color (Wiriya *et al*., 2010). The hue angle and chroma of yam flours between 5.35 to 18.40 and 14.54 to 18.77, respectively, while these values for fresh yam were 16.92 and 25.48, respectively (Table 4.2).

Table 4.2. Effect of air drying temperature on the color attributes and browning power of yam flours.

Sample	L*	a*	b*	ΔE	H	C	Whiteness Index	Browning Index (420nm)
Fresh Yam	69.24 ± 0.46a	23.19 ± 0.35a	7.14 ± 0.42a	-	16.92 ± 0.44a	25.48 ± 0.31a	58.60 ± 0.65b	-
Yam flour obtained at:								
50°C	65.85 ± 0.53^{b}	16.62 ± 0.61^{c}	5.75 ± 0.13^{b}	7.65 ± 0.19^{c}	18.40 ± 0.55^{a}	17.60 ± 0.57^{b}	60.70 ± 0.78^{b}	0.32 ± 0.01^{a}
60°C	51.33 ± 0.29^{d}	13.63 ± 0.58^{d}	3.31 ± 0.12^{d}	20.84 ± 0.28^{a}	13.76 ± 0.54^{b}	14.54 ± 0.45^{c}	51.16 ± 0.68^{c}	0.24 ± 0.22^{b}
70°C	67.28 ± 0.66^{b}	18.33 ± 0.38^{b}	1.58 ± 0.11^{e}	7.72 ± 0.22^{c}	5.35 ± 0.45^{c}	17.90 ± 0.49^{b}	64.34 ± 0.61^{a}	0.17 ± 0.01^{c}
80°C	56.61 ± 0.31^{c}	17.10 ± 0.56^{bc}	4.35 ± 0.14^{c}	14.01 ± 0.18^{b}	13.64 ± 0.53^{b}	18.77 ± 0.31^{b}	51.66 ± 0.69^{c}	0.12 ± 0.01^{d}

All values are mean ± SEM of three replicates.
Means followed by different lowercase letters in each column are significantly different among flour samples ($p < 0.05$).
L^* = lightness; a^* = red (+)/green (-); b^* = yellow (+)/blue (-); ΔE = Color Change; h = Hue angle; C = Chroma.

Whiteness index (WI) represents the overall whiteness of food products that may indicate the extent of discoloration during the drying process. It is shown in Table 4.2 that the values of whiteness index were ranged from 51.15-64.34 among the yam flour, which was 58.60 for fresh yam. This value indicates that discoloration of yam flour was found to be less in this study. For white yams, flour obtained by drying at 70°C resulted in higher WI than others. In the case of white yam flours, higher WI means better consumer acceptability whereas, lower WI of dried yam flour indicated less reduction in redness during drying; bright red is also a popular food colour for consumer (Hsu *et al*., 2003).

4.6 Browning Index of Yam Flours

Table 4.2 shows the effects of different drying temperatures on the browning index of yam flours. Browning index of yam flours was found to be significantly different ($P < 0.05$) and ranged from 0.12 to 0.32 at 420 nm, which were lower than the value reported by Ahmed et al. (2010) for sweet potato flours (0.23 to 0.43). Higher browning index was observed in yam flour obtained at 50°C and decreased with increasing drying temperatures (Table 4.2), which is corroborated with the findings of Ahmed et al. (2010). The decrease in the browning index may be explained by inactivation of phenolic compounds. Elevated temperatures have been reported to deactivate polyphenol oxidase (Akyildiz & Ocal, 2006). Moreover, browning appears to be a complex process involving several factors including substrate levels, enzymatic activity, the presence of ascorbic acid, and other inhibitors or promoters influencing the browning reaction, in addition to tissue damage (Zhang *et al*., 2005).

4.7 Functional Properties of Yam Flours

Functional properties in terms of bulk density, swelling power, water absorption power, water solubility power, iodine affinity of starch, starch gelatinization point are shown in Table 4.3.

4.7.1 Bulk Density

The bulk density (g/ml) of flour is the density measured without the influence of any compression. The bulk densities of yam flours ranged from 0.84 g/ml to 1.15 g/ml. The highest bulk density was observed in flour dried at 50°C (1.15 g/ml) followed by 60°C (1.04 g/ml), 80°C (0.90 g/ml), and 70°C (0.84 g/ml).

According to Appiah *et al*. (2011), higher bulk density is desirable for greater ease of dispersibility of flours, would occupy less space per unit weight and be easier to transport as it was lighter. The high bulk density of flour suggests their suitability for use in food preparations. On contrast, low bulk density would be an advantage in the formulation of complementary foods (Akapata and Akubor, 1999). Therefore, the present study suggests that bulk density of yam flour suggests its suitability to be used as a thickener in food products and for use in food preparation since it helps to reduce paste thickness which is an important factor in convalescing and child feeding.

4.7.2 Swelling Power

When starch is heated with excessive amount of water, granule hydrate progressively, hydrogen bonds are ruptured resulting in crystalline regions being converted into amorphous regions and granules continue to imbibe water and swell (Harijono *et al*., 2013; Ratnayake *et al*., 2002). Large starch granules are known to swell faster (Adejumo et al., 2011). In this study, the swelling power of yam flours was calculated as a multiple of the original volume as done by Ukpabi and Ndimele (1990). The swelling power of yam flours dried at the different temperature ranged between 2.10 to 2.63. From Table 4.3, it is clear that significant difference ($P < 0.05$) exists among the samples, being lowest value of swelling capacity was observed in flours dried at 60^{o}C (2.10) whereas the maximum in 50^{o}C (2.63). The variation may be due to various reasons as such the swelling capacity of flours depends on the size of particles, types of variety and types of processing methods or unit operations (Chandra *et al*., 2015).

4.7.3 Water Absorption Capacity

Water absorption capacity is a functional property that characterizes the ability of flour to rehydration (Himeda *et al*., 2014). The water absorption capacity for yam flours is given in Table 4.3. The WAC ranged between 132 to 176% for all flours. The WAC was observed highest in flour dried at 50^{o}C (267.61 %) and lowest in 50^{o}C (182.68 %). Kaushal *et al*. (2012) and Kuntz (1971) reported that lower WAC in some flours may be due to less availability of polar amino acids in flours. High WAC of composite flours suggests that the flours can be used in the formulation of some foods such as sausage, dough, processed cheese and bakery products (Chandra *et al*., 2015). The increase in the WAC has always been associated with the increase in the amylose leaching and solubility and loss of starch crystalline structure.

Table 4.3. Effect of air drying temperatures on the functional properties of yam flours.

Drying Temperature	Bulk Density (g/ml)	Swelling Power	Water Absorption Capacity (%)	Water Solubility Index (%)	Iodine Affinity of Starch (ppm)	Starch Gelatinization Point (°C)
50°C	1.15 ± 0.01^{a}	2.63 ± 0.01^{a}	267.61 ± 0.33^{a}	13.59 ± 0.36^{d}	353.33 ± 0.33^{a}	77.67 ± 0.23^{d}
60°C	1.04 ± 0.01^{b}	2.10 ± 0.01^{d}	221.19 ± 0.49^{b}	22.73 ± 0.23^{b}	213.33 ± 0.31^{c}	83.33 ± 0.18^{b}
70°C	0.84 ± 0.01^{d}	2.25 ± 0.01^{c}	182.68 ± 0.44^{c}	17.21 ± 0.12^{c}	243.33 ± 0.33^{b}	79.67 ± 0.13^{c}
80°C	0.90 ± 0.01^{c}	2.44 ± 0.01^{b}	220.56 ± 0.57^{b}	27.16 ± 0.21^{a}	196.66 ± 0.27^{d}	85.31 ± 0.22^{a}

All values are mean ± SEM of three replicates.
Means followed by different lowercase letters in each column are significantly different among flour samples ($p < 0.05$).

The flour with high water absorption may have more hydrophilic constituents such as polysaccharides. Protein has both hydrophilic and hydrophobic nature and therefore they can interact with water in foods. The observed variation in different flours may be due to different protein concentration, their degree of interaction with water and conformational characteristics (Chandra *et al*., 2015; Butt and Batool, 2010).

4.7.4 Water Solubility Index

The water solubility index for yam flours is given in Table 4.3. The WSI ranged between 13.59 to 27.16 % for all flours. The WSI was observed highest in flour dried at 80^{o}C (27.16 %) followed by 60^{o}C (22.73 %), 70^{o}C (17.21 %) and 50^{o}C (13.59 %) and were significantly different at 95% confident level. The water solubility index (WSI) reflects the extent of starch degradation (Hsu *et al*., 2003). It is revealed from Table 4.3 that the extent of starch degradation is less in yam flour obtained by drying at 50^{o}C. The water solubility index recorded in this study is higher than that was reported by Iwuoha (2004) and Hsu *et al*. (2003). The proteins, total sugars and crude fat play an important role in changing this functional property (Amon et al., 2014).

4.7.5 Iodine Affinity of Starch

The primary values obtained from the measurements of the iodine affinity of starch are shown in Table 4.3. In this study, the change in drying temperature led to a significant ($P < 0.05$) reduction in iodine affinity of starch. The iodine affinity of starch of yam flours dried at different temperature was ranged from 196.66 to 353.33 ppm (Table 4.3). Highest values for iodine affinity of starch was recorded in flours dried at 50^{o}C (353.33 ppm), followed by 70^{o}C (243.33 ppm), 60^{o}C (213.33 ppm) and lowest for 80^{o}C (196.66 ppm). These values for iodine affinity of starch contained in flours obtained by drying at different temperature are in line with Amon *et al*. (2014) for taro flours (220 to 330 ppm). The above results showed that the air dried yam flour sample contains starch granules with the highest affinity for iodine i.e. contains more amylose, which in consonance with reports by Iwuoha (2004).

4.7.6 Starch Gelatinization Point

The temperature at which gelatinization of starch takes place is known as the gelatinization temperature (Sahay and Singh 1996). From Table 4.3, it is shown that gelatinization temperature of yam flours ranged 77.67°C to 85.31°C. Highest gelatinization temperature was found for flours dried at 80ºC (85.31°C) and lowest for 50ºC (77.67°C). This result is comparable to the outcomes of the previous study of Baah (2009) and Iwuoha (2004). It is also clearly revealed in Table 3.4 that the flour which was higher in starch content took the lowest temperature for gelatinization. Chandra *et al*. (2015) also reported the same observation for composite flours prepared by blending wheat flour with rice flour, green gram flour and potato flour. The gelation capacity of flours is influenced by physical competition for water between protein gelation and starch gelatinization (Kaushal *et al*., 2012).

CHAPTER V

SUMMARY AND CONCLUSION

The present research was conducted to find out suitable drying temperature for yam tubers and to evaluate the effects of temperature on the nutritional composition and functional properties of yam flours.

To execute this research, four temperatures (50, 60, 70 and 80^{o}C) were selected on the basis of different literature along with pretreatment of yam slices by blanching in boiling water containing 1% citric acid and 2% NaCl. The drying procedure was carried out in a cabinet dryer maintaining the above temperature. In this study, the drying characteristics were evaluated for yam tubers and results revealed that time required for drying of yam slices were ranged from 420 to 730 minutes to reach equilibrium condition.

Chemical analysis in terms of proximate composition (moisture, ash, crude fat, crude protein, fiber and carbohydrate), total starch and total phenolic contents were studied and found to be significantly varied with drying temperature. Functional properties such as color attributes (e.g. Hunter 'Lab' color coordinates, hue angle, chroma, whiteness index), browning index, bulk density, swelling power, water absorption index, water solubility index, iodine affinity of starch and starch gelatinization were evaluated. Findings of this study indicated that temperature has vital influence on the properties of yam flours.

Results revealed that air drying temperature had a significant ($P < 0.05$) effect on the reduction in moisture content from initial 74.44% to a final level of 9.34 to 11.33 %. Also, the total phenolic content of fresh yam tubers (18.22 mgGAE/100mg) decreases (9.68 to 10.74 mgGAE/100g) after drying at different temperatures. On the other hand, before drying of yam slices had the protein, ash, fat, fiber, total carbohydrate and total starch content was 2.82%, 1.51%, 0.73%, 0.42 %, 20.06 % and 37.23 %, respectively. In flour samples, the values for protein, ash, fat, fiber, total carbohydrate and total starch content were found to be 4.24 to 5.42%, 4.64 to 5.99 %, 0.45 to 0.95 %, 0.75 to 1.33 %, 77.41 to 79.23 %, and 56.46 to 65.57 %, respectively.

Drying temperatures affected both chromatic parameters (L, a, b, h, C and whiteness index) and browning index, which contributed to the discoloring of yam flours. Moreover, the functional properties of yam flours in terms of bulk density (0.84 - 1.15 g/ml), swelling power (2.10 - 2.63), water absorption index (132 - 176%), water solubility index (13.59 – 27.16%), iodine affinity of starch (196.66 - 353.33 ppm) and starch gelatinization point (77.67 - 85.31°C) was found to be varied significantly ($P < 0.05$) among the flour obtained at different temperatures.

This study gives valuable information regarding to the drying characteristics of yam tubers. Results showed that yam flours contained significant amount of nutritious and health beneficial compounds. Information's on functional properties of yam flours will help the food processors about the quality and properties of yam flours during formulation and preparation of various food products.

Processing of yam tubers through drying and made it into flours could be a potential technique to reduce field wastage of yams and hence, its growers could be benefitted. This yam flours can be used with many food formulations in adjunct with wheat flour, rich, maize flours. Therefore, yam flour could be used to make a higher quality product that is more attractive to product developers and consumers.

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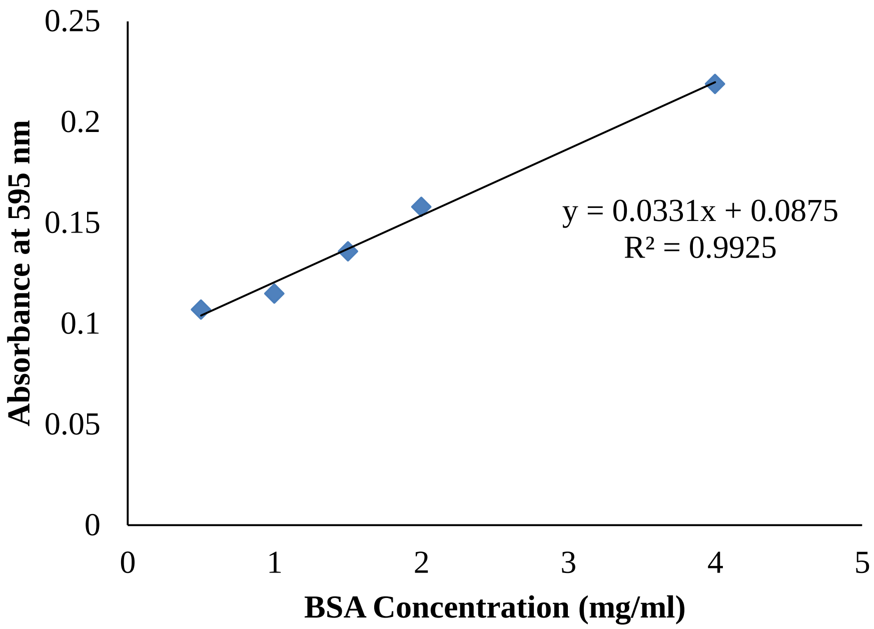
APPENDICES

Appendix I. Bovine Serum Albumin (BSA) standard curve for estimation of protein.



Appendix II. Gallic Acid (GA) standard curve for estimation of total phenolic content