NUTRITIONAL CHARACTERISATION OF SELECTED YAM VARIETIES AND CONTRIBUTION OF YAM TO NUTRIENT INTAKE IN EKITI STATE, NIGERIA

BY

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CERTIFICATION

We certify that this study was carried out by Yetunde Olukemi, **OLAWUYI** in the Department of Human Nutrition, Faculty of Public Health, College of Medicine, University of Ibadan under our joint supervision.

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DEDICATION

This work is dedicated to God the Father, God the Son and God the Holy Spirit.

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ABSTRACT

Excessive consumption of staples plays a contributory role in the global upsurge of the prevalence of diet related chronic diseases. Yam is a multi-species and multi-variety staple food with pivotal role in ensuring food security in Nigeria. Intra and inter species diversity of foods are being promoted as part of means to tackle malnutrition. Ekiti State is one of the highest producers and consumers of yam, without well documented information on varieties commonly consumed and their dietary diversity. This study was conducted to assess the available and commonly consumed yam varieties, inter-varietal nutritional differences, evaluate dietary diversity and contribution of yam to nutrient intake in Ekiti State.

Proximate, mineral and phytochemical analyses were carried out on 12 purposively selected yam varieties using standard methods. Cross-sectional study of 450 adults selected from six Local Government Areas (LGA) in Ekiti State was done using a four-stage sampling method. Interviewer-administered questionnaire was used to collect data on socio-demographic characteristics, commonly-consumed yam varieties, yam consumption pattern, and dietary intake. Dietary intake was assessed with multi-pass 24-hour dietary recall to calculate the Individual Dietary Diversity Score (IDDS), energy and nutrients intake. The IDDS was derived from nine (9) food groups and categorised into low (1-3), medium (4-6) and high (7-9). Contribution of yam to total energy and nutrient intake was determined using standard procedure. Data were analysed using descriptive statistics, Chi square test and ANOVA at $\alpha_{0.05}$.

Nutritional composition per 100g of yam varieties was significantly different for moisture (50.1-69.8)g, carbohydrate (27.3-46.1)g, protein (1.8-3.0)g, ash (0.5-1.3)g, and metabolisable energy (119-194) kcal. Saponin, alkaloids, phenols, phytate and tannin content ranged from 19.38-33.19%, 1.11-4.29%, 6.11-10.11 GEmg/100g, 1.26-1.93%, and 0.06-3.00%, respectively. Twenty five yam varieties were identified in the state and the seven most commonly-consumed varieties were G*ambari* (29.2%), *Olo* (15.1%), *Aro* (7.8%), *Ileusu* (3.1%), *Dagidagi* (2.4%), *Gbakumo* (2.2%) and *Odo* (2.2%). Respondents' age was 34.1±12.2 years, and 56.0% were females. About 61% of the respondents consumed yam or its products daily, including pounded yam (65.5%) and boiled yam (24.0%). Preference for yam varieties was largely determined by season/availability (53.3%) and organoleptic properties (30.6%). Mean IDDS was 3.6±0.9, 57.6% fell within medium and 42.0% had low IDDS. Daily energy, protein, carbohydrate, iron and magnesium intake were 1985.4±615.3 kcal, 55.1±27.3g, 422.5±117.3g, 15.3±5.8mg, and 251.9±86.0mg, respectively. Yam and its products contributed an average of 31.7%, 5.4%, 27.3% and 31.9% of total energy, protein, iron and magnesium intake, respectively. The choice of the most preferred yam varieties was significantly associated with LGA, age, educational qualification, occupation and household monthly income. Only marital status was significantly associated with IDDS.

Yam varieties had disparate macro- and micronutrient contents, and largely contributed to energy, carbohydrate and magnesium intake. The diet of respondents was not diverse enough, hence the need to address dietary diversity in order to improve nutrient intake adequacy in Ekiti State.

Keywords: Dietary diversity, Yam consumption pattern, Dietary assessment, Varieties of yam

Word count: 470

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
AOAC	Association of Analytical Chemists
BMGF	Bill and Melinda Gates Foundation
BMI	Body Mass Index
CBD	Convention on Biological Diversity (Secretariat)
DDS	Dietary Diversity Score
FANTA	Food and Nutrition Technical Assistance
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	FAO Statistics
FHI	Family Health International
GDP	Gross Domestic Product
GI	Glycemic Index
HDDS	Household Dietary Diversity Score
HH	House Hold
IDDS	Individual Dietary Diversity Score
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
INFOODS	International Network of Foods Data System
IYCDDS	Infant and Young Child Dietary Diversity Score
LGA	Local Government Area
LSMS-ISA	Living Standards Measurement Study- Integrated Survey on Agriculture
MDD-W	Minimum Dietary Diversity-Women
NBS	Nigeria Bureau of Statistics

NNHS	National Nutrition and Health Survey
NPC	National Population Commission
NRCRI	National Root Crop Research Institute
RDI	Recommended Daily Intake
RDA	Recommended Daily Allowance
SPSS	Statistical Package for Social Sciences
TDA	Total Dietary Assessment
UCH	University College Hospital
UI	University of Ibadan
UNICEF	United Nations Children's Fund
USD	United States Dollars
WDDS	Women's Dietary Diversity Score
WFP	World Food Programme
WHO	World Health Organization
YIIFSWA	Yam Improvement for Income and Food Security in West Africa

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Currently, approximately 820 million people worldwide are affected by food insecurity and hunger (defined as not having enough calories to live an active healthy life), threatening the hope of achieving by 2030 the Zero Hunger target. According to data, there has been an upsurge in the number of people worldwide who consume insufficient dietary energy. Africa continues to be the hardest hit by this unfortunate trend, with an estimated 22.3 percent of the Sub-Sahara African population affected (IFPRI, 2019). The prevalence of malnourished people in Africa is steadily increasing, reaching nearly 260 million in 2018, with the majority living south of the Sahara. Undernourishment in Western Africa is steadily worsening, from 10.8% in 2013 to 14.7% in 2018 (FAO, IFAD, UNICEF, WFP, WHO, 2019).

Yam (*Dioscorea* spp.) is a key staple in the sub-Saharan part of Africa which has been reported to play a critical role in guaranteeing livelihood systems and food security for at least sixty million people (Mignouna *et al.*, 2014). Tuber crops, roots and other starchy foods have been identified as vital constituents of the diet, responsible for approximately 50% of the nourishment consumed by Africans south of the Sahara, and this constitutes important staples for approximately a billion people in the developing countries (Diouf 2005, Dilworth *et al.*, 2012). Yams are the most important source of calories for many people in the sub-Saharan region, particularly in West Africa's yam zones. Some of the world's tropical countries, from Nigeria to Cote d'Ivoire, are home to the world's yam belt, where approximately 300 million people get more than 200 kilocalories per person per day from yam (Nweke *et al.*, 2013). In Nigeria, the fourth most significant source of calorie after sorghum, millet, and cassava is yam and its consumption is high (Nweke *et al.*, 2013). Many countries are gradually moving away from traditional foods, however there is a growing awareness of the nutritional importance of traditional food crops (Onimawo, 2010).

Traditional foods available in Nigeria are numerous and diverse, depending on the climate and vegetation of the region. Benue, Edo, Cross River, Delta, Ondo, Imo, Adamawa, Kaduna, Ekiti, Ogun, Osun, Kwara. Oyo, and Plateau have been identified as the states with the highest yam production (BMGF, 2014). As a result, it is critical to investigate the rich biodiversity of this important crop, as well as identify and highlight varieties with significant nutritional qualities that could also serve as functional food. In many cases, the nutritional and health benefits provided by biodiversity of the food humans consume, have not received sufficient attention (De Clerck *et al.* 2011).

Mucin, allantoin, dioscin, choline, dioscorin, diosgenin, polyphenols, and vitamins such as tocopherols and carotenoids are all found in yam tubers (Bhandai, Kasa and Kawabata, 2003). The mucilage of yam tuber contains soluble glycoprotein and dietary fiber. Many studies have shown that yam extracts have hypoglycaemic, antioxidant and antimicrobial properties (Chan *et al.*, 2004; Dilworth *et al.*, 2012; Maswada. 2013; Chandrasekara, 2018). Aside from the characteristics of yam starch content, *Dioscorea* species may serve as anti-clotting, antioxidants, anti-inflammatory immunological boosters, and hormone modulators due to the presence of phenols (Farquer, 1996; Okwu and Omodamiro, 2005). Yams may also stimulate the proliferation of gastric epithelial cells and increase the activity of digestive enzymes in the small intestine (Chen *et al.*, 2003). Highlighting the nutritional potential of yams and exploring its intervarietal biodiversity may enhance food security in the tropical zone (Senavirathna *et al.*, 2014).

Nigeria is the world's leading yam producer. In 2012, the country was responsible for more than 65 percent (38 million metric tons) of global production valued at $7.75 billion and cultivated approximately 2.9 million hectares of land, followed by Ghana and Cote d'Ivoire (FAOSTAT, 2015). Yams contribute significantly to the socio-cultural and economic well-being of millions of people in Nigeria and around the world. Because of its high market demand and ease of exchange for cash in rural and urban markets, it is a major source of cash income for millions of producing households. Because its consumption is more widely spread than its production, yam is a contributor to the economy in West Africa (Nweke *et al.*, 2013). Since early 2010, the European Union (EU) has provided support for yam as a source of revenue and food security through a program managed by the International

Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, in collaboration with 13 other research institutes from six countries: Benin, Cameroon, Cote d'Ivoire, Ghana, Nigeria, and Togo. It aims to provide a sub-regional research response to the challenges that producers face. There are over 600 species in the genus *Dioscorea*, although only a few are farmed for food and others for medical purposes around the world (Mignouna *et al.*, 2014). These species contain many varieties which are yet to be fully explored.

1.2 Statement of the problem

Nigeria is a country scourged by food insecurity and malnutrition especially in the rural areas where ironically many of them are farmers (Onimawo, 2010). Regionally important crops have suffered as a result of dietary changes. According to Khoury *et al.*, (2014), cereals like sorghum, millets, and rye, as well as root crops like cassava, sweet potato, and yam, have lost a lot of their importance. The world risks losing a varied array of adaptive alternative crops unless concerted conservation, research, and advocacy efforts are made.

The genetic diversity within yam species, which can contribute to food security and improved nutrition, has received little attention. It's vital to investigate the possible health benefits of staple foods like yam, given documented micronutrient deficits and poor overall food quality. With the exception of cassava, sweet potatoes, and Irish potatoes, many starchy tuber crops have not yet been properly explored for nutrition and health advantages (Chandrasekara *et al.*, 2016). Yam is a multi-species and multi-variety crop with properties that vary across species and varieties, according to studies from other countries, including Cameroon (Egbe and Treche, 1984), Jamaica (Muzac-Tucker *et al.*, 1993), Cote d'ivoire (Amani *et al.*, 2004) and Ethiopia (Tamiru *et al.*, 2008). There has been a scarcity of information on many of them in the tropics, particularly in Nigeria, because very limited reports on the variability and diversity of Nigerian yams landraces are available. As a result, it is critical to identify varieties that are best suited for specific products and have potential health benefits.

In the 2018 National Nutrition and Health Survey (NNHS) report, Ekiti State was one of five states that showed a significant deterioration, with a more than 50% increase in the prevalence of malnutrition among women of reproductive age compared to the 2015 NNHS.

More research is needed to understand the reasons for changes in malnutrition indicators, particularly in relation to food consumption (NNHS, 2015; NNHS, 2018).

1.3 Justification of the study

Among the world's continents, Africa is still the major centre of hunger, poverty and it is currently suffering from a double burden of diseases. The traditional food system, which feeds the majority of Africa's population, requires special attention (Onimawo, 2010). Africa is the leading supplier of cassava and yam, accounting for 50% and 95% of global supplies, respectively. If research and development efforts are made to bring yam into the forefront of the fight against hunger, poverty and deadly diseases in West Africa, the crop has the potential to be a formidable force in the fight against poverty, hunger, and deadly diseases (Mignouna *et al.*, 2014).

With current efforts to reposition yams for improved and increased yam production for both local consumption and export, it is critical that yam biodiversity be explored. The importance of yam in food diversification and income generation must be emphasized and expanded. When the nutritional and health benefits provided by biodiversity in the foods we eat are considered, agriculture, biodiversity and health can form a collaborative path to improved nutrition and food security (Toledo and Burlingname, 2006). However, in nutrition science, diet diversity primarily refers to inter- and intra-species biodiversity, and it is still an unexplored dimension from a nutritional standpoint. (WHO, 2015). Food intra- and inter-varietal diversity is being promoted as a means of dietary diversity in order to combat malnutrition in all of its forms (Adepoju, 2017). Several studies have shown that agricultural biodiversity have the potential to make more sustainable and culturally acceptable solutions available to several malnutrition problems in various regions (Burlingame and Toledo 2006; Englberger *et al.*, 2009; Kuhnlein *et al.*, 2009, 2013; Rubiang-Yalambing *et al.*, 2014). Biodiversity is an important source of food diversity because it makes a natural richness of micro and macronutrients available and provides bioactive non-nutrients for healthy human diets (Blasbalg *et al.* 2011; Fanzo *et al.* 2013). The present Nigerian and West African Food Composition Table lacks sufficient information on intraspecies variety. Therefore, more useful data (on yams in this case) needs to be generated for both the West African and the Nigerian Food Composition Databases and Tables.

Yam is the second most important root and tuber crop in the tropics, with Nigeria producing the most, but only a few species are grown for health food and/or medicinal purposes. Highlighting varieties with high nutritional and functional properties will increase both local consumption and export. In view of links between dietary habits and higher occurrences of metabolic illnesses in the Western world, tubers and other staples are being examined in attempt to figure out any such associations and, by extension, any beneficial association between their consumption and overall health. Studies have been carried out on the production of yams in Nigeria in terms of the trends of production (Awoniyi *et al.,* 2007; Verter and Becvarova, 2015; Bassey, 2017; Toluwase and Sekumade, 2017), problems/ constraints of production (Omojola and Jegede, 2010; Ayanwuyi, Akinboye and Oyetoro, 2011; Migap and Audu, 2012). Very few studies have been done on yam consumption pattern and the contribution of yam to nutrient intake of Nigerians, however such studies have been too generalised to a large people group or too species specific. For instance, Nweke *et al.,* (2013) assessed yam consumption pattern in West Africa and Adepoju, (2012 and 2017) focused on white yam *(Dioscorea rotundata*) and yellow yam (*Dioscorea cayenensis*) products in Nigeria, respectively.

Yam is a traditional food to the people of Ekiti, hence it is postulated that the consumption of this traditional food is also high among the people. However, there is paucity of information on the consumption of yams (varieties commonly consumed and pattern of consumption) among these group of people, as most of the studies on yam among Ekiti people had been targeted towards farmers- enabling higher yield.

A very important aspect of diet quality is variety which refers to both inter and intra food group variety (Gil *et al.,* 2015; Guerrero and Perez-Rodriguez, 2017). This study was therefore aimed at underscoring the biodiversity of this major staple in our traditional food system (that is the intervarietal differences in yam) in terms of nutritional content and bioactive components of the varieties while also providing current data on the consumption pattern and dietary contribution of yam to the intake of Ekiti people. The dietary diversity of diets consumed in this part of Nigeria and the nutritional status of the people was also assessed.

1.4 Research questions

- Are there significant differences or similarities in the macronutrients and micronutrients composition of the selected yam varieties?
- What are the phytochemicals present in the selected yam varieties?
- What determines the preference of yam varieties in Ekiti?
- How much does yam and its products contribute to nutrient intake in Ekiti?
- How diverse is the diet of Ekiti people?

1.5 Objective of the study

The general objective of the study was to determine the nutritional characteristics of selected yam varieties and contribution of yam to the dietary intake of selected consumers in Nigeria.

1.6 Specific objectives

The specific objectives of the study were to;

1. determine and compare the proximate composition 12 identified yam landraces.
2. determine some phytochemical components (total phenolic components, saponin, phytate, alkaloid and tannin content) of the selected varieties in the raw and cooked samples.
3. assess the varieties of yam available and factors influencing consumers' preference for yam varieties in Ekiti State.
4. estimate the contribution of yam and its products to the nutrient intake of consumers in Ekiti State; and
5. assess the dietary diversity and nutritional status of adult men and women in Ekiti State

1.7 Research hypotheses

The null hypotheses (H_0) were;

1. There is no significant difference in the nutrient composition of the yam varieties.
2. There is no significant difference in the phytochemical contents of the yam varieties.
3. The dietary diversity of adults in Ekiti State is not adequate

The alternate hypotheses (H_a) were;

1. There are significant differences in the nutrient composition of the yam varieties.
2. There are significant differences in the phytochemical contents of the yam varieties.
3. The dietary diversity of adults in Ekiti State is adequate

CHAPTER TWO

LITERATURE REVIEW

2.1. Overview of yams

Yams (*Dioscorea* sp.) are tuber-bearing, climbing plants that are either annual or perennial. There are over 600 species in the genus *Dioscorea*, but only a few are cultivated for food and others for medicinal purposes (Mignouna *et al.*, 2004) Water yam (*Dioscorea* alata), white yam (*Dioscorea* rotundata), yellow yam (*Dioscorea* cayanensis), Chinese yam (*Dioscorea* esculenta), aerial yam (*Dioscorea* bulbifera), and trifolate yam (*Dioscorea* dumentorum) are the most economically important species (FAO, 1998; Ike and Inoni, 2006; Zaknayiba and Tanko, 2013). Yam is a tropical staple food crop farmed predominantly in the savannah region of West Africa, where rainfall is separated into dry and wet seasons (Etejere and Bhat, 1986). Thousands of individuals in Nigeria and around the world benefit from their contributions to their socio-cultural and economic well-being. In West African countries like Nigeria, it is one of the most significant food and cash crops (NBS, 2012).

2.1.1 Why focus on yams?

Yams are the most significant source of calories for many people in the Sub-Saharan region, particularly in West Africa's yam zones. Roots, tuber crops, and other starchy foods have been identified as key dietary components, accounting for about half of the food consumed by half of the people in Sub-Saharan Africa, and are key staples for about one billion people in the developing world (Diouf 2005, Dilworth *et al.*, 2012).

Nigeria is the world's leading producer of yams, supplying roughly 70% of global production with 40.5 million tons grown on 3.2 million hectares (Sangiga, 2015). Yam is Africa's second most important tuber crop, after cassava root, with production exceeding one-third that of cassava (FAO, 2008). Yam (*Dioscorea* spp.) is essential for not less than sixty million West African's food security and livelihood systems. Farmers cultivate it for household food supply and income generation because it is a superior economic crop (Sangiga 2015).

As yam festivals are conducted in African countries like Ghana and Nigeria, yam growing is also a tradition in Asian-Pacific and Latin American countries including the Philippines, Colombia, Indonesia, Fiji, and Jamaica, (Durroux-Malpartida, 2013). Several nations are shifting away from traditional foods, but there is a growing awareness of the importance of traditional food crops in nutrition. In the aftermath of Africa's nutrition transition, where there is a need to encourage increased consumption of traditional staples, yams readily come to mind as an important staple in West Africa, particularly Nigeria. Yam is a highly regarded staple with several traditional methods of converting its fresh tubers into primary food products. It can be boiled, mashed into a pottage, roasted, baked, or fried. Peeled tuber pieces are also parboiled, dried (chips or elubo), and ground into flour before being reconstituted into a thick paste (amala) for consumption. Between 1990 and 2009, domestic consumption of yam increased by 12.6 percent, according to estimates from the Food and Agriculture Organization of the United Nations (FAOSTAT, 2015).

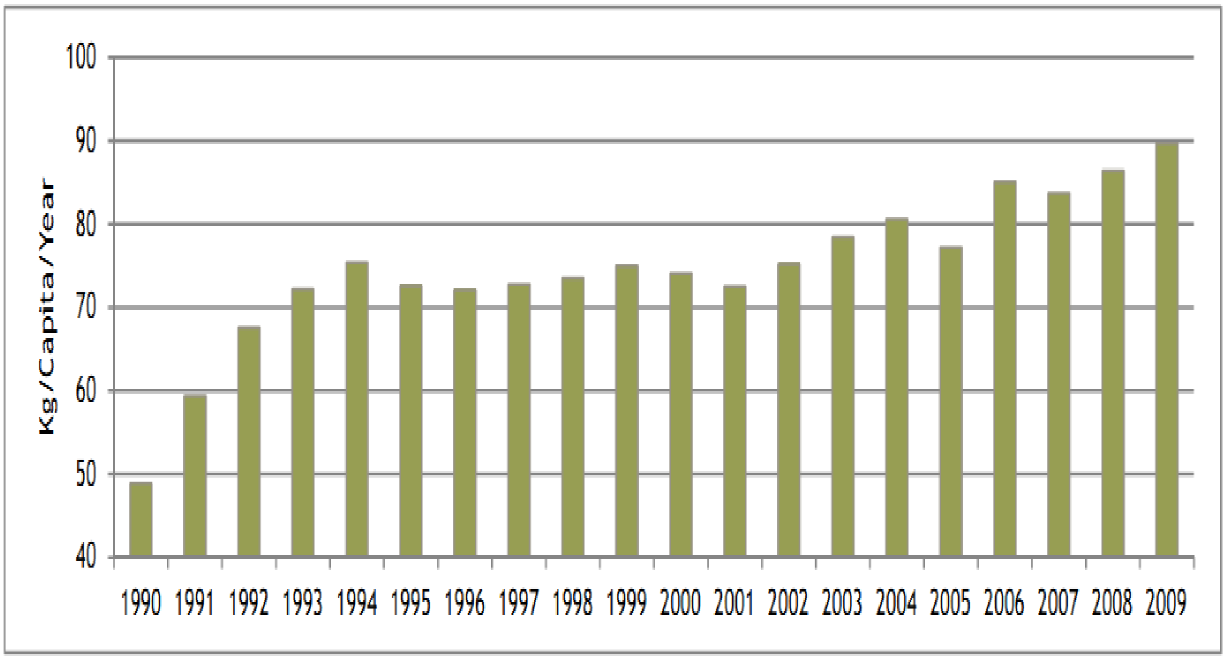
2.1.2 Yam consumption

According to the Living Standards Measurement Study- Integrated Survey on Agriculture (LSMS-ISA), 46 percent of households in Nigeria consumed yams at least once a week after the planting season and 53 percent of households after the harvest season (NBS, 2012). A large portion of yam is consumed in West Africa as boiled, roasted, or fried yam, yam balls, pounded yam, amala, or instant pounded yam flour. Yam flour is the most commonly processed traditional product from yam, and it contains carbohydrates, proteins and trace amounts of vitamins and minerals (Abioye *et al.*, 2008). Nigeria's per capita yam consumption has steadily increased, from 48.9 kg/year in 1990 to 89.7 kg/year in 2009. (Nweke *et al.*, 2013). The role of yam in the nutritional status of the average Nigerian has risen in tandem with its consumption. Yam is a staple of millions of Nigerians' diets, but consumption patterns differ according to region: In the Southwest, it is usually eaten in the form of boiled yam, porridge, fried yam, pounded yam, ojojo (water yam cookies), and ikokore, which is a delicacy in Ogun state especially among the Ijebu people. Amala is another choiced yam product which is obtained by drying yam into flakes, which is then ground into flour, and sold as "elubo," used to make the famous meal "*amala.*". Yam flour is usually not used for food in the South-eastern area of Nigeria. Consumers tend to eat yam boiled, roasted, fried, or in porridge form in the South East. The few yam flour produces available in markets are bought by people of the South West who live in the South East. Boiled yam and pounded yam are the most popular forms of yam consumption in the North. However, yam flakes are produced and "amala" is consumed in this area, but at a much lower rate than in the Southwest (BMGF, 2014).

Figures 2.1 and 2.2 show the trend in the per capita yam consumption pattern and comparative frequency of consumption of yam respectively. Based on a population growth rate of 1.97 percent per year, a GDP growth rate of 4% per year, and an income elasticity of demand for yam of 0.05, Nweke *et al.*, (2013) predicts that collective yam consumption in Nigeria will increase from 13 million tons in 2010 to 18 million tons in 2025 (Figure 2.3). According to predictions, gross production will rise from 28 million tons in 2010 to 57 million tons in 2025.

2.1.3 Yam as an important crop for food security

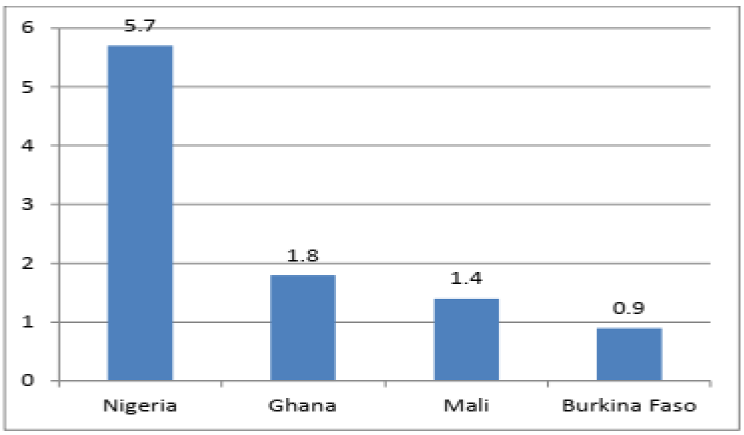
By 2030, the Sustainable Development Goals (SDGs) seek to eliminate hunger, boost food security and nutrition, and encourage sustainable agriculture. Agriculture plays a crucial role in ensuring food and nutrition security (Ramiro, 2013). 'Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life'. - 1996 World Food Summit.



Years

Figure 2.1: Per capita yam consumption as food, 1990-2009

Source: FAOSTAT, 2014

times/week 

country

Figure 2.2: Yam consumption frequency in Nigeria, Ghana, Mali and Burkina Faso

Source: Nweke *et al.*, 2013

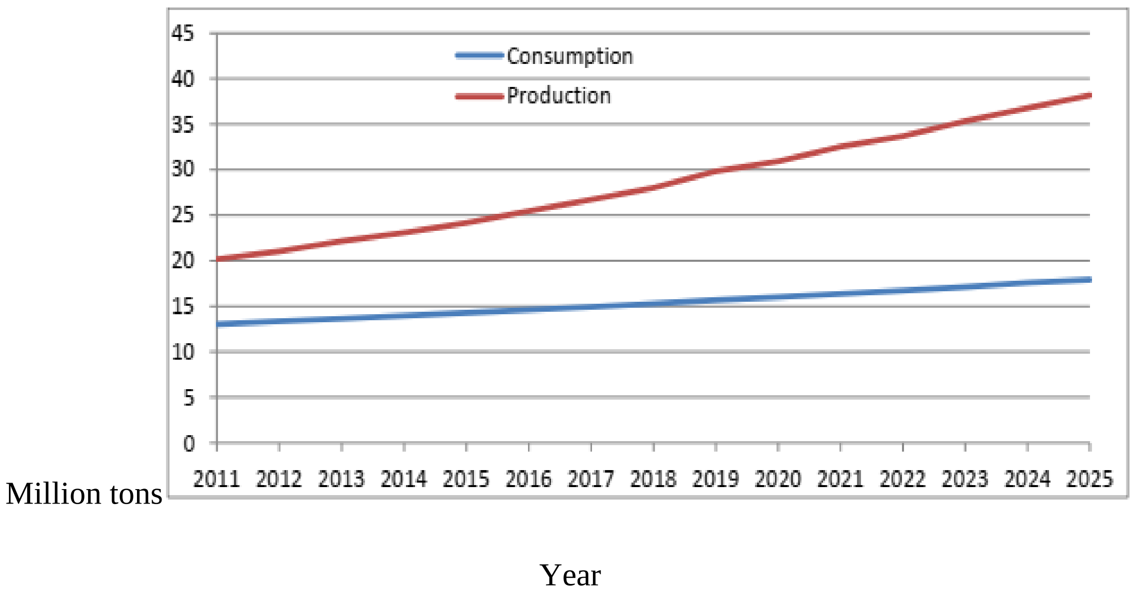


Figure 2.3 Nigeria Yam consumption and production estimates for 2011 to 2025 (million tons/year)

Yam is a common staple food with high nutritional value and good short-term postharvest storage characteristics (4–6 months). It is an important crop for income generation and ‘food security', in part because it can be kept, traded, and consumed during the dry, off-season months, when other crops cannot be grown (Salawu *et al.*, 2014). Yams are a significant source of income for all parties in the value chain. For farmers in Eastern Nigeria, yams accounted for 32 percent of their gross crop income. Among the nine major food crops compared in Nigeria in 2004, yam farm gate sales (31%) were second only to cassava (37%) in terms of volume. According to a survey of yam farmers and traders in Nigeria's Taraba State (Migap and Audu, 2012), 96 percent of respondents agree that yam cultivation has a huge impact on their standard of living. According to the same survey, yam sales helped 84 percent of respondents afford better housing, and yam cultivation helped 91 percent of respondents pay for their children's school fees. In Nigeria, after cassava, yams have the second greatest level of production of any food crop in the last 50 years. According to FAO estimates, production and area harvested grew steadily until 2006 and 2007, after which production and area harvested began to decline. Yams accounted for the largest proportion of all crops in the country in 2010, with a total agricultural output value of $15,041 million (FAOSTAT, 2015).

Root and tuber crops (potato, cassava, and yam) are the most widely consumed food crops in Africa; they make up a significant portion of the diet and provide food security for smallholder farmers and other consumers (Verter and Bervarova, 2014). Inspite of the prominence of yams to people and as a source of food security, there is still insufficient focus on yam cultivation in Nigeria, where many rural inhabitants are hungry. Apart from their significance in nutrition, yams greatly influence the societal life of some people. For example, the New Yam Festival celebrated in West Africa which has been exported abroad by some ethnic people who migrated there. In certain places in the South East of Nigeria, the foods sacrificed to deities and ancestors consists mainly of mashed yam. Yams can be preserved for a longer time than other tropical fresh produce, so they are known as savings that can be sold throughout the year. Some Igbo people in South Eastern Nigeria have a custom of giving yams to their daughters as a wedding gift to help them raise a family (Opara, 2003).

Ending food insecurity among farmers is critical due to the negative consequences. Since agriculture serves as the primary source of income for most of the poor people in rural areas, studies have shown that by improving productions that are yam-based, yam farmers could double their income and improve their food security (Fu *et al.*, 2011). This is because in Nigeria and Ghana, the staple crop-yam, is the most significant source of dietary calories. They are the preferred tuber and root crop over all others for many people in the region. Dorosh (2000) discovered that yam demand has a positive income elasticity. Given that households preferred yam as their income increases, it is not surprising that the Bill and Melinda Gates Foundation awarded a grant of $12 million to support the yam improvement for income and food security in West Africa (YIIFSWA), a project which spread across Ghana and Nigeria, in the hopes of alleviating the problem of food insecurity (Osayande and Osarenren, 2015). After harvest and storage, the average profit per seed yam was estimated to be over US$13,000 per hectare grown, and more than 60% of Nigerians grow yams as a main source of income (IITA, 2013).

Recent analyses of agriculture's role in improving nutrition have concluded that, while agricultural initiatives have enormous potential or ability to enhance nutrition, this potential is still largely untapped (Masset *et al.* 2011; Ruel and Alderman 2013).

2.1.4 Nutritional facts about yam

Carbohydrates abound in the yam tuber, which contains 50–80 percent starch by dry weight. Yam is a good source of energy, with around 118 calories per 100 grams. The edible part of the plant is mostly made up of complex carbohydrates and soluble dietary fibre. Amino acids and some micronutrients such as potassium, manganese, iron, vitamins B6 and C are also contained in yams (Baah, 2009). The amount of sodium and saturated fat in yam is however minimal. Even after nutritional losses from cooking, yam can provide above the required daily amount of vitamin C for an adult. Furthermore, the blend of low sodium and high potassium in yam makes it potentially beneficial in preventing heart diseases and osteoporosis (Hamadina, 2011).

Generally, a 100g serving of yam contains 116-118 calories. It is renowned for its high carbohydrate content. The nutritional value and moisture content of different yam species, vary slightly but starch (a digestible type of carbohydrate), water, small amounts of protein, and other minor nutrients make up all varieties. A brief of the nutritional values of yams is presented in Table 2.1, though the processing method affects the final nutritional value of yam-based foods. Yams should be peeled and properly cooked or processed before being consumed. Immature yams and some species of wild yams contain naturally occurring plant toxins such as dioscorene that may taste bitter or cause vomiting and diarrhoea (Bhandari and Kawabata, 2005). Yam tubers are high in carbohydrates, vitamin C, and essential minerals, and contain about 21% dietary fibre. The yam tuber is basically a starchy food whose main nutritional purpose is to provide calories to the body (Onwueme, 1978). When compared to foremost staples including rice, maize and wheat, yam has a lower nutritional content but it vies well with other roots and tubers, such as plantain. Table 2.2 shows the nutrient content of some Nigerian staples in comparison to yams.

In model systems, extracts of browned yam flour demonstrated antioxidative activity (Farombi, Britton, and Emerole, 2000). Traditional Chinese medicine has used yams as a health food and herbal medicinal ingredient (Liu *et al.,* 2007). In a study by Jimoh *et al.*, (2008), amala made from yam flour had better postprandial glycemic response indices despite undergoing more processing, with a Glycaemic Index (GI) of 36.8 ± 7. This was compared to other yam products such as boiled yam, which had a GI of 52.9 ± 7, and pounded yam, which had a GI of 81.6 ± 10. Diabetic Nigerians can benefit from yam-based products, especially yam flour (amala). Patients with diabetes should be able to eat as much yam carbohydrate as they like (Fasanmade and Anyakudo, 2007). Depending on the variety and cooking process, the glycemic index of different yam species varies significantly (Ihediohanma *et al.,* 2012, Nestor *et al.*, 2009).

Table 2.1: Some *Dioscorea* yam species and their nutrient value per 100g fresh edible tuber portions

Nutrient (g/100g)	*D. alata* (water yam)	*D. rotundata* (white yam)	*D. cayenensis* (yellow yam)
% Moisture	65-78.6	50.0-80	60-84
% Carbohydrate	22-31	15-23	16
% Starch	16.7-28	26.8-30.2	16.0
% Free sugar	0.5-1.4	0.3-1	0.4
% Protein	1.1-3.1	1.1-2.3	1.1-1.5
% Crude fat	<0.1-0.6	0.05-0.1	0.06-0.2
% Fibre	1.4-3.8	1.0-1.7	0.4
% Ash	0.7-2.1	0.7-2.6	0.5
Phosphorous (mg)	28- 52	17	17
Calcium (mg)	28 -38	36	36
Vitamin C (mg/100g)	2.0-8.2	6.0-12.0	-
Iron (mg)	5.5-11.6	5.2	5.2

Source: Baah, 2009.

.

Table 2.2 Nutrient content of some Nigerian staples per 100g (raw) portion

Staples	Yam	Cassava	Sweet Potato	Plantain	Maize	Rice	Wheat
Water (g)	70	60	77	65	10	12	13
Protein (g)	1.5	1.4	1.6	1.3	9.4	7.1	12.6
Fat (g)	0.14	0.28	0.05	0.37	4.74	0.66	1.54
Carbohydrates (g)	28	38	20	32	74	80	71
Fibre (g)	4.1	1.8	3	2.3	7.3	1.3	12.2
Sugar (g)	0.5	1.7	4.18	15	0.64	0.12	0.41
Calcium (mg)	17	16	30	3	7	28	29
Iron (mg)	0.54	0.27	0.61	0.6	2.71	0.8	3.19
Magnesium (mg)	21	21	25	37	127	25	126
Phosphorus (mg)	55	27	47	34	210	115	288
Potassium (mg)	816	271	337	499	287	115	363
Sodium (mg)	9	14	55	4	35	5	2
Zinc (mg)	0.24	0.34	0.3	0.14	2.21	1.09	2.65
Copper (mg)	0.18	0.10	0.15	0.08	0.31	0.22	0.43
Manganese (mg)	0.40	0.38	0.26	-	0.49	1.09	3.99
Vitamin C (mg)	17.1	20.6	2.4	18.4	0	0	0
Vitamin B1-Thiamin (mg)	0.11	0.09	0.08	0.05	0.39	0.07	0.30
Vitamin B2-Riboflavin (mg)	0.03	0.05	0.06	0.05	0.20	0.05	0.12
Vitamin B3-Niacin (mg)	0.55	0.85	0.56	0.69	3.63	1.6	5.46
Vitamin B5-Pantothenic (mg)	0.31	0.11	0.80	0.26	0.42	1.01	0.95
Vitamin B6 (mg)	0.29	0.09	0.21	0.30	0.62	0.16	0.3
Vitamin A (IU)	138	13	14187	1127	214	0	9
Energy (KJ)	494	670	360	511	1528	1528	1369

Source: BMGF. 2014

2.2 Bioactive components and potential health benefits of yam

Bioactive compounds are vital and non-vital compounds (such as polyphenols or vitamins) that occur naturally, they are part of the food chain, and can be shown to have an impact on human health are known as bioactive compounds. They appear as natural constituents in food but provide health benefits that go beyond the product's basic nutritional value (Biesalski *et al.*, 2009). They are phytochemicals found in foods that have the ability to modulate metabolic processes, thereby promoting good health. They have beneficial effects such as antioxidant activity, enzyme inhibition or induction, receptor inhibition, gene induction and inhibition (Dilworth *et al.*, 2012).

Bioactive substances are secondary plant metabolites that have pharmacological or toxicological aftermath in humans and animals. In addition to the primary biosynthesis required for growth and development, plants create secondary metabolites. These molecules help plants protect themselves from adverse effects, attract pollinators, and signal critical functions, among other things (Chandrasekara, 2018).

What are phytochemicals?

Phytochemicals are tributary plant metabolites found in different parts of plants. They serve a variety of functions in plants, including providing vigour, attracting insects for pollination and feeding, providing colour, and defense against predators. Some phytochemicals are simply unwanted products (Chandrasekara, 2018). When these phytochemicals are consumed by animals, they produce a variety of biochemical and pharmacological effects (Trease and Evans, 1989).

Tuber crops contain a variety of bioactive constituents, including saponins, hydroxycoumarins, bioactive proteins, phenolic compounds, phytic acids and glycoalkaloids. The phytochemical profile of yams, like that of higher plants, is complex (Chandrasekara, 2018). The presence of dioscorine alkaloid and diosgenin saponin is the most prominent phytochemical characteristic of yam. While dioscorine and diosgenin are toxic in the past, they are no longer toxic when washed, boiled, or cooked (Eka, 1998).

Yam tubers contain bioactive proteins, phytic acids, glycoalkaloids, saponins, and phenolic compounds, which are responsible for yam tubers' nutritional and physiological benefits, such as hypoglycaemic, antibacterial, hypocholesterolemic, antioxidative, and immunomodulatory properties (Chandrasekara and Kumar, 2016). Mucin, dioscin, dioscorin, and allantoin are soluble glycoproteins contained in yam tuber mucilage. Yams also contain choline, diosgenin, polyphenols, and vitamins including tocopherols and carotenoids, as well as dietary fibre (Bhandai, Kasa, and Kawabata, 2003). Many tests have shown that yam extracts possess antioxidant, antimicrobial, and hypoglycemic properties (Chan *et al.*, 2004). Yams can cause the activity of digestive enzymes to increase in the small intestine and stimulate the proliferation of gastric epithelial cells (Chen *et al.*, 2003).

Diosgenin is a phytochemical that can save you from colon cancer and lower cholesterol absorption. Yam polysaccharides that are water soluble may be used to lower blood glucose and cholesterol levels, especially LDL cholesterol (Corbiere *et al.*, 2003). If the nutritional importance of yams as a food or food ingredient is established or highlighted, it can help to improve food security in the tropics (Senavirathna, Ekanayake, Jansz, and Welihinda, 2014).

2.2.1 Saponins

Saponins are glycosides with a sugar moiety connected to a triterpene or steroid aglycone. They are secondary metabolites with a high molecular weight. Saponins get their name from the Latin word "sapo," which means "soap," and one of their most common characteristics is their ability to foam. Their surfactant properties cause them to form stable soap-like foam when shaken in aqueous solution, and this foaming property is due to their surfactant properties. They can be used to make soaps, detergents, shampoos, fire extinguishers, certain cosmetics, and beer because of their foaming properties (Moghimipour and Handali, 2015). Microbial, haemolytic, anti-tumor, anti-inflammatory and hepatoprotective activities have all been identified for saponins. They can also be used as an adjuvant in vaccines and lower blood cholesterol levels (Oboh and Omofoma, 2008; Bhargava *et al.* 2012; Faizal and Geelen, 2013). Saponin and steroids are also linked to sex hormones such as oxytocin, which regulates the commencement of labour in pregnant women and the release of milk subsequently (Okwu and Lawal *et al.*, 2014). The ability of saponins to suppress or destroy cancer cells is an excellent and exciting prospect. They seem capable of doing so without killing healthy cells, unlike how other cancer-fighting drugs work. On their membranes, cancer cells tend to have have more cholesterol-like compounds than other normal cells. Saponins adhere to cholesterol and thus prevent cells from growing and dividing. They also aid in the reduction of blood cholesterol, making them beneficial in the treatment of cardiovascular disorders and other health issues (Ryam and Shattuck, 1994; Sodipo *et al.*, 2000)

Saponins have a hydrophobic and hydrophilic component. Sapogenin is the hydrophobic portion of the saponin molecule, which is the aglycone portion. Saponins are classified as triterpenoid (30 carbon atoms) saponins, steroidal saponins (27 carbon atoms with a 6-ring spirostane or 5-ring furostane skeleton), or steroidal alkaloid saponins, subject to the form of genin in them. Birth control pills (containing estrogen and progesterone), related hormones, and corticosteroids are all made from steroidal saponins (Yang *et al.,* 2006). The hydrophilic component of steroidal saponins consists of multiple saccharide remains bound to the hydrophobic frame by glycoside bonds, indicating that they may be a new class of prebiotics for lactic acid bacteria and could be useful for treating yeast and fungal infections in humans and animals. D-glucose, L-rhamnose, D-galactose, D-glucuronic acid, L-arabinose, D-xylose, and D-fructose make up the hydrophilic sugar moiety found in saponins, which consists of one to three branched or straight sugar chains (Rejinolda *et al.* 2011). Yams are mostly used for medicinal purposes due to their sapogenins and aglycones however, the toxic saponins are separated from tubers before ingestion by washing them. (Eka, 1998).

2.2.2 Alkaloids

Alkaloids are secondary metabolites that were originally known as pharmacologically active nitrogen-based compounds (Ziegler & Facchini, 2008). They're made from lysine, tyrosine, and tryptophan, three of the few popular amino acids. Alkaloids are nitrogenous organic compounds found in nature that have pharmacological effects in humans and other animals. The word alkaline inspired the name. More than 12,000 alkaloids have been detected in plants, spanning more than 150 families, and alkaloids are found in roughly 20% of all flowering plants. Alkaloids can be recovered from their sources by treating them with acids (usually sulfuric acid or hydrochloric acid, though organic acids such as maleic acid and citric acid are sometimes used), and they can be found in plants such as tomatoes and potatoes, also in animals such as shellfish and fungi. These organic molecules are very changeable due to their wide variety of structural configurations. There are numerous broad categories under which pyrrolidine, pyridine, quinoline, isoquinoline, indole, quinazoline, and other alkaloids are categorized. Despite the fact that most alkaloids are pharmacologically active or toxic in large doses, some alkaloids are found in foods that are eaten on a regular basis. The most well-known "purine alkaloids" are caffeine, theobromine, and theophylline, which are mostly present in chocolate, cocoa beans, and tea leaves (Aniszewski, 2015).

As a result of their toxicity, plant alkaloids help plants protect themselves against pathogens and predators. Plant alkaloids' toxicity is thought to be influenced by dosage, length of exposure, and biologic factors including site of action, age, and susceptibility. Alkaloids are chemical bases, and some of them are medicinal, addictive, or toxic (morphine, cocaine) (pyrrolizidine alkaloids). Caffeine, nicotine, emetine, vincristine, and vinblastine are all popular alkaloids. Alkaloids in cell sap occur as salts, which can be removed using acidified water or alcohol; they're often soluble in organic solvents (Onaolapo and Onaolapo, 2019).

Dihydrodioscorine has been found in the alkaloids of *Dioscorea* species. This substance is a convulsant alkaloid that paralyzes animals' central nervous systems. The alkaloids present in most cultivated yam species are removed by simple processing such as boiling (Eka, 1985; Fasaanu *et al.*, 2013). According to Eka (1985), most alkaloids are harmful to animals and may cause gastrointestinal upsets and neurological disorders despite their therapeutic uses.

2.2.3. Phenolic compounds

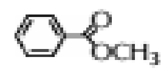
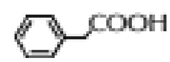
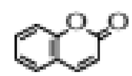
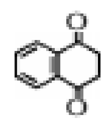
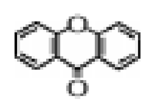
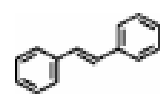
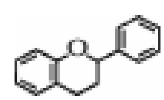
Phenolic compounds are phytochemicals (secondary metabolites) found in a wide range of plant tissues. A class of substances with an aromatic ring and a hydroxyl substituent, as well as their useful derivatives, are referred to as "phenolic compounds." They are separated into a number of classes according to their makeup. Due to these variations, they have a variety of traits, one of which is antioxidant activity, which is correlated with phenolic compounds' molecular structure. Despite not being nutrients, they have a variety of bioactive qualities and their ingestion has positive impacts on health (De la Rosa et al., 2019). They are closely related to taste, palatability, nutritional value, pharmacological and toxic effects, and microbial degradation.

Plants contain more than 8000 naturally occurring phenolic chemicals. The structures of phenolic compounds varies from being relatively water soluble (eg, quercetin 3-sulfate) to being extremely lipophilic (such as tangeretin). The size of the molecule varies significantly, ranging from straightforward, low molecular-weight, single aromatic-ringed molecules to huge, complex tannins and derived polyphenols. They can be categorized according to the quantity and configuration of their carbon atoms (as shown in Table 2.3) and are frequently found conjugated to organic acids and sugars. Flavonoids and non-flavonoids are the two categories into which phenols can be divided. (Crozier *et al.*,2006).

A number of biological systems have demonstrated the antioxidant activity of flavonoids, which are polyphenolic compounds with fifteen carbons and two aromatic rings connected by a three-carbon bridge (benzopyrone ring structure). They are the most prevalent phenolics and are present throughout the entire plant world (Harborne 1993). They are abundant in the epidermis of leaves and the skin of fruits, where they play vital and diversified roles as secondary metabolites. Plants use flavonoids for a number of purposes, such as disease resistance, pigmentation, nitrogen-fixing nodule stimulation, and UV protection (Pierpoint, 2000). Flavones, flavonols, flavan-3-ols, isoflavones, flavanones, and anthocyanidins are the main subtypes of flavonoids. Flavonoids' biological roles include protection against allergies, inflammation, free radicals, platelet aggregation, bacteria, ulcers, hepatoxins, viruses, and cancers, in addition to their antioxidant characteristics (Barakat *et al.*, 1993, Okwu and Omodamiro, 2005). Flavonoids lowered cancer rates by tampering with estrogen-producing enzymes. For example, flavonoids block estrogen synthetase, an enzyme that binds estrogen to receptors in a variety of organs (Okwu and Omodamiro, 2005; Farquer, 1996). Flavonoids have been demonstrated to have anti-inflammatory properties. By lowering edema, they prevent platelet stickiness and thereby platelet aggregation. Pigments called flavonols and anthocyanins can be found in a variety of fruits and vegetables. While many common polyphenols are not quality-enhancing pigments, they are important dietary ingredients because they induce off-colours in fruits and vegetables during storage and processing, most commonly browning. Browning reactions involve many phenolic compounds, both enzymatic and nonenzymatic.

Table 2.3 shows the structural skeletons of phenolic and polyphenolic compounds. The C6–C1 phenolic acids, most notably gallic acid, which is the precursor to hydrolysable tannins, the C6–C3 hydroxycinammates and their conjugated derivatives, and the polyphenolic C6–C2–C6 stilbenes are the primary non-flavonoids of nutritional significance (Crozier *et al.*,2006). Polymeric materials such as lignins, melanins, and tannins, as well as simple monocyclic phenols, phenolic quinones, lignans, and xanthones, are all regarded essential phenolic compounds. Only a few polyphenols are thought to be significant in foods and feeds. The common flavonoids and their glycosides, as well as p-coumaric, caffeic, ferulic, sinapic, gallic acids and their derivatives The rising evidence that polyphenol compounds in the diet have a long-term health benefit and may prevent or lessen the risk of several chronic diseases is an important function of polyphenol compounds in terms of human health benefit.

Table 2.3 Structural skeletons of phenolic and polyphenolic compounds (not including the hydroxyl group).

Number of carbons	Skeleton	Classification	Example	Basic structure
7	$C_6–C_1$	Phenolic acids	Gallic acid	
8	$C_6–C_2$	Acetophenones	Gallacetophenone	
8	$C_6–C_2$	Phenylacetic acid	*p*-Hydroxyphenyl-acetic acid	
9	$C_6–C_3$	Hydroxycinnamic acids	*p*-Coumaric acid	
9	$C_6–C_3$	Coumarins	Esculetin	
10	$C_6–C_4$	Naphthoquinones	Juglone	
13	$C_6–C_1–C_6$	Xanthones	Mangiferin	
14	$C_6–C_2–C_6$	Stilbenes	Resveratol	
15	$C_6–C_3–C_6$	Flavonoids	Naringenin	

Source: Crozier *et al.,* 2006

2.2.4. Tannins

Tannins, also known as tannic acid, are water-soluble polyphenols found in a variety of plant diets. Seguin coined the term "tannin" to describe the substances found in vegetable extracts that aid in the conversion of animal skin to leather. These substances exist as polyphenols of various molecular sizes and complexities in plant extracts (Chung *et al.*,1998). They are an important group of secondary plant metabolites that were originally used in the leather industry in the tanning of animal hides. The tannin group's diverse chemical structures and stability result in their classification as hydrolysable, complex, and volatile. All tannins share some characteristics that allow them to be divided into two categories: hydrolysable tannins and condensed (non hydrolysable) tannins.

The three types of hydrolysable tannins include gallotannines, ellagitannines, and complex tannins (sugar derivatives such as glucose, gallic acid, and ellagic derivatives). Procyanidins, also referred to as condensed tannins, are flavonoids having a condensed carbon chain (Popova and Mihaylova, 2019). Condensed tannins offer greater antibacterial, antiviral, and antifungal activities than hydrolysable tannins and are more resistant to microbial oxidation. Tannins' chemical composition determines how biologically active they are. Depending on their concentration, tannins can also be utilised as a biological antioxidant, a complexing or precipitating agent, a metal ion chelating agent, or a biological antioxidant (in low concentrations as a complexing, and in high as a precipitating, agent). Many tannin components and polyphenols found in tea have been shown to have anticarcinogenic properties. A number of mutagens' mutagenic activity has been shown to be reduced by tannin molecules. For interaction with cellular macromolecules, many carcinogens and mutagens create oxygen-free radicals. Tannins' anticarcinogenic and antimutagenic properties could be linked to their antioxidative properties, which are vital in protecting cells from oxidative damage, such as lipid peroxidation. Tannins and similar substances have been shown to suppress the production of superoxide radicals. Tannins have also been shown to hasten blood coagulation, lower blood pressure, lower serum cholesterol levels, cause liver necrosis, and regulate immune responses, among other physiological effects. These effects are very dependent on the amount and type of tannins used (Chung *et al.,* 1998).

Tannins are phenolic substances that obstruct iron absorption by forming a complex with iron in the gastrointestinal lumen, lowering iron bioavailability. They can be used to protect the kidneys, as well as to treat sore throats, diarrhoea, dysentery, bleeding, tiredness, skin ulcers, and gangrenous wounds. Tannins are water soluble chemicals that can be removed through cooking (Lawal *et al.*, 2014)

2.2.5 Phytate

The main phosphorus storage molecule in seeds is phytic acid, which accounts for up to 80% of the total phosphorus in seeds and up to 1.5% of the dry weight of seeds (Bhon et al., 2008). Phytate is the salt of phytic acid, also called myoinositol hexakisphosphate (InsP6), it is found in large quantities in plant seeds and possibly in all plant cells. Phytates act as a phosphorus and mineral storage area, accounting for 60-90 percent of the plant's phosphorus. An inositol ring and at least one phosphate group make up inositol phosphates. The prefix "myo" alludes to the conformation of the hydroxyl groups on the inositol ring, and when the name is broken down into its component pieces, it specifies the precise structure and appearance. There are numerous ways to annotate the nine potential arrangements of the inositol ring. Myoinositol is the major nutritionally relevant form of inositol. It is present in variable concentrations in all edible seeds, grains, legumes, and nuts, ranging from 0.4 to >1%, and because phytate is a storage form of phosphorus and inositol, it is also found in minor levels in roots and tubers. In vegetal tissues and animal foods, however, only trace amounts are observed. The high phytate content of these crops has been blamed for decreasing mineral bioavailability.

Phytic acid rapidly binds to mineral cations due to the chelating action of the phosphate groups, especially Cu2+ and Zn2+, which seem to have a strong affinity for inositol phosphates. Cu2+>Zn2+>Cd2+ has been discovered to be the order of the mineral cations' ability to form complexes with inositol phosphates in vitro for all InsP3InsP6 at pH 37, but binding strength is weaker for the lower inositol phosphates (Persson et al., 1998). Many food components, such as organic acids, lactic acid, ascorbic acid, and proteins, can help to prevent mineral inhibition. During food processing, the phytate can be degraded as well as by enzyme phytase in optimum conditions, such as soaking, germination, malting and fermentation.

Phosphates are stored as phytic acid in seeds as a source of energy and as an antioxidant for the growing seed, this is one of the major functions of phytic acids (Raboy, 2003). Another significant mineral reserve in seeds is phytate, which is the mineral-bound salt of phytic acid and is kept in protein storage vacuoles in the aleurone cell layer or the seed embryo. Additionally, membrane biogenesis, intracellular signalling, and stress responses all include lower inositol phosphates (Storcksdieck et al., 2007; Loewus and Murthy, 2000). In cereals, legumes, nuts, and oil seeds, phytic acid makes up 60% to 90% of the total phosphorous content and builds up during seed development until the seeds are mature. (Lott *et al.*, 2000; 2001).

Phytate was once thought to be an antinutrient because of its ability to precipitate and reduce the bioavailability of minerals like calcium, iron, and zinc, but it is now thought to have beneficial properties such as preventing oxidation, cancer, atherosclerosis, and kidney stones (Jenab and Thompson, 2002). The ability of to inhibit Fe ions in solution through attaching to them is one of its best-known features. This stops the ferric irons from taking part in the Fenton reaction, which results in the hydroxyl radical •OH being produced as a result of the oxidation of Fe2+ to Fe3+ when it reacts with H2O2 or other peroxides. These radicals are very reactive chemicals that react with proteins, lipids, or DNA quickly and randomly to damage or kill cells. Radicals have been related to a number of diseases, including cancer, cirrhosis, arthritis, and cancer (Benzie, 2003). As a result, phytic acid may be able to prevent all of these conditions. Phytic acid or inositol phosphate intermediates have a role in gene regulation, effective mRNA export, RNA editing, and DNA repair at the cellular level. Vucenik and Shamsuddin have also extensively discussed the use of phytic acid as a cancer treatment. Similar to the phytic acid's roles in the aforementioned processes, most of its impacts are attributed to its chelating properties, the lower inositol's role in signalling pathways, or their capacity as phosphate donors or acceptors. Since absorption is not a requirement, the results to date have mostly been in relation to colon cancer, where the efficacy of phytic acid in cancer therapy is still being studied. (Bohn et al., 2008).

Phytic acid's consumption has some detrimental effects, it is well known that malnutrition and mineral insufficiency are the results of consuming a diet that is substantially rich in phytic acid (Cheryan, 1980; Bohn et al., 2008). The adverse effects of phytic acid result from the same chemical characteristics as its possible advantages. Because of the low solubility of phytic acid: metal-complexes at the pH of the majority of the intestines, the ability of phytic acid to bind minerals makes it an antinutritional factor. It has been demonstrated that when the phytic acid:metal ratio rises above 10:1, iron and zinc uptake are both hindered. (Gharib *et al.,* 2006; Glahn *et al.,* 2002). Phytic acid has been shown to impede the absorption of zinc, iron, magnesium, calcium and manganese in human tests, but unexpectedly not copper (Bohn et al., 2004). In dietary applications, phytases may enhance mineral bioavailability. As a result of their greater stability, fungal phytases are likely the most effective at breaking down phytic acid, and in the acidic environment of the stomach, the activity of Aspergillus niger, for example, is even boosted.

2.3 Importance of inter and intra species differences (biodiversity) on nutrition

2.3.1 Cultivars and varieties

A "variety" can often be found in the plant kingdom, which is sometimes abbreviated as "var.". Plants grown from its seeds are often true to their kinds. In contrast to a species, cultivars are plants that are often not propagated by the seed but rather vegetatively (short for 'cultivated varieties') (for example, via stem cuttings). The offspring will keep the characteristics of their parents only for one generation with this method of propagation. In other words, plants grown from cultivar seeds may deceive you, because they are ineffective. Cultivar is a plant or group of selected plants that can be maintained by propagation for desirable characteristics (FAO/INFOODS, 2013a). Enhanced varieties (cultivars) are the result of formal breeding processes that have been tested and released formally.

A landrace is a native variant of a traditional plant species that has evolved over time, mostly because it has adapted to its natural and cultural surroundings. It is not the same as a cultivar that has been selectively bred to correspond to a set of traits (Feed The Future, 2016). Although the appearance of landrace populations varies, they can be distinguished by their appearance and share a genetic similarity. Improved varieties maintain the continuity of landraces. One of the advantages of landraces over modified types is their relatively high level of genetic variety. Although yields may be lower, landraces are known for their resilience in the face of adversity. As a result, new pests or diseases may impact some members of the population, but not all (FAO, 2013).

2.3.2 Food biodiversity

Biodiversity refers to the 'variance between living animals from all sources, including terrestrial, marine and other aquatic ecosystems and their environmental complexes; this includes species diversity, and ecosystem diversity." Food biodiversity refers to the diversity of plants, animals, and other things used as food, as well as the genetic resources available within and among species as dictated by ecosystems (CBD, 2016).

Despite the fact that rises in food production have contributed to the feeding of 4 billion people more, improved human nutrition, and decreased the prevalence of hunger from 33% to 18% over the past 40 years (Sanchez et al. 2005), the number of people who are chronically or acutely malnourished is still very high, surpassing 800 million (FAO, 2014). A loss of biodiversity in agro-ecosystems has typically followed gains in food production (and the subsequent improvements in overall human health in many locations), creating new public health issues. Food for human consumption and the nutritional and physiological advantages offered by biodiversity have too frequently been disregarded (De Clerck *et al.*, 2011). Biodiversity, agriculture, and health can work together to improve food security and nutrition when these relationships are considered (Toledo and Burlingame, 2006). Though intra-species biodiversity is a nutritionally understudied aspect, in nutrition science food diversity generally refers to inter-species biodiversity.

Women and children are the most obvious and susceptible victims of malnutrition, which is still one of the most serious health issues in the world. Theoretically, food produced by agriculture should be sufficient to feed everyone on the planet (FAOSTAT, 2014). Despite this, it is believed that half of the world's population is still malnourished in some way. Malnutrition is a cause and effect of disease in all of its manifestations, and it is the single largest contributor to the global burden of illness (WHO 2012a). Biodiversity is an important source of dietary diversity because it supplies a natural abundance of nutrients and bioactive non-nutrients that are essential for a healthy human diet (Blasbalg *et al.* 2011; Fanzo *et al.* 2013). Furthermore, biodiversity buttresses the crucial supporting ecosystem services like soil fertility and pollination, which are both vital to food production in quantity and quality.

In many national dietary surveys, food intake has been reported at a very aggregated level, sometimes using the common name of the species (e.g., spinach) without mentioning the genetic variety, sometimes as a food type without mentioning the species (e.g., leafy greens), and sometimes just as a broad category without any specific indication of the food (e.g. vegetable). The aim of food composition has, up to this point, been to provide nutritional data at the same aggregate level, striving for "year-round, nation-wide mean values," concealing any compositional variations related to agro-ecological zone, seasonality, and, most crucially, biodiversity. Despite the fact that experts on food composition are aware that there may be more variation in nutrient content between variants of the same species than there is between species, this has unfortunately been the case.

The concentrations of nutrients and physiologically active substances in foods derived from plants are always variable. This shows that only a diversified supply at suggested levels can meet the nutrition needs of people of all ages and genders. However, since the turn of the century, 75 percent of plant genetic diversity has been lost as farmers around the world ignore a wide range of local varieties and landraces in favor of planting genetically improved uniform and high-yielding varieties, resulting in a large proportion (roughly 75 percent) of the world's food being produced by only 12 plant and 5 animal species (Dolan *et al.,* 2010).

Many foods of plant origin have large intraspecific differences in nutritional content, according to scientific research (FAO/INFOODS, 2013a). The changes are statistically and nutritionally significant, with 1000-fold and more differences recorded in several cases. Individuals and populations can be differentiated by variety-specific differences in nutritional sufficiency and deficiency (Lutaladio *et al.*, 2010). Several studies highlight the necessity of understanding biodiversity's nutritional composition. A study by Ek *et al.*, (2013) for example, showed substantial differences in seven tested potato cultivars, with one cultivar having a GI of 53 and being classified as low GI, another having a GI of 69 and being classified as medium GI, and the other five cultivars being classified as high GI. In studies where the cultivar was specified and tested with no additional ingredients, the GI values of potatoes ranged from 56 to 104 (Fernades *et al.*, 2005; Atkinson *et al.*, 2008; Ek *et al.*, 2013). Huang and colleagues (1999) investigated the nutrient content of various sweet potato varieties, finding significant variety-specific differences, with high-carotenoid varieties containing 65 times more -carotene than low-carotenoid varieties. Depending on the variety consumed, 200 g of rice can provide less than 25% or more than 65 percent of the recommended daily intake (RDI) of protein (protein ranging from 4.5-15.9g/100g in *oryza gliberrima* varieties) (Kennedy and Burlingame, 2003). Agricultural biodiversity has been shown in studies to provide more sustainable and culturally acceptable solutions to a variety of malnutrition problems in various regions (Englberger *et al.* 2003a, 2003b, 2003c, 2006, 2008, 2009; Kuhnlein *et al.*, 2009, 2013; Burlingame and Toledo, 2006; Rubiang-Yalambing *et al.*, 2014).

Cassava root protein content varied significantly between countries and varieties, ranging from 0.95 g to 6.42 g protein/100 g cassava (mean value = 3.24 g protein/100 g cassava). Depending on the variety ingested, 6 to 41% of the RDI for protein can be fulfilled with a daily consumption of 286 g cassava/person, as in the Democratic Republic of Congo. In many African countries, where cassava is a staple crop and protein intake is a concern, encouraging the growth of high-protein cassava would make a significant difference (FAO/INFOODS, 2013).

2.3.3 Yam diversity

Even within the same geographical site, a diverse range of roots and tubers creates a diverse biodiversity. Thus, in addition to providing several beneficial nutritional and physiological benefits such as antioxidative, hypoglycemic, hypocholesterolemic, antibacterial, and immunomodulatory properties, it adds variety to the diet (Chandrasekara and Kumar. 2016). Only ten species of the *Dioscorea* genus are edible, despite the fact that the genus contains over 600 species worldwide (McAnuff *et al.*, 2005). Water yam (*Dioscorea* alata), white yam (*Dioscorea* rotundata), yellow yam (*Dioscorea* cayanensis), Chinese yam (*Dioscorea* esculenta), aerial yam (*Dioscorea* bulbifera), and trifolate yam are the most economically important species (D.dumentorum) (FAO, 1998; Ike and Inoni, 2006; Zaknayiba and Tanko, 2013).

2.4 Commonly grown and consumed yam varieties in Nigeria

Yam (*Dioscorea spp.*) is a staple food in Nigeria and West Africa, with cultural, economic, and nutritional significance. *Dioscorea rotundata* (white yam) is the major dominant and most important species in this sub-region (Alamu *et al.,*2014). In Nigeria, there are various indigenous yam species. All of the variants accessible in Nigeria, however, come from three main species: *Dioscorea rotundata, Dioscorea alata, and Dioscorea cayenensis* (BMGF, 2014).

2.4.1 *Dioscorea rotundata* (White yam): This is the most common and extensively eaten yam species in Nigeria. Within its species, there is a lot of variety, but the most popular types are *Abuja yam, Amula, Efuru and Ada Onitsha*. White yam is grown in practically every section of the country, with the exception of a few states in the northeast. It is eaten in a variety of ways, including boiling, fried, roasted or in the form of pottage, and it is the only species used by processors for making quick flour for pounded yam.

2.4.2 *Dioscorea alata* (Water yam): Farmers in Southwest Nigeria produce the most of it. In the producing areas, there are various native kinds of water yam available, as well as an improved type said to have been introduced by research institutes. Water yam is used to make yam flakes by a few informal processors, and it's used in traditional foods like *ikokore and ojojo*. Along with other late maturing ware yam types, it is commonly planted in late January or February and usually harvested around December or January. Table 2.4 lists the traditional variants that are available.

2.4.3 *Dioscorea cayenensis (*Yellow yam): In Nigeria, it is grown in fewer quantities than white yam in yam-producing areas. Except for the colour, it's extremely similar to white yam. The majority of people are unaware of the nutritional value of yellow yam. It is usually eaten as boiling yam and porridge in yam-producing areas, and as a substitute for white yam. Because of its colour, it is rarely utilized to make pounded yam (BMGF, 2014).

Table 2.4 Common water yam varieties in Nigeria

Varieties	Characteristics
Olorun etu	Old white variety
Ewura boko	Old white variety. Sweet to taste and often mixed with other ware yam (yellow yam) to produce pounded yam locally
Ewura oya/pagi	Newly introduced variety
Ewura ohanran	Gradually going into extinction. Possess high water content and mainly used for yam flakes
Ewura lanseje	Red fleshed variety
Ewura Emi	Red when scratched outside but has white flesh
Ewura agric	Newly introduced variety commonly grown in Oyo North. It is believed to have been introduced by a research institution such as IITA

Source: Sahel Capital Field Research, BMGF 2014

2.4.4 *Dioscorea dumetorum* (Bitter yam): In West Africa, it is also a traditional yam variety. Bitter yam is often cultivated in hedgerows around farms in Nigeria to put off animal invaders, and some farmers purposefully plant bitter yam at spare areas that it may serve as insurance against small harvests of the more preferred types (white, yellow and water yams). Some farmer households consume it in the boiled form. The increased interest in yam production and processing has sparked study into bitter yam, with the goal of determining its value-added potential and other applications. Bitter yam is also known as trifoliate yam (BMGF, 2014).

Landraces of *Dioscorea rotundata* have adapted to their surroundings and evolved resistance to local pests and illnesses. Farmers recognized *Dioscorea rotundata* landraces for their good properties, as they might be exploited for genetic recombination. Some of these landraces have excellent agronomic properties, allowing them to be recommended and registered as varieties. The landraces also offer valuable sources of resistance to significant diseases and pests, as well as other desired features such as high dry matter content, which is linked to customer preferences for culinary qualities. Some of these varieties include *Aloshi, Obiaoturugo, Hembakwasi, Ekpe, Amola, Yandu, Alumaco* (Nwankwo *et al.*,2017)

Although it is challenging to correlate the traditional names of the many yam variations that exist to their scientific names, it's usually acceptable to presume that they are mostly *Dioscorea rotundata* species because many of them are white yam. One is also not sure of the better ones among the many varieties. Consumers and processors prefer high-quality yam varieties (typically white yams), which command higher prices than lower-quality variations based on consumers' perceptions of colour, flavour, and variety name. *Ada Onitsha, Amula, Efuru, Oju Iyawo, Bankwasi,* and other types are in high demand.

Table 2.5: The major states producing yams in Nigeria, varieties available and their characteristics.

S/N	Local Names of Yam	Locations (States)	Planting Period	Harvesting Period	Characteristics	Variety
1	*Mumuye*	Ekiti, Benue, Kogi, Ondo	October February	June/July	It is the first to be harvested and sold in the market due to early planting.	White (*Dioscorea rotundata)*
2	*Amula, Agbaobe, Omiefun, Lasinrin, Efuru, Lariboko, Boki, Igangan, Aro, Gbongi, Sowofini, Lofere, Ajebeluko, Aganke, Ajelanwa, Ada Onitsha, Oju Iyawo, Okunmojo, Gbenra, Gore, Saja, Ikokoro*	Oyo, Kwara, Osun	October February	June till December/ January	Widely available in the market for longer periods of time throughout the year.	They are white yam varieties with the exception of Lasinrin which has a white and a yellow variant, Igangan and Aro which are yellow yam (*Dioscorea cayenensis*)
3	*Pampers, Ada Onitsha, Lagos/Ame/Idiot, Akwasi, Akulki Pepa, Idiot/Lagos, Aloshi,, Ogoja Hembamkwase,*	Niger state/Abuja Nasarawa state; Benue	February March/ April	August/ September till February	Harvesting of ware yam starts in August and extends through December to February. Yams are available all year round due to large scale production.	White (*Dioscorea rotundata)*
4	*Abii, Oku, Usekpe, Obiaturugo, Nwapoko, Ji Mbana, Ji Onitsha, Nwagba, Nwadaka, Okwocha, Abana, Iyio, Igum, Okpembe, mbana, opalenkata*	South East (Enugu, Ebonyi)	December April	August February	Early maturing varieties such as Us*ekpe* & Abii are harvested in August/September.	White (*Dioscorea rotundata)*
5	Water yam	Oyo, Kwara, Osun	November/ December January	December/ January February	High water content and it is mostly grown in the Southwest	Water yam (*Dioscorea alata)*

Within the same species of yams, physical traits such as tuber size, flesh colour, presence of roots, and peel thickness can vary significantly (Chandrasekara, 2018). Previous studies on South African potato cultivars showed that the nutritional composition and eating quality of potatoes varies significantly depending on cultivar, farming region, and season (Gibson, 2006; Booysen, 2010). In terms of GI, the disparity in HI values between cultivars and ages of potatoes may serve as motivation to determine separate GI values per cultivar rather than the single GI value now assigned to all boiling potatoes.

Landraces relate to the genetic heterogeneity found in the white yam population of clones, which is not intentionally manufactured by man but is present naturally (Teshome and Amenti, 2010). Yam growers in Nigerian yam-growing states rely on landraces to survive. Yam is an important food security crop for farmers with limited resources. Some types are harvested in piecemeal by milking for household use when they are planted, and are thus classified as a security crop (Nweke, 2016).

Aside from landraces, NRCRI has introduced 19 improved yam varieties in Nigeria, all of which were created with IITA's assistance. However, as demonstrated in Table 2.6, farmer adoption of these cultivars is quite limited. Although there is no statistics on how common the improved yam varieties are in the market, interviews conducted on the field indicate that adoption is still quite low and the formal seed system only serves about 2% of the total yam planted area (Feed the Future, 2016).

Table 2.6: Major enhanced yam varieties released in Nigeria

Variety name	Developing Institute	Characteristics	Year of release
TDR 89/02677	NRCRI,IITA	Stable yield, very good cooking and pounding qualities, cream tuber parenchyma, 25% tuber dry matter content	2001
TDR 89/02565	NRCRI,IITA	Stable yield, very good cooking and pounding qualities, cream non-oxidizing parenchyma, 35% tuber dry matter content	2001
TDR 89/02461	NRCRI,IITA	Stable yield, very good cooking and pounding qualities, cream tuber parenchyma, 26.7% tuber dry matter content	2001
TDR 89/02665	NRCRI,IITA	Stable yield, very good cooking and pounding qualities, cream non-oxidizing parenchyma, 35.3% tuber dry matter content	2003
TDR 89/01213	NRCRI,IITA	Stable yield, very good cooking and pounding qualities, white non-oxidizing parenchyma, 29.8% tuber dry matter content	2003
TDR 89/01438	NRCRI,IITA	Stable yield, very good cooking and pounding qualities, white non-oxidizing parenchyma, 29.3% tuber dry matter content	2003
TDR 95/01924	NRCRI,IITA	Stable yield, very good cooking and pounding qualities, white non-oxidizing parenchyma, 32.8% tuber dry matter content	2008
DRN 200/4/2	NRCRI	High yielding, pest and disease resistance, very good for fufu, frying and boiling.	2008
TDa 98/01176	NRCRI	High yielding, pest and disease resistance, very good for fufu, frying and boiling. Suitable for both rainy and dry seasons	2008
TDa 98/01168	NRCRI	High yielding, pest and disease resistance, very good for fufu, frying	2008
TDa 98/01166	NRCRI	High yielding, pest and disease resistance, very good for fufu, frying and boiling. Suitable for both rainy and dry seasons	2009
TDr 95/19158	NRCRI	High yielding, pest and disease resistance, very good for fufu, frying and boiling,	2009
TDr 89/02602	NRCRI	High yielding, pest and disease resistance, very good for fufu, frying and boiling.	2009
TDr 89/02660	NRCRI	High yielding, pest and disease resistance, very good for fufu, frying and boiling.	2009
TDa 00/00194	NRCRI	High yielding, pest and disease resistance, very good for fufu, frying and boiling.	2009
TDa 00/00104	NRCRI	High yielding, pest and disease resistance, very good for fufu, frying and boiling.	2009
UMUDa-4	NRCRI	High yielding, pest good for amala, pouded yam, frying and boiling	2010
UMUDa-17	NRCRI	High yielding under dry season yam cropping system	2010
UMUDa-18	NRCRI	High yielding, pest and disease resistance, very good for fufu, frying and boiling.	2010

Source: National Root Crop Research Institute (NRCRI) Umudike, (Feed the Future. 2016)

IITA- International Institute of Tropical Agriculture

2.5 Dietary diversity

Dietary diversity: is a recommended approach to alleviate nutritional problems resulting from food insecurity and inadequate intake of micronutrients (Jayawardena *et al.,* 2013). It is an element of diet-based strategies that can be used to increase intake of multiple micronutrients. It enhances the likelihood of nutrient adequacy among grown-ups and leads to positive health outcomes (such as reduced complications of diabetes, incidence of several cancers and all-cause mortality) (Jayawardena *et al.,* 2013). Many developing countries are undergoing demographic and economic transitions, which are causing significant changes in nutrition and lifestyle, which have a significant impact on disease risks among the adult population (Jayawardena *et al.*, 2013). Most times, nutritional deficiencies are not only caused by a lack of food quantity, but oftentimes as a result of poor quality evidenced by a lack of variety in the diet (Sibhatu and Qaim, 2018)

Dietary diversity is associated with lower rates of overweight and obesity, two other major nutritional issues that are escalating in many regions of the world (Jacks *et al.,* 2015). Rather than obtaining appropriate levels of micronutrients from a single food item, a more diversified diet is required. Because developing countries' diets are often poor in diversity, dietary variety is of special concern to them (Swindale and Punam 2005).

Dietary diversity metrics have been demonstrated to be effective in predicting nutritional adequacy (Sanusi *et al.*, 2014). Dietary diversity is also linked to micronutrient density, dietary adequacy, and a favourable health outcome (Oldewage-Theron *et al.,* 2011; Rathnayake *et al.,* 2012)

2.5.1 Dietary Diversity Score

The Dietary Diversity Score (DDS) is a heuristic tool that is based on the premise that "dietary diversity is a major part of diet quality, and a varied diet helps to ensure adequate intake of important nutrients that promote health" (Ruel *et al.*, 2013). The DDS calculates the number of food categories consumed in a diet over a given time period and is used as a possible measure of nutritional adequacy. The DDS provides a simple score that indicates how many different foods and/or food types were ingested during a period of time (Hoddinott *et al.,* 2002). It is normally measured by counting how many different food groups a household or individual consumes over a period of time, which can range from one to three days, but can sometimes go up to a week or even two weeks. The Household Dietary Diversity Score (HDDS) and the Individual Dietary Diversity Score (IDDS) are the two basic types of DDS (IDDS).

A 12-food category count is used to generate the HDDS. It is used to assess the quantity and quality of food available to households. The data are normally gathered from a single qualitative 24-hour recall, which excludes foods consumed outside the home (Swindale and Punam 2005; FAO, 2010). Many indicators have been created to measure the IDDS with the number of food groups, target population, and cut-off point varying (FAO/FANTA/IRD, 2014). The Minimum Dietary Diversity – Women (MDD-W) and Infant and Young Child Dietary Diversity Score (IYCDDS) are the most recent ones (WHO/UNICEF, 2010).

The MDD-W indicator was developed from the Women's Dietary Diversity Score and is intended to be used as a universal indicator of dietary diversity (FAO, 2010, Martin-Prével *et al.*, 2015, 2017). The IDDS was created as a preliminary stage in the development of the dichotomous MDD-W. Earlier study suggested a number of ratings to reflect micronutrient sufficiency, but no single score was established for global use (Arimond *et al.*, 2010). The IDDS was created using a basic count of a nine-food group indicator, but there was no set cut-off threshold. The IDDS was modified to the MDD-W indicator in response to a growing demand for a dichotomous indicator that could be used for target-setting and promotion. The MDD-W is a dichotomous indicator of whether or not women aged 15–49 have ingested at least five of ten food groups during the preceding day and night (FAO, 2015). The following are the food groups:

1. All starchy foods
2. Legumes (beans and peas)
3. Seeds and nuts
4. All dairy products
5. Foods made of flesh
6. Eggs
7. Dark green leafy vegetables high in vitamin A
8. Other vitamin A-rich fruits and veggies

9. Other vegetables

10. Other fruits

The percentage of 15–49-year-old women in a population who meet the minimal dietary diversity (five or more food groups) can be used as a potential measure for micronutrient adequacy. Adequacy is an integral part of diet quality (FAO/FHI360, 2016; Martin-Prével *et al.*, 2015). The MDD-W data is easy to obtain, and the score is straightforward to calculate. Individuals recollect foods ingested in the previous 24 hours using a qualitative 24-hour recall questionnaire, which includes items consumed outside the home (FAO, 2018). The "Proportion of children 6–23 months of age who get meals from four or more food groups" (WHO/UNICEF, 2010) is the description of the IYCDDS. This suggests that children who had food from four or more of the seven food categories the day before were more likely to have an adequate diet than children who ate food from less than four food categories. The data on a child's food consumption is obtained through an interview with the parents or carers to create the IYCDDS score. Using a 24-hour recall strategy, the interviewer inquires about the various sorts of foods the baby consumed the day before the interview. For the creation of the IYCDDS score, the respondent's food items are underlined and given a value of 1 in one of the seven food groups (WHO/UNICEF, 2010). The following food groups are included in the classification:

1. Grains, tubers, and roots
2. Nuts and legumes
3. Milk and dairy products (milk, yogurt, cheese)
4. Meat, fish, fowl, and organ meats (meat, fish, fowl, and liver/organ meats)
5. Eggs
6. Fruits and vegetables high in vitamin A
7. Fruits and vegetables in general

CHAPTER THREE

METHODOLOGY

3.1 Study design:

The study was descriptive cross sectional and experimental in design. Laboratory analyses (for specific objectives one and two) and Descriptive cross sectional study (for specific objectives three, four and five).

3.2 Sample collection and preparation:

Twelve genetically characterized yam varieties (ten varieties of *D. rotundata* and two varieties of *D. alata)* were obtained from the yam programmes of the National Root Crops Research Institute (NRCRI), Umudike, and International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria.

3.2.1 Yam sample selection:

From literature (Nweke *et al.,* 2013; BMGF, 2014; Nwankwo *et al.,* 2017), the following yam types (landraces) were purposefully chosen as being commonly farmed, highly productive, and resistant to main field pests and diseases (as seen in tables 3.1 and 3.2). The *Dioscorea rotundata* varieties are *Obiaoturugo, Ekpe, Amola, Abi, Ogoja, Punch, Ozibo, Sandpaper, Malaikwusa* and TDr11/00396. The *Dioscorea alata* varieties are *Sugar agbo* and TDa11/0055.

3.2.2 Preparation of (raw) yam flour

In preparing the yam flour, a modified procedure of Wireko-Manu *et al.* (2011) was used. The yam tubers were peeled, washed, thinly sliced, and dried for 72 hours in an air convection oven at 60°C. The dry chips were finely milled and sieved through a screen of 250μm before being sealed in a polyethylene bag (figure 3.1). This was placed in a desiccator for further analysis.

Table 3.1: The most typically farmed yam cultivars in Nigeria's major yam regions

Yam zone	Variety
Shaki, Nigeria	*Kokoro (Ihobia)*
	Amula
	Lasiri
	Kemi
Otuocha	*Ekpe*
	Adaka
	Obiaoturugo
	Agbocha
	Abi
Zaki Ibiam, Nigeria	*Ogoja*
	Danacha
	Gbango
	Sampeper
	Gisa

Source: Nweke *et al.*, 2013

Table 3.2: Some common local yam varieties and their harvest time

Region	Variety Name		Harvest Timeline
SouthWest	Amula	Ajebeluko	July through October (early maturing varieties)
	Agbaobe	Aganke	
	Omiefun	Aje lanwa	
	Lasinrin	Ada Onitsha	August through June (all other varieties)
	Efuru	Oju Iyawo	
	Lariboko	Okunmojo	
	Boki	Gbenra	
	Igangan	Gore	
	Gbongi	Ikokoro	
	Lofere		
South East	Abii	Ji Onitsha	August through September (early maturing varieties)
	Oku	Nwagba	
	Usekpe	Nwadaka	
	Obiaoturugo	Okwocha	February through March (all other varieties)
	Nwapoko	Abana	
	Ji Mbana	Iyio	
North Central	Pampers	Pepa	December through January
	Ada Onitsha	Lagos	
	Lagos/Ame/Idiot	Aloshi	
	Akwasi	Hembamkwase	
	Akulki	Ogoja	

Source: Sahel Capital field research BMGF (2014).

Yam Tubers

↓

Peeling

↓

Washing

↓

Thin slicing

↓

Oven drying (60^{o}C for 72 hours)

↓

Milling

↓

Sieving

↓

Yam flour

Figure 3.1. Flowchart for yam flour preparation

Source: Wireko-Manu *et al.*, 2011

3.2.3 Preparation of boiled yam from yam tubers

The conventional method of preparing boiled yam at the household level was employed. This involves peeling the yam tuber, washing and slicing to a thickness of about 2.5 cm. The sliced yam was cooked for about 30 minutes as described by Adepoju (2012). The boiled yam samples were then dried for 72 hours in an air convection oven at 60°C. The dry chips were finely crushed and sieved through a screen of 250μm before being stored in a well-sealed polyethylene container and kept in a desiccator for analysis at a later time.

3.3 Proximate analysis

The raw and boiled yam samples were analysed for their proximate composition, (moisture, crude protein, ash, crude lipid, crude fibre) using the methods of AOAC (2010) on dry weight basis and then recalculated for the fresh weight. All analyses were performed in triplicates.

3.3.1 Determination of moisture content

Two grams of samples was weighed into moisture cans. The samples were dried at a temperature of 105^{0}C until constant weights were obtained (AOAC, 2010, (967.08)). From the final weights, the replicated percentage moisture content was determined using the following formula;

$$\%\ \text{moisture content (on wet basis)} = \frac{\begin{array}{c}\text{initial weight of sample and can} - \text{final weight} \\ \text{of the sample and can}\end{array}}{\text{Weight of wet sample}} \times 100$$

$$\%\ dry\ matter = 100 - moisture\ content$$

……………..Equation 1

3.3.2 Determination of crude lipid

Two grams of samples was weighed in a filter paper and dropped into a pre-dried extraction thimble, with porosity permitting a rapid flow of petroleum ether. The petroleum ether was poured into the dried round bottom boiling flask. The boiling flask, soxhlet extractor and condenser were assembled followed by heating for 4 hours for complete extraction. At the end of the extraction process, the fat content was determined using the formula;

$$\% \text{ fat on dry weight basis} = \frac{Weight\ of\ fat\ in\ sample\ (g)}{Weight\ of\ dried\ sample\ (g)} \times 100$$

(AOAC, 2010(2003.06))

…………..Equation 2

3.3.3 Determination of crude protein content

The Kjedahl method (AOAC, 2010, (988.05)) was used to determine the crude protein content of the sample. The sample (1g) was weighed into the Kjedahl flask, 20ml of concentrated H_2SO4 added to the sample in the flask, with the addition of two tablets of selenium catalyst. The flask was placed in the Kjedahl digester and heated until its content became clear and then cooled.

This was moved to the Kjedahl apparatus's neutralization and distillation chamber, where it was neutralized and distilled for four minutes with a 40 percent NaOH solution. Using two to three drops of indicator, the distillate was titrated with standardized HCl (0.1M) until the blue grey end point was reached.

$$\% \text{ Nitrogen} = \frac{(\mathrm{Ts} - \mathrm{Tb}) \times \mathrm{C} \times 1.4007}{\mathrm{S}}$$

$$\% \text{ Crude Protein} = \% \text{ Kjedahl Nitrogen} \times \mathrm{N}$$

Where; Ts = titre value

Tb = titre value of the blank determination

C = Concentration of acid (0.1M HCl)

S = Sample weight (grams)

N = Conversion factor for nitrogen to protein (6.25)

……………Equation 3

3.3.4 Determination of ash content

Two grams of sample was weighed into a pre-dried and pre-weighed crucible. The crucible was placed in warm muffle furnace with the use of tongs. It was heated at 550^{0}C for about 4-6 hours, after which it was turned off and the temperature allowed to drop to 100^{0}C before the furnace was carefully opened. The crucible was transferred to a desiccator using safety tongs and allowed to cool to room temperature prior to weighing. The ash content was calculated as follows; $\%\ \text{ash on dry basis} = \frac{\begin{array}{c}\text{Weight after ashing} - \\ \text{weight of crucible}\end{array}}{\text{original sample weight}} \times 100$

(AOAC, 2010, (942.05)).

………..Equation 4

3.3.5 Determination of crude fibre

Crude fibre was determined using the method of AOAC (2010 (958.06)). One gram of sample was placed in predried and pre-weighed crucible, with addition of one gram of celite (to simplify filtration). Pre-heated 1.25% H_2SO_4 (150ml) and 2-4 drops of n-octanol (anti-foaming agent) was added to the crucible, and the fibretec hot extraction put on, and the mixture boiled for 30minutes. After the digestion process, the sample was washed three times with hot de-ionized water. The digestion process was repeated using 150ml of preheated 1.25% NaOH solution for 30 minutes, after which it was washed with hot de-ionized water. This was transferred to the fibretec cold extraction unit, where 25ml of acetone was added and this extracted and filtered out using vacuum valve, after which it was left at room temperature until the acetone has evaporated. The crucible was dried for 2hours at 130 ± 2^{0}C, cooled in a dessicator and weighed accurately to 0.1mg. The sample in the crucible was then ashed for at least 3 hours at 525 ± 15^{0}C, cooled after ashing and the weight accurately determined to 0.1mg. The crude fibre determination procedure was also repeated for blank. The percentage crude fibre was determined with the formula below:

$$\%\ \text{crude fibre} = \frac{\text{W2} - \text{W3}}{\text{W1}} \times 100$$

W1 = Sample weight (g)

W2 = Crucible + residue weight after drying (g)

W3 = Crucible + residue weight after ashing (g)

……….Equation 5

3.3.6 Carbohydrate

Total carbohydrate content was calculated by difference

3.3.7 Metabolisable energy

Metabolisable energy (ME) was calculated using the Atwater factors (Atwater and Woods, 1896) for the energy giving nutrients as below;

M.E= (Protein x 4+ fat x 9 + carbohydrate x 4 + crude fibre x 2) …….Equation 6

3.4 Determination of minerals

The mineral content was determined using AOAC's 2010 methodology. The sample was ashed at 550^0C for 4-6 hours using dry ashing. 5 mL 6N HCl was combined with the ash and distilled water was added to make a total volume of 50 mL. The potassium and sodium content of the samples was evaluated by digesting the ash with perchloric acid and nitric acid, then measuring the results with a digital flame photometer (975.11). The ammonium-molybdate colorimetric technique was used to quantify phosphorus (AOAC, 2010: (975.16)). Calcium, magnesium, iron, zinc, and copper were measured spectrophotometrically using an atomic absorption spectrophotometer and compared to the absorption of these minerals' standards (AOAC, 2010: (975.23); Adepoju and Etukumoh, 2014; Bamigboye and Adepoju, 2015).

3.5 Determination of phytochemicals-

The following phytochemicals content were determined: Total phenols, phytates, saponin, tannin and alkaloids.

3.5.1 Total phenols

Total phenolic content was assessed by a modification of the Lister and Wilson (2001) Folin-Ciocalteu colorimetric assay method as described by Maswada (2013). The sample (0.5g) was extracted using 10mls of 80% ethanol. From the extract, 1ml was taken and mixed with 2.5ml 1/10 dilution of folin- Ciocalteu's phenol reagent (2.5mls). After 3 minutes, 2 mls of saturated sodium carbonate solution (7.5g/100ml) was added to the mixture, which was then adjusted to a final volume of 10 mL with distilled water. The reaction was held in the dark for 90 minutes before the absorbance was measured with a spectrophotometer at 725nm using a Jenway 6,505 UV/Vis spectrophotometer. The total phenol concentration was calculated from a calibration curve, using Gallic acid (0.05g to 50ml of 80% ethanol) as standard. The results were expressed as GEmg/100g.

3.5.2 Phytate determination

The modified indirect colorimetric approach of Wheeler and Ferrel (1971) for determining phytate concentration decribed by Alamu *et al.* (2014) was used. The method is based on the capacity of standard ferric chloride to precipitate phytate in a dilute HCl extract of the sample with an iron to phosphorus ratio of 4:6. The sample (5g) was extracted with 20ml of 3% trichloroacetic acid and filtered, with 5ml of the filtrate being utilized for analysis. By adding 5ml of 1M NaOH, the phytate was precipitated as ferric phytate and transformed to ferric hydroxide and soluble sodium phytate. The precipitate was dissolved in hot 3.2M HNO_3 and the absorbance was measured at 480nm almost immediately. The following steps were taken to construct the phytic acid standard curve: To calculate the ferric iron concentration, a standard curve of various known concentrations of $Fe(NO_3)_3$ was plotted against the matching absorbance of a spectrophotometer. The phytate phosphorus concentration was determined using the ferric iron concentration and a 4:6 iron:phosphorus molar ratio.

3.5.3 Saponin content determination

The total estimation method of Nahapetian and Bassiri (1975) was used to determine this in percentages. A gram of the material was weighed, and 5 milliliters of 20% ethanol were added. The mixture was cooked for 4 hours in a water bath at 550°C. The mixture was filtered, and the residue was washed twice with 20% ethanol. In a separating funnel, 5ml of petroleum ether was added to the concentrated extract after it was reduced to around 5ml in the oven. The Pet Ether layer was removed and replaced with 3ml of butanol. 5mL of 5% aqueous Sodium Chloride was used to wash the mixture. Butanol was then poured into a petri dish that had been weighed. The mixture was baked until it was completely dry, and the residue was weighed.

$$\% \text{ Saponin} = (\text{End weight})/(\text{Start weight}) \times 100$$

…………………..Equation 7

3.5.4 Tannin determination

Markkar and Goodchild's (1996) technique for determining tannins was used. A 50 mL sample flask was filled with the finely ground sample (0.2 g). A total of ten milliliters of 70% aqueous acetone was introduced and thoroughly stirred. The bottle was shaken for 2 hours at 300 ^{O}C in an ice bath shaker, then centrifuged and the supernatant stored in ice. Pipette 0.2 mL of the solution into a test tube, then add 0.8 mL of distilled water. A 0.5 mg/ml stock of tannin acid was used to make a standard tannin acid solution, which was then diluted to 1 ml with distilled water. To the sample and standard, 0.5 mL Folinciocalteau reagent was applied, followed by 2.5 mL 20 percent Na_2CO_3. The solution was vortexed and incubated at room temperature for 40 minutes before being measured at 725nm against a reagent blank concentration of the same solution from a standard tannic acid curve.

$$\text{Tannin (mg/100g)} = \frac{Absorbance - intercept}{slope \times density \times weight\ of\ sample}$$

…………………..Equation 8

3.5.5 Alkaloid determination

A 5g portion of each sample was weighed into a 250 ml beaker and 200 ml 20% acetic acid in ethanol was added and covered to stand for 4 hours. This was filtered and the extract was concentrated using a water bath to one quarter of the original volume.

Concentrated ammonium hydroxide was added drop wise to the extract until the precipitation was complete. The whole solution was allowed to settle and the precipitate was collected by filtration and weighed. Filtered precipitate washed with dilute ammonium hydroxide and then again filtered. This precipitate residue is alkaloid which was dried and weighed.

Weight of total alkaloids: $\frac{W2-W1}{W3} \times 100$

…………………..Equation 9

Where, W1 = weight of crucible, W2 = weight of crucible with alkaloids, W3 = initial weight of plant sample taken for estimation.

(Obadoni and Ochuko, 2001; Harborne, 1973).

3.6 Yam Consumption Survey

3.6.1 Study location: Ekiti State is located between latitude 7^0 30' and 8^0 15' north of the equator and longitude 4^0 47' and 5^0 40' of the Greenwich meridian. Ekiti State was created on the 1st of October, 1996 and Ado-Ekiti is the administrative headquarter. The estimated population figure of Ekiti State as projected from the National Population Commission (NPC) figure of 2006 is now about 3,399,258 (NNHS, 2018).

3.6.2 Sample size determination:

The sample size was determined using the formula:

$$n= \frac{Z^2pq}{d^2}$$ ……………………………………………….. (Fischer *et al.* 1991)

n = minimum sample size

Z = 1.96 (a constant)

P = prevalence

Q = 1-P

d = tolerance/error (5%)

$$= \frac{1.96^2 (0.5)(0.5)}{0.05^2} = 384$$

…………………..Equation 10

With 10% attrition rate of 38.4, the minimum sample size for this study was 422.4 which was approximated to 450.

3.6.3 Sampling technique

A four-stage sampling technique was used in selecting the individuals for this study. Ekiti State has 16 Local Government Areas (LGAs) and is divided into three Senatorial Districts namely Ekiti North with 5 LGAs, Ekiti South District which has 6 LGAs and Ekiti Central District with 5 LGAs.

Stage 1: Ekiti State was purposively selected because of its reported high yam consumption and production (BMGF, 2014; Feed the future, 2016; Toluwalase and Sekumade, 2017).

Stage 2: Simple random sampling technique was used to select two Local Governments from each senatorial district from the list of Local Governments in the senatorial districts. The selected LGAs are: Ado and Ijero from Ekiti Central Senatorial district, Ido/Osi and Ikole from Ekiti North Senatorial district, Gbonyin and Ikere from Ekiti South Senatorial District.

Stage 3: Simple random sampling was used to select three communities from each Local Government selected making a total of eighteen (18) communities.

Stage 4: From the total number of eligible homes found during the household listing activity in the enumeration areas, systematic random selection was employed to pick 25 households (HH) in each community. In each family, one adult (male or female) was interviewed. If a selected family was unavailable during data collection, the next eligible household on the list was substituted.

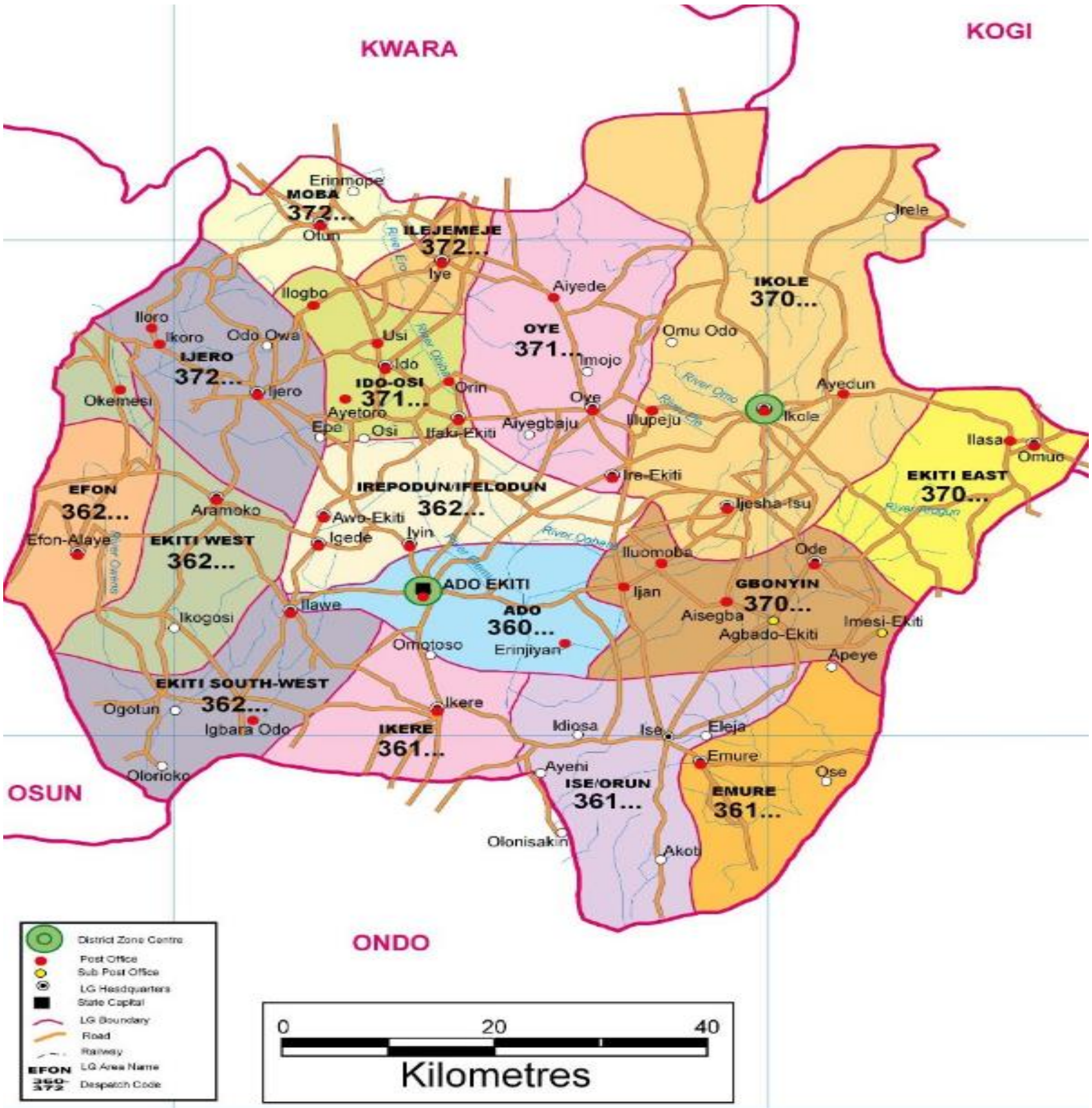


Figure 3.2: Map of Ekiti State showing the Local Government Areas

3.6.4 Inclusion criteria: The study included male and female adults (19-65 years) who are resident in the location for minimum period of three years, apparently healthy individuals who were not taking medications that will affect their dietary intake, adults who gave informed consent to participate in the study.

3.6.5 Exclusion criteria: This study excluded individuals on medications that can affect dietary intake, residents of the location less than three years, individuals who did not give informed consent to participate in the study.

3.6.6 Data collection procedure and tools

Data was collected via an interviewer-administered questionnaire. Six interviewers who had been previously trained performed the interview at the respondents' homes. The following information was gathered:

Demographic and socioeconomic factors: This included household identification, composition, size, age, relationship to household head, highest educational level attained by respondent and head of the household, primary occupation of the respondent and household head, method of refuse disposal, type of toilet, ownership of house, source of fire for cooking and estimated monthly income of the house hold head.

Dietary assessment: A multi-pass 24-hour dietary recall was used to obtain information on respondent's dietary intake. Respondents were asked to recall all foods eaten and beverages taken in the previous twenty-four hours prior to the interview. A repeat recall was done on 10% of the participants in a community.

Yam consumption: A portion of the questionnaire included questions to tease out the factors influencing consumers' preference for different yam varieties for specific products in Ekiti State. Information on subject's yam and yam products consumption pattern was obtained using a food frequency questionnaire.

Dietary diversity: The number of food categories ingested in the previous 24 hours was used to determine dietary diversity. The MDDW (Minimum Dietary Diversity for Women) and the IDDS (Individual Dietary Diversity Score) were both utilized.

The MDDW employs a ten-point scale to assess respondents' dietary diversity, whereas the IDDS employs a nine-point scale. Minimum dietary diversity for women (MDDW) is a binary indicator that asks if respondents ingested at least five of ten food groups the day before or the night before. Individual DDS were thus classified as adequate if >=5 and insufficient if <=4. Dietary Diversity terciles were created from the nine (9) food groups for IDDS and were divided into three categories: low (1-3), medium (4-6), and high (7-9) dietary diversity terciles.

The dietary diversity ratings for participants were calculated using data from the 24-hour dietary recall and the FAO recommendations (FAO and FHI 360, 2016). Each food group consumed during the reference period was given a point, and the sum of all points was used to compute the dietary variety score for each participant.

Nutrient intake: The Total Dietary Assessment (TDA) software was used. This was used to convert food intakes into nutrient intakes. Energy, carbohydrate, protein, calcium, sodium, phosphorus, potassium, zinc, iron and magnesium were assessed.

3.7 Anthropometric measurements:

A stadiometer was used to measure height, and a sensitive bathroom scale was used to determine weight. On the scale, each participant was required to stand erect in light clothing and without shoes. The measurements were in kilogrammes (kg). Before instructing the subject to stand on the scale, it was always permitted to return to zero. Body Mass Index (BMI = Weight/Height2 kg/m2) was then calculated using individual height and weight.

3.8 Quality control

Six Research Assistants were recruited and trained on how to collect data from the respondents. Immediate and accurate recording of data was ensured. Pilot study was done to ensure validity and reliability of the research instrument.

3.8.1 Validity and Reliability

Validity: The content validity of the instrument (i.e. the questionnaire) was ensured using variables teased out from the literature review. All fundamental aspects of the study were captured to enhance face validity of the instrument.

Reliability: In order to determine the reliability of the instrument the questionnaire was pre-tested. This was carried out using about 10% of the intended study participants (40 respondents) in Akure and Ado Ekiti. Cronbach's alpha coefficient (α) of 0.70 was obtained.

3.9 Ethical considerations: Approval for the study was obtained from the University of Ibadan and University College hospital (UI/UCH) Ethics Review Committee with the Registration Number NHREC/05/01/2008A. Permission was obtained from the Local Government Chairpersons to carry out the study in the communities. Informed consent was obtained from all participants by their endorsement of the informed consent form attached to the questionnaire.

3.10 Data analyses

The information was coded and entered into a spreadsheet. The Statistical Package for Social Sciences (SPSS) version 21.0 was used for the analysis. The level of statistical significance was fixed at 0.05. The transform and compute section of the SPSS software was used to calculate dietary diversity scores for individuals.

The BMI for individuals was derived from their weights and heights using the transform and compute section of the SPSS package. Pearson chi square test was used to assess the factors associated with yam preferences and also to test for association between the DDS, BMI and other variables. The respondents were divided into three age groups: 19-34, 35-39, 50-65.

Results of chemical analyses are expressed as means ± SD. Statistical significance was established using one-way analysis of Variance (ANOVA). Means were separated according to Duncan's multiple range analysis. Two factor ANOVA test was done to test for significance of varietal differences and the effect of boiling.

CHAPTER FOUR

RESULTS

In this chapter, the results obtained in the research work is presented in sections based on the objectives of the study.

Objective one: To determine and compare the proximate (carbohydrate, protein, fat, crude fibre, moisture, ash) and mineral (calcium, magnesium, sodium, potassium, phosphorus, iron, zinc, copper) contents of the 12 identified yam landraces.

4.1 Proximate and mineral composition of yam samples

The proximate composition of raw and boiled yam samples are presented in Tables 4.1 and 4.2 respectively. The moisture content of the fresh (raw) *D. rotundata* samples ranged from 50.1% to 62.1% while that of the boiled samples ranged from 52.1% to 68.2% with the samples '*ekpe*' and '*Malaikwusa*' having the lowest and the highest values respectively for both the raw and boiled samples. The mean moisture content for the raw *D. rotundata* was 57.9±0.0 while for *D. alata* was 67.9±0.0 which differed significantly ($p<0.05$).

The carbohydrate content of the raw *D. rotundata* samples ranged from 34.4% (*Malaikwusa*) to 46.1% (*Ekpe*) with a mean of 38.3±0.1. The raw *D. alata* samples had carbohydrate content of 28.9±0.0. The boiled *D. rotundata* samples had a carbohydrate content range of 28.3% (*Malaikwusa*) to 44.3% (*Ekpe*) with a mean value of 35.5±0.1 while the mean value for the boiled alata samples was 35.7±0.0. The carbohydrate contents of the varieties were significantly different ($p<0.05$).

The protein content in the studied varieties were significantly different ($p<0.05$). The protein content of the raw *D. rotundata* samples ranged from 1.8% (*ekpe*) to 3.0% (TDr11/00396) and had a mean value of 2.2±0.1. The protein value of the boiled *D. rotundata* samples ranged from 1.5% (*amola*) to 3.3% (*ogoja*) and had a mean value of

2.4±0.1. The protein level in the boiled *D. alata* (3.0±0.0) was greater than the mean value for *D. rotundata* (2.4±0.1)

All the yam varieties had low fat contents below 1.0%. The crude fibre content of the raw *D. rotundata* samples ranged from 0.6% (*Ogoja*) to 0.9% (*Ekpe*) with a mean of 0.7±0.0. The raw *D. rotundata* samples had a mean crude fibre content of 0.7±0.0 while the mean value of the *D. alata* samples was a little lower at 0.6±0.0. The boiled *D. rotundata* samples crude fibre value ranged between 0.3% (*punch*) to 0.7% (*obiaoturugo*) with a mean value of 0.5±0.1 while the mean value for the boiled *D. alata* samples was 1.9±0.0.

The ash content in the raw *D. rotundata* samples ranged from 0.5% (*punch*) to 1.3% (TDr/00396) with a mean of 0.8±0.0. The raw *D. alata* samples had a mean ash content of 0.8±0.0. The boiled *D. rotundata* samples had an ash content range of 0.1% (*punch*) to 0.8% (malaikwasa) with a mean value of 0.2±0.0 while the mean value for the boiled *D. alata* samples was 0.6±0.0. Ash contents of the varieties were significantly different ($p<0.05$).

The result of two factor ANOVA test in Table 4.3 showed that there were significant differences in the means of the proximate content of the varieties except for the fat content. Also boiling significantly affected the proximate content but did not affect Mg, K, Zn, Cu and metabolisable energy.

The mineral composition of the raw and boiled varieties are presented in Tables 4.4 and 4.5 respectively. The calcium content of the raw *D. rotundata* samples ranged from 8.2mg to 18.7mg while that of the boiled samples ranged from 4.6mg to 15.3mg. The mean calcium content for the raw *D. rotundata* was 12.6±0.1mg while for *D. alata* was 12.2±0.0 which differed significantly ($p<0.05$). There were significant differences in the means of the mineral content of the varieties except the iron content. Table 4.6 shows that boiling significantly reduced the Calcium, Sodium and Phosphorus content but did not affect the Magnesium, Potassium, Zinc, Iron and Copper content.

Table 4.1. Proximate and energy composition of the raw yam samples (g/100g fresh samples).

Sample	Moisture	CHO	Protein	Fat	Crude Fibre	Ash	ME (kcal)
Ekpe	50.05±0.02[a]	46.08±0.03[k]	1.79±0.05[a]	0.12±0.00[j]	0.93±0.04[i]	1.03±0.01[f]	194.43±0.01[k]
Ogoja	58.53±0.02[e]	38.29±0.06[h]	1.96±0.03[c]	0.09±0.00[b]	0.61±0.01[a]	0.52±0.04[b]	163.03±0.18[b]
Sandpaper	54.28±0.02[b]	42.19±0.02[f]	2.11±0.01[f]	0.11±0.00[d]	0.73±0.02[g]	0.59±0.01[b]	179.62±0.09[i]
Punch	60.84±0.02[g]	35.97±0.15[d]	2.00±0.01[e]	0.08±0.01[a]	0.64±0.01[b]	0.46±0.01[a]	153.95±0.09[d]
Amola	59.87±0.02[f]	36.67±0.03[e]	1.87±0.03[b]	0.12±0.00[e]	0.71±0.01[e]	0.77±0.02[d]	156.64±0.07[b]
Abbi	60.03±0.01[f]	36.40±0.01[e]	1.95±0.01[c]	0.10±0.00[c]	0.85±0.02[h]	0.67±0.01[c]	156.01±0.03[e]
Ozibo	58.13±0.59[d]	38.09±0.54[f]	2.23±0.04[j]	0.11±0.00[fg]	0.71±0.02[j]	0.69±0.02[c]	163.66±0.03[f]
TDr11/00396	57.34±0.11[c]	37.59±0.12[f]	3.01±0.03[j]	0.09±0.00[b]	0.67±0.02[i]	1.29±0.03[g]	164.58±0.06[g]
Obiaoturugo	58.25±0.02[d]	37.39±0.03[f]	2.58±0.03[i]	0.10±0.00[c]	0.67±0.02[i]	1.00±0.02[e]	162.15±0.04[f]
Malaikwusa	62.09±0.02[h]	34.43±0.01[c]	1.98±0.01[d]	0.09±0.00[b]	0.68±0.01[cde]	0.73±0.01[d]	147.79±0.02[c]
	57.94	**38.31**	**2.15**	**0.10**	**0.72**	**0.78**	**164.19**
TDa							
Sugar agbo	66.04±0.00[i]	30.56±0.00[b]	1.92±0.00[c]	0.11±0.00[d]	0.72±0.00[f]	0.65±0.00[e]	132.33±0.00[b]
TDa11/00555	69.75±0.00[j]	27.25±0.00[a]	2.18±0.00[g]	0.10±0.00[c]	0.65±0.00[bc]	0.88±0.00[e]	119.88±0.00[a]
	67.90	**28.91**	**2.16**	**0.10**	**0.69**	**0.77**	**126.11**

TDr: Dioscorea rotundata (white yam) species, *TDa: Dioscorea alata* (water yam) species, CHO- Total Carbohydrates, ME- Metabolisable Energy

Values are Means ± standard deviation from triplicate analyses. Values with same superscripts in the same column are not significantly different at $p > 0.05$. The figures in 'bold' are the mean values of each parameter. *Calculated ME (kcal/100 g sample) = (Protein x 4+ fat x 9 + carbohydrate x 4 + crude fibre x 2)

Table 4.2: Proximate and energy composition of the boiled yam samples (g/100g boiled samples).

Sample	Moisture	CHO	Protein	Fat	Crude Fibre	Ash	ME (kcal)*
Ekpe	52.05±0.03^{a}	44.27±0.02^{l}	2.85±0.03^{g}	0.06±0.00^{a}	0.56±0.03^{e}	0.21±0.01^{d}	190.16±0.04^{l}
Ogoja	58.73±0.03^{b}	36.96±0.03^{j}	3.34±0.04^{j}	0.12±0.01^{e}	0.52±0.01^{d}	0.34±0.04^{e}	163.28±0.01^{k}
Sandpaper	67.77±0.03^{j}	29.72±0.06^{b}	1.82±0.04^{b}	0.08±0.02^{b}	0.54±0.01^{e}	0.08±0.01^{c}	127.93±0.13^{b}
Punch	61.99±0.01^{h}	35.75±0.04^{g}	1.90±0.02^{c}	0.07±0.02^{a}	0.25±0.03^{a}	0.12±0.03^{a}	151.68±0.10^{d}
Amola	67.43±0.03^{i}	30.56±0.01^{c}	1.52±0.01^{a}	0.06±0.01^{a}	0.42±0.01^{c}	0.05±0.02^{ab}	129.66±0.03^{c}
Abbi	61.84±0.01^{f}	35.41±0.12^{d}	2.19±0.04^{d}	0.08±0.01^{b}	0.43±0.02^{c}	0.05±0.01^{ab}	152.01±0.01^{e}
Ozibo	59.49±0.01^{e}	38.09±0.03^{k}	2.51±0.00^{e}	0.11±0.03^{d}	0.73±0.01^{f}	0.08±0.03^{bc}	160.82±0.17^{i}
TDr11/00396	58.94±0.01^{d}	36.73±0.03^{i}	3.21±0.02^{i}	0.11±0.02^{d}	0.37±0.02^{b}	0.66±0.01^{f}	161.43±0.11^{j}
Obiaoturugo	60.50±0.01^{f}	35.65±0.02^{f}	2.96±0.01^{h}	0.08±0.00^{b}	0.72±0.01^{f}	0.09±0.00^{b}	156.61±0.04^{g}
Malaikwusa	68.81±0.00^{k}	28.27±0.01^{a}	1.80±0.03^{b}	0.09±0.01^{c}	0.28±0.01^{a}	0.76±0.01^{g}	121.61±0.04^{a}
	61.76	**35.03**	**2.41**	**0.09**	**0.48**	**0.24**	**151.52**
Sugar agbo	59.76±0.02^{e}	35.53 ±0.00^{e}	2.71±0.00^{f}	0.11±0.01^{d}	0.80±0.02^{g}	1.09±0.00^{h}	155.52±0.00^{f}
TDa11/00555	59.76±0.01^{e}	35.92±0.00^{h}	3.34±0.00^{j}	0.14±0.00^{f}	0.78±0.01^{g}	0.05±0.00^{ab}	159.90±0.00^{h}
	59.76	**35.73**	**3.03**	**0.13**	**0.79**	**0.57**	**157.71**

TDr: Dioscorea rotundata (white yam) species, *TDa: Dioscorea alata* (water yam) species, CHO- Total Carbohydrates, ME- Metabolisable Energy. Values are Means ± standard deviation from triplicate analyses. Values with same superscripts in the same column are not significantly different at $p > 0.05$. The figures in 'bold' are the mean values of each parameter. *Calculated ME (kcal/100 g sample) = (Protein x 4+ fat x 9 + carbohydrate x 4 + crude fibre

Table 4.3: Two factor ANOVA result showing the effect of boiling and varietal difference on the proximate contents

Variable	Factor	F	P-value
Moisture Content	Sample	6.856	0.000
	Processing	6.279	0.000
Carbohydrate	Sample	8.032	0.000
	Processing	6.143	0.017
Protein	Sample	8.080	0.000
	Processing	18.609	0.000
Fat	Sample	1.914	**0.063**
	Processing	5.555	0.023
Crude fibre	Sample	3.999	0.000
	Processing	41.637	0.000
Ash	Sample	7.096	0.000
	Processing	59.118	0.000
Metabolizable Energy	Sample	7.037	0.000
	Processing	3.842	**0.056**

Highlighted figures are not significant at $p>0.05$

Table 4.4: Mineral content of the raw yam varieties (mg/100g) on dry weight basis.

Sample	Ca	Mg	Na	K	P	Fe	Zn	Cu
Ekpe	18.77±0.10^{g}	25.63±0.10^{bcd}	14.00±10.00^{ab}	256.25±10.00^{c}	41.48±1.00^{a}	0.13±0.01^{a}	1.43±0.01^{e}	0.20±0.01^{b}
Ogoja	11.93±0.01^{cd}	24.46±0.01^{b}	14.00±10.00^{ab}	233.75±1.00^{bc}	45.42±0.10^{b}	0.13±0.01^{a}	1.37±.0.02^{d}	0.15±0.01^{a}
Sandpaper	13.77±0.01^{e}	24.90±1.00^{bc}	12.75±1.00^{a}	248.13±1.01^{bc}	69.00±1.00^{f}	0.13±0.01^{a}	1.47±.0.02^{f}	0.56±0.02^{e}
Punch	15.23±1.02^{f}	25.95±1.01^{cd}	12.50±0.00^{a}	288.13±1.01^{c}	61.68±1.01^{e}	0.13±0.01^{a}	1.23±0.02^{b}	0.91±0.01^{i}
Amola	8.19±1.00^{a}	26.02±0.02^{cd}	13.75±0.20^{ab}	251.25±1.10^{bc}	125.20±1.10^{g}	0.13±0.01^{a}	1.31±0.01^{c}	0.71±0.01^{g}
Abbi	12.77±0.01^{d}	27.56±1.01^{e}	14.00±10.00^{ab}	263.75±1.01^{c}	57.96±1.01^{d}	0.13±0.01^{a}	1.78±0.01^{h}	0.45±0.01^{c}
Ozibo	10.20±1.00^{b}	22.98±1.01^{a}	13.50±10.00^{ab}	242.50±10.10^{bc}	40.35±0.05^{a}	0.12±0.01^{a}	1.16±0.01^{a}	0.81±0.01^{h}
TDr11/00396	11.03±0.02^{bc}	26.68±0.10^{de}	13.25±1.10^{ab}	182.50±1.10^{a}	43.91±1.01^{b}	0.12±0.01^{a}	2.68±0.01^{i}	0.71±0.01^{g}
Obiaoturugo	10.33±0.02^{b}	26.42±1.01^{de}	14.00±10.00^{ab}	250.63±0.99^{bc}	41.21±1.01^{a}	0.13±0.01^{a}	1.47±0.02^{f}	0.61±0.01^{f}
Malaikwusa	12.58±0.01^{d}	25.55±0.02^{bcd}	14.00±10.00^{ab}	245.00±2.00^{bc}	45.56±1.01^{b}	0.12±0.02^{a}	1.70±0.01^{g}	0.51±0.01^{d}
	12.58	**25.62**	**13.75**	**246.19**	**57.18**	**0.13**	**1.60**	**0.60**
TDa								
Sugar agbo	11.88±0.01^{cd}	22.55±016^{a}	14.50±1.41^{ab}	267.50±1.41^{c}	41.89±0.01^{a}	0.13±0.01^{a}	1.18±0.00^{a}	1.11±0.00^{j}
TDa11/00555	12.56±0.14^{d}	25.57±1.41^{bcd}	13.25±0.00^{ab}	155.13±1.77^{c}	54.94±1.41^{c}	0.27±0.14^{b}	2.21±0.00^{i}	0.56±0.14^{e}
	12.22	**24.06**	**13.87**	**211.32**	**48.41**	**0.20**	**1.70**	**0.84**

TDr: Dioscorea rotundata (white yam) species *TDa: Dioscorea alata* (water yam) species

Values are Means ± standard deviation from triplicate analyses. Those with the same superscripts in the same column are not significantly different at $p > 0.05$. The figures in 'bold' are the means of each parameter

Table 4.5: Mineral content of the boiled yam varieties (mg/100g) on dry weight basis.

Sample	**Ca**	**Mg**	**Na**	**K**	**P**	**Fe**	**Zn**	**Cu**
Ekpe	14.89±1.41^{e}	27.95±0.28^{d}	13.50±2.82^{e}	208.13±2.82^{a}	33.29±2.82^{b}	0.49±0.01^{c}	2.09±0.01^{i}	0.61±0.08^{bcd}
Ogoja	4.56±0.14^{a}	24.01±1.41^{bc}	10.59±1.07^{a}	257.72±2.96^{e}	42.75±1.56^{d}	0.13±0.01^{a}	0.99±0.00^{b}	0.25±0.01^{ab}
Sandpaper	8.46±0.1^{b}	25.43±0.28^{bcd}	10.84±2.82^{ab}	215.65±0.14^{ab}	42.21±1.41^{d}	0.14±0.00^{a}	1.64±0.01^{f}	0.35±0.01^{abc}
Punch	15.30±0.03^{e}	24.75±0.14^{bc}	12.85±0.03^{e}	255.17±7.07^{d}	41.40±1.56^{d}	0.14±0.01^{a}	1.18±0.01^{d}	0.45±0.01^{abc}
Amola	12.75±0.28^{d}	26.55±2.82^{bcd}	11.84±2.83^{cd}	250.07±7.07^{cd}	72.87±1.41^{f}	3.68±0.14^{d}	2.68±0.01^{k}	1.76±0.11^{d}
Abbi	10.91±0.00^{c}	23.36±0.14^{ab}	12 09±0.00^{d}	215.00±7.07^{ab}	30.27±0.03^{a}	0.13±0.01^{a}	1.13±0.01^{c}	0.71±0.01^{bc}
Ozibo	5.42±0.29^{a}	20.57±0.14^{a}	14.86±1.41^{f}	229.67±14.14^{b}	40.61±0.29^{d}	0.13±0.01^{a}	0.88±0.01^{a}	0.15±0.01^{a}
TDr11/00396	4.92±0.29^{a}	25.72±2.84^{bcd}	10.84±2.98^{ab}	216.92±2.82^{ab}	43.02±1.41^{d}	0.13±0.01^{a}	2.04±0.00^{h}	0.46±0.01^{abc}
Obiaoturugo	14.68±0.14^{e}	25.45±0.14^{bcd}	11.09±0.03^{abc}	248.80±22.42^{c}	41.47±0.28^{d}	0.13±0.01^{a}	1.47±0.03^{e}	0.76±0.01^{c}
Malaikwusa	12.22±0.16^{d}	26.09±1.41^{bcd}	11.59±1.07^{bcd}	240.51±7.07^{cd}	41.07±1.41^{d}	0.12±0.03^{a}	1.65±0.01^{f}	0.56±0.01^{abc}
	10.41	**24.99**	**12.01**	**235.85**	**38.02**	**0.52**	**1.52**	**0.61**
TDa								
Sugar agbo	12.36±0.00^{fg}	25.57±0.01^{bcd}	13.25±1.41^{e}	285.63±1.41^{e}	54.94±1.41^{d}	0.27±0.01^{b}	2.21±0.01^{j}	0.56±0.01^{abc}
TDa11/00555	12.99±0.00^{gh}	27.04±0.03^{cd}	16.04±0.01^{g}	201.88±0.15^{a}	37.25±0.03^{c}	0.13±0.01^{a}	2.21±0.01^{j}	0.41±0.01^{abc}
	12.68	**26.31**	**13.44**	**243.75**	**46.09**	**0.20**	**2.21**	**0.49**

TDr: Dioscorea rotundata (white yam) species   *TDa: Dioscorea alata* (water yam) species

Values are Means ± standard deviation from triplicate analyses. Values with same superscripts in the same column are not significantly different at $p > 0.05$. The figures in ‘bold’ are the means of each parameter

Table 4.6: Two factor ANOVA result showing the effect of boiling and varietal difference on the mineral composition.

	Factor	F	P-value
Calcium	Sample	7.840	0.000
	Processing	9.043	0.004
Magnesium	Sample	4.547	0.000
	Processing	0.357	**0.553**
Sodium	Sample	2.457	0.017
	Processing	17.168	0.000
Potassium	Sample	3.346	0.002
	Processing	0.494	**0.486**
Phosphorus	Sample	17.666	0.000
	Processing	25.064	0.000
Iron	Sample	2.709	**0.090**
	Processing	5.286	**0.062**
Zinc	Sample	6.816	0.000
	Processing	0.933	**0.339**
Copper	Sample	2.691	0.010
	Processing	1.242	**0.271**

Highlighted figures are not significant at $p>0.05$

Objective two: Determine some phytochemical components (total phenolic components, saponin, phytate, alkaloid and tannin content) of the selected varieties in the raw and cooked samples.

4.2 Phytochemical content of the yam samples

The phytochemical contents of the yam samples are presented in Tables 4.7, 4.8 and 4.9. The mean saponin, alkaloids, phytate and tannin contents were 27.6±1.2, 2.1±0.7, 1.8±0.1 and 0.9±0.1 respectively for the raw *D. rotundata* yam samples while it was 18.6±3.2, 1.6±0.3, 1.5±0.1 and 0.6±0.1 respectively for the boiled samples. The mean total phenolic compounds for the raw and boiled samples were 7.1GEmg/100g and 7.6GEmg/100g, respectively. There were no significant differences in the means of saponin and alkaloid content of the yam varieties while there were significant differences in the total phenols, phytate and tannin content.

Boiling significantly affected the phytochemicals tested (causing a decrease) except the phenolic component.

Table 4.7: Phytochemical content of the raw yam samples

Sample	% Saponin	% Alkaloids	Phenols (GEmg/100g)	% Phytate	% Tannin
Ekpe	30.83 ± 2.91^{ab}	2.63 ± 1.17^{ab}	6.11 ± 0.13^{ab}	1.93 ± 0.01^{g}	1.03 ± 0.09^{c}
Ogoja	28.49 ± 7.09^{ab}	3.39 ± 0.45^{b}	7.61 ± 0.35^{c}	1.67 ± 0.01^{b}	0.09 ± 0.11^{a}
Sandpaper	29.27 ± 0.81^{ab}	2.84 ± 1.01^{b}	7.04 ± 0.54^{c}	1.75 ± 0.01^{d}	2.24 ± 0.15^{e}
Punch	31.16 ± 0.24^{ab}	2.59 ± 0.92^{ab}	7.22 ± 0.45^{c}	1.71 ± 0.01^{c}	1.13 ± 0.08^{c}
Amola	31.27 ± 1.82^{ab}	1.19 ± 0.36^{a}	6.22 ± 0.57^{ab}	1.73 ± 0.01^{c}	0.57 ± 0.03^{b}
Abbi	21.65 ± 3.23^{ab}	1.11 ± 0.51^{a}	8.18 ± 0.03^{cd}	1.78 ± 0.01^{e}	0.55 ± 0.15^{b}
Ozibo	33.19 ± 0.93^{b}	1.79 ± 0.68^{a}	9.21 ± 1.05^{e}	1.87 ± 0.01^{f}	0.76 ± 0.14^{b}
TDr11/00396	22.12 ± 0.09^{ab}	2.03 ± 0.98^{ab}	6.89 ± 1.03^{abc}	1.85 ± 0.01^{f}	1.27 ± 0.11^{e}
Obiaoturugo	28.86 ± 0.00^{ab}	2.40 ± 1.41^{ab}	10.11 ± 0.3^{e}	1.98 ± 0.01^{h}	0.06 ± 0.04^{a}
Malaikwusa	19.38 ± 3.39^{a}	1.28 ± 0.32^{a}	7.12 ± 0.19^{bc}	1.26 ± 0.01^{a}	1.85 ± 0.18^{d}
	27.62	**2.12**	**7.57**	**1.75**	**0.95**
Sugar agbo	31.51 ± 1.20^{de}	4.29 ± 0.29^{b}	7.69 ± 0.04^{c}	1.40 ± 0.01^{ab}	3.00 ± 0.03^{f}
TDa11/00555	24.78 ± 2.89^{de}	1.99 ± 0.71^{a}	7.89 ± 0.15^{d}	1.53 ± 0.01^{ab}	2.57 ± 0.08^{f}
	28.14	**3.14**	**7.79**	**1.46**	**2.78**

GEmg/100g = Gallic Equivalent milligram per 100grams. *TDr: Dioscorea rotundata* (white yam) species; *TDa: Dioscorea alata* (water yam) species

Values are Means ± standard deviation from duplicate analyses. Values with same superscripts in the same column are not significantly different at $p > 0.05$. The figures in 'bold' are the means of each parameter.

Table 4.8: Phytochemical content of the boiled yam samples

Sample	% Saponin	% Alkaloids	Phenols (GEmg/100g)	% Phytate	% Tannin
Ekpe	27.52±6.23^{de}	2.55±1.05^{d}	7.37±0.61^{bc}	1.56±0.01^{e}	0.64±0.18^{bc}
Ogoja	23.70±4.42^{cd}	0.48±0.47^{a}	6.87±.0.04^{ab}	1.48±0.01^{c}	0.49±0.01^{b}
Sandpaper	23.25±0.58^{cd}	0.71±0.17^{ab}	6.70±0.42^{ab}	1.43±0.01^{a}	0.24±0.08^{a}
Punch	17.40±3.19^{cd}	2.76±0.54^{d}	7.32±0.11^{bc}	1.46±0.01^{b}	0.10±.012^{a}
Amola	13.89±0.93^{ab}	0.95±0.14^{ab}	7.39±0.24^{bc}	1.47±0.01^{b}	0.65±0.15^{bc}
Abbi	21.96±2.24^{e}	0.30±0.18^{a}	7.39±0.35^{bc}	1.64±0.01^{h}	0.51±0.17^{b}
Ozibo	7.75±4.26^{a}	2.94±0.34^{d}	7.01±0.44^{bc}	1.47±0.01^{c}	1.01±0.03^{de}
TDr11/00396	23.31±5.17^{e}	1.88±0.27^{cd}	6.58±0.51^{a}	1.53±0.01^{d}	0.16±0.13^{a}
Obiaoturugo	19.83±5.91^{bc}	0.59±0.00^{ab}	7.61±0.74^{bc}	1.73±0.01^{g}	0.85±0.09^{cd}
Malaikwusa	7.78±3.26^{a}	3.05±0.15^{d}	7.12±0.65^{ab}	1.63±0.01^{f}	1.01±0.14^{de}
	18.64	**1.62**	**7.14**	**1.54**	**0.56**
Sugar agbo	28.98±6.20^{de}	0.93±0.13^{ab}	5.94±0.03^{a}	1.93±0.01^{h}	2.43±0.02^{f}
TDa11/00555	15.55±2.89^{bc}	1.80±0.23^{bc}	6.48±0.11^{ab}	1.93±0.01^{h}	2.99±0.07^{g}
	22.26	**1.36**	**6.21**	**1.93**	**2.71**

GEmg/100g = Gallic Equivalent milligram per 100grams. *TDr: Dioscorea rotundata* (white yam) species; *TDa: Dioscorea alata* (water yam) species

Values are Means ± standard deviation from duplicate analyses. Values with same superscripts in the same column are not significantly different at $p > 0.05$. The figures in 'bold' are the means of each parameter.

Table 4.9: Two factor ANOVA result showing the effect of boiling and varietal difference on the phytochemical contents

	Factor	F	P-value
Saponin	Sample	1.432	**0.203**
	Processing	9.242	0.004
Alkaloids	Sample	1.059	**0.420**
	Processing	4.323	0.045
Phenols	Sample	2.154	0.042
	Processing	0.148	**0.702**
Phytate	Sample	630.706	0.000
	Processing	11016.000	0.000
Tannin	Sample	12.718	0.000
	Processing	5.341	0.027

Highlighted figures are not significant at P>0.05

Objective three: To assess the varieties of yam available and factors influencing consumers' preference for different yam varieties in Ekiti State.

4.3 Socio demographic and socio economic characteristics of respondents

A cross sectional survey of 450 respondents was carried out. The mean age of the respondents was 34.1±12.2 years (table 4.10) and majority of the respondents (54.9%) were aged between 19-34years. More than half (56.0%) of the respondents were female while 44% (198) were males. Most of the respondent (90.9%) were Christians and the majority of the respondents were married (60.2%). The mean monthly income across the six LGAs ranged from ₦35868.7 to ₦51926.23, with the respondents in Ado LGA having the highest mean monthly income. Most of the respondents (88.7%) had been living in Ekiti for more than 10years, and (79.8) were actually natives of Ekiti state.

Table 4.10a: Socio demographic characteristics of respondents

	Ekiti Central		Ekiti North		Ekiti South		Total
	Ado μ(SD)	Ijero μ(SD)	Ikole μ(SD)	Ido/Osi μ(SD)	Gbonyin μ(SD)	Ikere μ(SD)	μ(SD)
Age (years)	32.64 (10.36)	34.52 (12.11)	35.52 (13.32)	31.91 (11.19)	35.79 (13.18)	34.48 (12.51)	34.14 (12.17)
Mean monthly income (naira)	51926.23 (39701.79)	40212.50 (27084.15)	35868.97 (27656.24)	37254.10 (26258.40)	39002.86 (26311.62)	38298.00 (25190.94)	40473.63 (29500.23)
HH size	3.73 (2.54)	4.32 (2.21)	4.16 (2.0)	4.49 (1.93)	4.73 (2.173)	4.23 (1.87)	4.28 (2.14)
AGE GROUP	**N (%)**						
(19.-34)	44 (58.7)	40 (53.3)	40 (53.3)	46 (61.3)	36 (48.0)	41 (54.7)	247 (54.9)
(35-49)	26 (34.7)	25 (33.3)	20 (26.7)	20 (26.7)	22 (29.3)	22 (29.3)	135 (30.0)
(50-65)	5 (6.7)	10 (13.3)	15 (20.0)	9 (12.0)	17 (22.7)	12 (16.0)	68 (15.1)
Total	**75(100)**	**75(100)**	**75(100)**	**75(100)**	**75 (100)**	**75(100)**	**450 (100)**

Table 4.10b: Socio demographic characteristics of respondents

	Ekiti Central		Ekiti North		Ekiti South		Total
	Ado n(%)	Ijero n(%)	Ikole n(%)	Ido/Osi n(%)	Gbonyin n(%)	Ikere n(%)	n(%)
Gender							
Male	37 (49.3)	32 (42.7)	40 (53.3)	27 (36.0)	30 (40)	32 (42.7)	198 (44.0)
Female	38 (50.7)	43 (57.3)	35 (46.7)	48 (64.0)	45 (60)	43 (57.3)	252 (56.0)
Total	**75 (100)**	**75 (100)**	**75 (100)**	**75 (100)**	**75 (100)**	**75 (100)**	**450 (100)**
Marital Status							
Single	35 (46.7)	24 (32.0)	28 (37.3)	26 (34.7)	24 (32)	27 (36.0)	164 (36.4)
Married	39 (52.0)	48 (64.0)	43 (57.3)	48 (64.0)	49 (65.3)	44 (58.7)	271 (60.2)
Divorced/ Separated	1 (1.3)	0	2 (2.7)	0	0	1 (1.3)	4 (0.9)
Widowed	0	3 (4.0)	2 (2.7)	1 (1.3)	2 (2.7)	3 (4.0)	11 (2.4)
Total	**75 (100)**	**75 (100)**	**75 (100)**	**75 (100)**	**75 (100)**	**75 (100)**	**450 (100)**
Religion							
Christian	59 (78.7)	67 (89.3)	71 (94.7)	72 (96.0)	67 (89.3)	73 (97.3)	409 (90.9)
Islam	16 (21.3)	8 (10.7)	4 (5.3)	3 (4.0)	8 (10.7)	2 (2.7)	41 (9.1)
Total	**75 (100)**	**75 (100)**	**75 (100)**	**75 (100)**	**75 (100)**	**75 (100)**	**450 (100)**

Table 4.10c: Socio demographic characteristics of respondents

	Ekiti Central		Ekiti North		Ekiti South		Total
	Ado n(%)	Ijero n(%)	Ikole n(%)	Ido/Osi n(%)	Gbonyin n(%)	Ikere n(%)	n(%)
Length of stay in Ekiti							
More than 10years	59 (78.7)	62 (82.7)	69 (92.0)	70 (93.3)	65 (86.7)	74 (98.7)	399 (88.7)
3 to 10 years	16 (21.3)	13 (17.3)	6 (8.0)	5 (6.7)	10 (13.3)	1 (1.3)	51 (11.3)
State of origin							
Ekiti	51 (68.0)	66 (88.0)	62 (82.7)	66 (88.0)	51 (68)	63 (84.0)	359 (79.8)
S/W state	20 (26.6)	7 (9.3)	5 (7.7)	9 (12.0)	20 (26.7)	11 (14.6)	72 (16)
Others	4 (5.3)	2 (2.7)	8 (10.7)	0	4 (5.3)	1 (1.3)	19 (4.2)
Relationship to Household Head							
Head	42 (56.0)	30 (40.0)	44 (58.7)	31 (41.3)	31 (41.3)	31 (41.3)	209 (46.4)
Wife	17 (22.7)	27 (36.0)	13 (17.3)	28 (37.3)	30 (40)	23 (30.7)	138 (30.7)
Son	10 (13.3)	8 (10.7)	7 (9.3)	6 (8.0)	8 (10.7)	3 (4.0)	42 (9.3)
Daughter	4 (5.3)	9 (12.0)	10 (13.3)	9 (12.0)	6 (8)	13 (17.3)	51 (11.3)
Relative	2 (2.7)	1 (1.3)	1 (1.3)	1 (1.3)	0	5 (6.7)	10 (2.2)
Total	**75 (100)**	**75 (100)**	**75 (100)**	**75 (100)**	**75 (100)**	**75 (100)**	**450 (100)**

Table 4.11: Socio economic characteristics of respondents

	Ekiti Central		Ekiti North		Ekiti South		Total
	Ado N (%)	Ijero N (%)	Ikole N (%)	Ido/Osi N (%)	Gbonyin N (%)	Ikere N (%)	N (%)
Educational level of HH head (n=349)							
No formal education	3 (5.0)	2 (3.4)	4 (6.6)	5 (6.7)	5 (6.7)	4 (5.3)	23 (6.6)
Primary	1 (1.7)	3 (5.2)	5 (8.2)	1 (1.3)	3 (4)	2 (2.7)	15 (3.3)
Secondary	21 (35.0)	23 (39.7)	26 (42.6)	20 (26.7)	21 (28)	34 (45.3)	145 (41.5)
Tertiary	35 (58)	30 (51.7)	26 (42.6)	23 (30.7)	32 (42.6)	20 (26.7)	166 (47.6)
Education level of respondents (n=420)							
No formal education	3 (4.5)	2 (2.7)	5 (6.9)	6 (8.0)	5 (6.7)	4 (5.3)	25 (5.9)
Primary	2 (3.0)	5 (6.8)	5 (6.9)	2 (2.7)	5 (6.7)	2 (2.7)	21 (5.0)
Secondary	28 (42.4)	36 (48.6)	30 (41.7)	32 (46.4)	31 (41.3)	42 (56.0)	199 (46.9)
Tertiary	33 (50.1)	31 (42)	32 (43.11)	29 (41.9)	27 (36.0)	27 (36.0)	179 (42.2)
Occupation of respondent (n=420)							
Civil servant	6 (9.2)	8 (11.0)	9 (12.5)	2 (2.9)	5 (6.7)	6 (8.0)	36 (8.6)
Farmer	6 (9.2)	10 (13.7)	10 (13.9)	4 (5.8)	13 (17.3)	5 (6.7)	48 (11.4)
Teacher	1 (1.5)	5 (6.8)	0	0	3 (4.0)	1 (1.3)	10 (2.4)
Business	10 (15.4)	21 (28.8)	20 (27.8)	19 (27.5)	18 (24.0)	23 (30.7)	111 (26.4)
Artisan	20 (30.8)	12 (16.4)	7 (9.7)	20 (29.0)	17 (22.7)	17 (22.7)	93 (22.1)
Student	13 (20.0)	14 (19.2)	21 (29.2)	18 (26.1)	10 (13.3)	17 (22.7)	93 (22.1)
Retired	1 (1.5)	2 (2.7)	1 (1.4)	0	1 (1.3)	0	4 (1.0)
*Professional	8 (10.7)	0	2 (2.7)	5 (7.2)	2 (2.7)	1 (1.3)	17 (4.0)
**Others	0	1 (1.3)	2 (2.7)	1 (1.4)	0	3 (4.0)	9 (2.1)

*Professional such as health workers, lawyers, accountant, engineers, etc

**Others include specified professions not listed

4.3.2 Available and most preferred yam varieties in Ekiti State

More than 25 varieties were mentioned in all across the 6 LGAs (table 4.12), these include; *Gambari, Olo, Aro, Ileusu, Dagidagi, Gbakumo, Odo, Efuru, Idere, Eleyintu, Ayigbiri, Ikerikete, Morodojo, Seyindara, Sogbe, Apepe, Apesan, Tiwantiwa, Adan, Ajiloku, Obabe, Egbe, Lasinrin, Awana, Petisan, Ewura* (water yam), *Esuru* and Cocoyam. The most preferred yam variety was '*Gambari'* also generally called white yam or *'ako isu*' (29.2%), followed by *'Olo'* (15.1%). The choice of the most preferred yam varieties was significantly associated with LGA, age, educational qualification, occupation and household monthly income (table 4.13). The relationship between preferred yam varieties and some social factors are further explained in figures 4.1 and 4.2.

Figure 4.1 presents 'preferred yam varieties' by age group where it was found that majority in each age bracket still preferred *gambari* to other types of yam although the proportion of those who were indifferent in the 35-49 age group were more than those who had preference for *gambari.* In figure 4.2 which shows preference based on income classes, the highest proportion of those who earned below ₦20000 preferred gambari however, majority of the other income groups were indifferent.

The respondents were asked if they have specific varieties preferred for various yam products. The result in Fig 4.3 showed that 53.6% gave a positive response while 46.4% gave a negative response. However, even those who reportedly have specific varieties that they prefer admitted that availability of the varieties is the major determinant of their choice.

Table 4.12: Most preferred yam varieties in Ekiti State

	Ekiti Central		Ekiti North		Ekiti South		Total
	Ado	Ijero	Ikole	Ido/Osi	Gbonyin	Ikere	
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Gambari	28 (37.3)	10(13.4)	31(41.4)	24 (32.0)	19 (25.3)	20 (26.6)	131(29.2)
Olo	3 (4.0)	14 (18.7)	8 (10.7)	11 (14.7)	17 (22.7)	15 (20.0)	68 (15.1)
Aro	5 (6.8)	2 (2.7)	2 (2.7)	5 (6.7)	8 (10.7)	13 (17.3)	35 (7.8)
Ileusu	3 (4.0)	2 (2.7)	2 (2.7)	0	1 (1.3)	6 (8.0)	14 (3.1)
Dagidagi	2 (2.7)	0	1 (1.3)	4 (5.3)	2 (2.7)	2 (2.7)	11 (2.4)
Gbakumo	2 (2.7)	1 (1.3)	1 (1.3)	5 (6.7)	0	1 (1.3)	10 (2.2)
Odo	2 (2.7)	2 (2.7)	0	2 (2.7)	3 (4.0)	1 (1.3)	10 (2.2)
Yellow yam	0	3 (4.0)	1 (1.3)	4 (5.3)	1 (1.3)	0	9 (2.0)
Water yam	3 (4.0)	2 (2.7)	0	1 (1.3)	2 (2.7)	1 (1.3)	9 (2.0)
Others	3 (4.0)	10 (13.3)	4 (5.3)	8 (10.7)	11 (14.7)	3 (4.0)	39 (8.7)
Indifferent	24 (32.0)	29 (38.7)	25 (33.3)	11 (14.7)	11 (14.7)	13 (17.3)	114 (25.4)

Others include varieties like Efuru, Idere (awana), Eleyintu, Ayigbiri, Ikerikete, Morodojo, Seyindara, Sogbe, Apepe (lasirin), etc

Table 4.13: Most preferred yam varieties and association with demographic factors

Variables	Chi Square	P value
LGA	**198.489**	**0.000**
Gender	20.287	0.503
Age	**80.313**	**0.000**
State of Origin	150.663	0.066
Marital Status	82.076	0.054
Educational Qualification	**237.174**	**0.003**
Occupation	**198.474**	**0.048**
HH Size	167.420	0.986
HH monthly income	**130.794**	**0.045**

HH- Household

Highlighted sociodemographic factors are significantly associated with the choice of the most preferred yam varieties at $p<0.05$

p=0.00

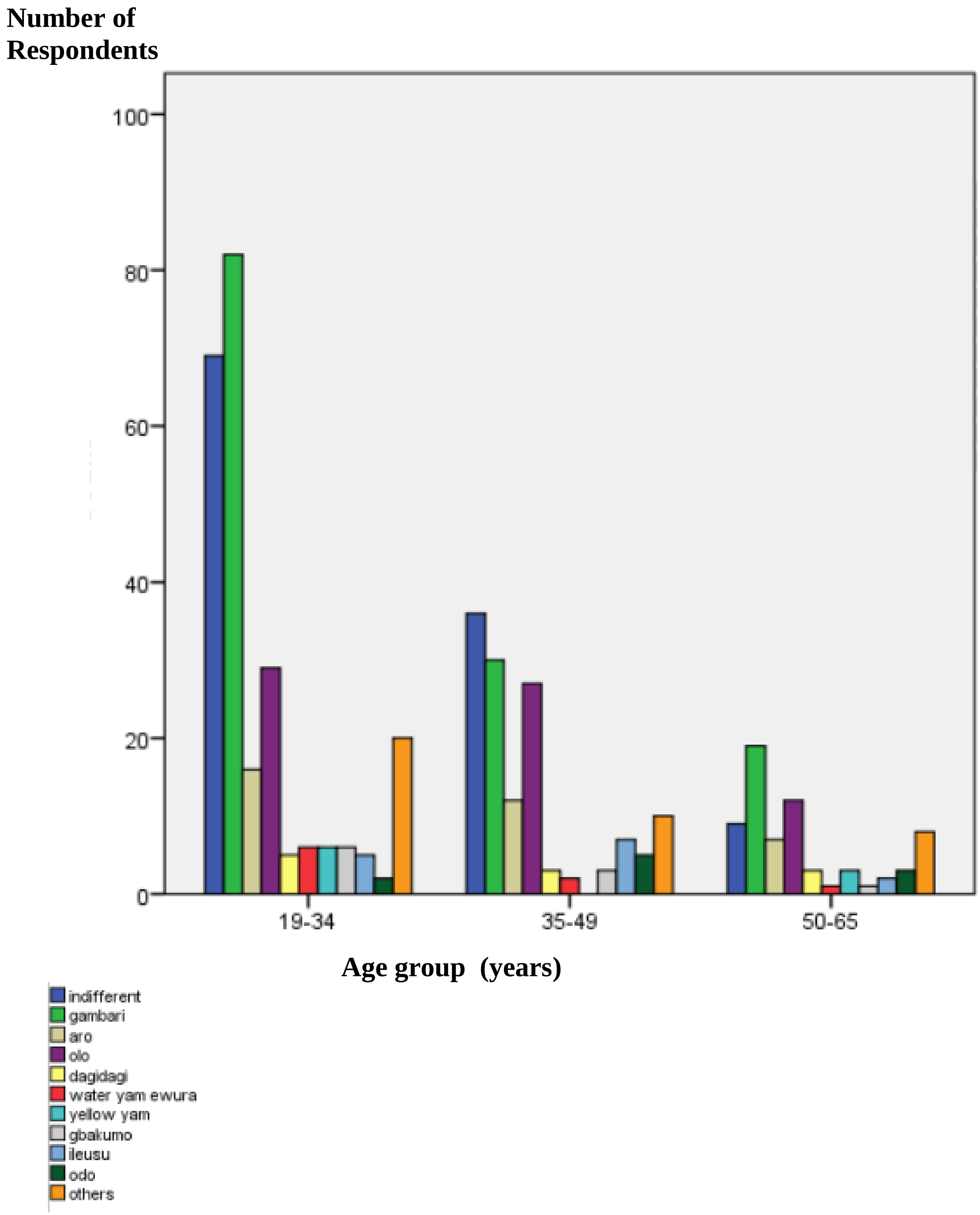
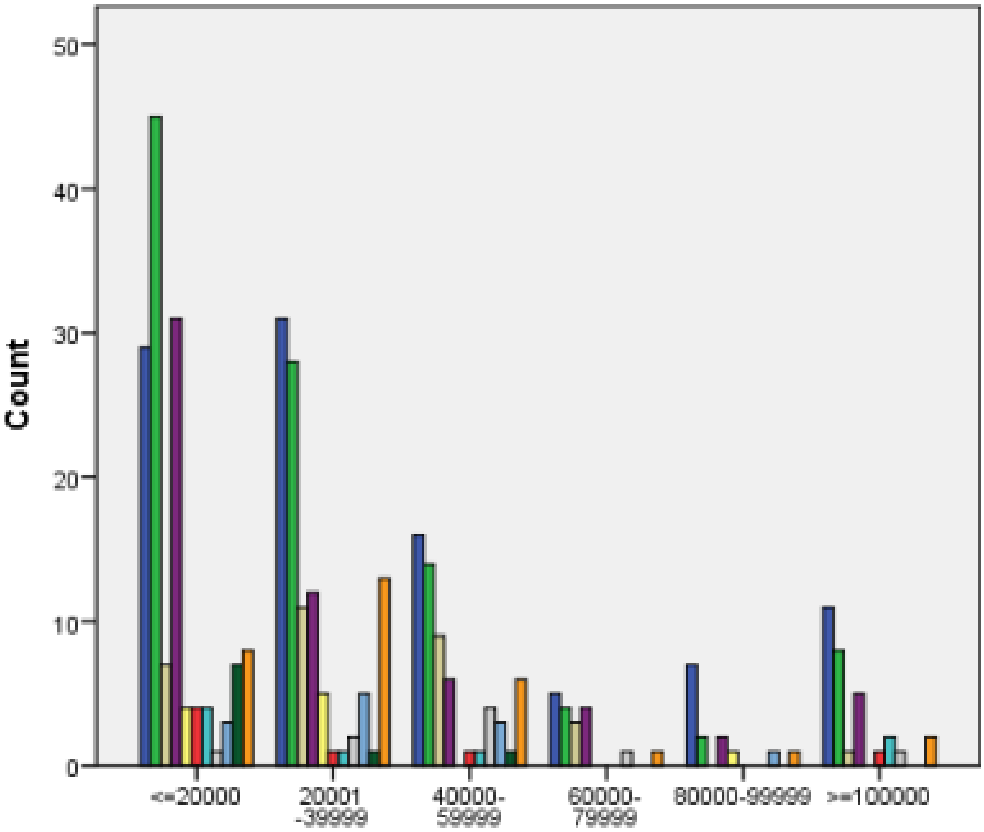


Fig 4.1: Most preferred yam varieties by age group

p= 0.045

Number of Respondents



Household monthly income (Naira)

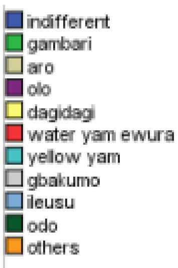


Fig 4.2: Most preferred yam varieties by household monthly income

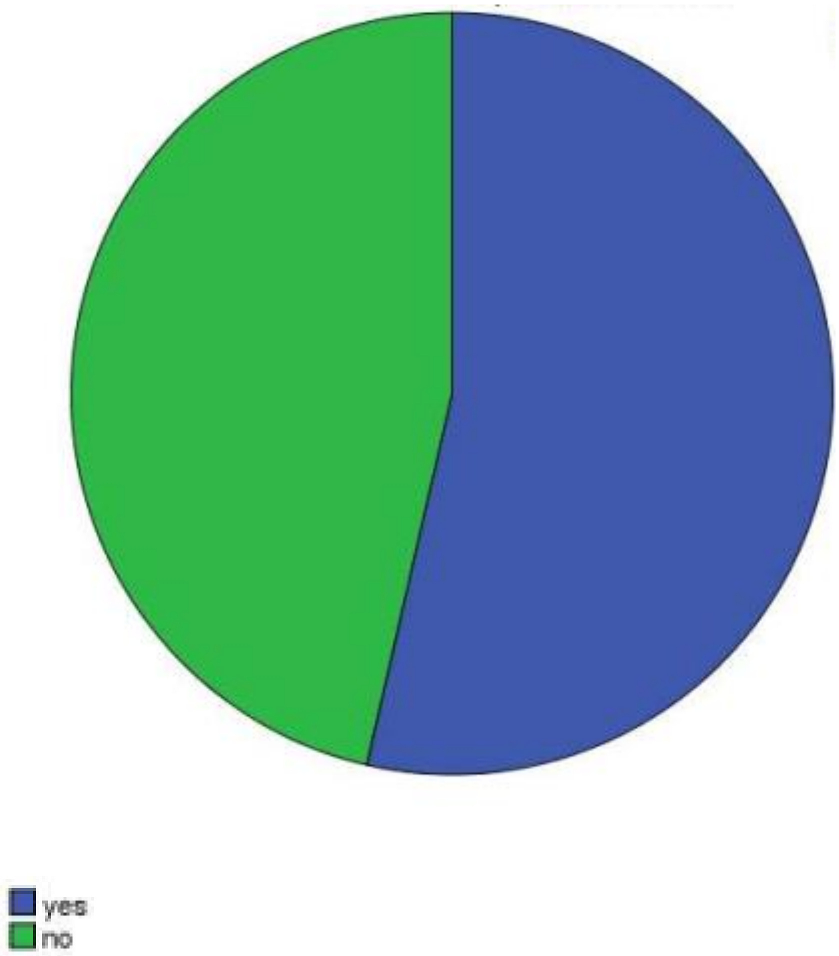


Fig 4.3 Preference of specific varieties for different yam products

4.3.2 Factors influencing preference of yam varieties consumed in Ekiti state

Some factors influencing preference for yam varieties are availability, organoleptic properties, ability to identify yam varieties, etc as presented in Table 4.14. Availability was a major factor as reported by a majority (53.3%) of the respondents. Other factors include; ability to identify yam varieties, source of yams for consumption and seasonality.

Seasonality was a strong factor affecting the choice and frequency of yam consumption among Ekiti people. Most (89.0%) of them reported that seasonality affects their choices and pattern of yam consumption with 59.7% of respondents reporting to consume more yam products during the harvest (rainy) season, while 29.3% only consumed certain yam products and varieties during the dry season. Varietal preferences during different seasons was further explored to identify varieties mostly consumed during the two major seasons that exist in Nigeria (Table 4.15).

Factors associated with the ability to identify yam varieties were also investigated (Table 4.16). The ability to identify yam varieties was significantly associated with LGA, age, state of origin and occupation. In Ijero and Ado Ekiti for instance only 52% and 70.7% respectively could identify different yam varieties whereas in other LGAs, more than 80% of their respondents reported the ability to identify different yam varieties. The relationship between the ability to identify yam varieties with age, state of origin and occupation are further presented in figures 4.4, 4.5, 4.6 and 4.7.

Table 4.17 shows the factors associated with choice of yam for consumption. State of origin, LGA, occupation and household monthly income were significantly associated with the choice of yams for consumption. These factors are further shown in figures 4.8, 4.9. and 4.10. In Table 4.18 the factors associated with seasonal influence on yam consumption are presented, these factors are occupation and household monthly income (figures 4.11 and 4.12). The source of yams for consumption was associated with gender, age, marital status, educational qualification and occupation as shown in Table 4.19. Most males obtained their yams from their farms while females either bought from the market, got the yams as gifts or both (figure 4.13). The highest proportion of those who obtained their yams as gift items, were singles unlike for ‘other sources’ where the married formed the highest proportion (figure 4.14). The highest proportion of those who obtained yams as gifts were students (figure 4.15).

Table 4.14: Factors influencing consumers' purchase and preference for different yam varieties in Ekiti state.

	Ekiti Central		Ekiti North		Ekiti South		Total
	Ado N (%)	Ijero N (%)	Ikole N (%)	Ido/Osi N (%)	Gbonyin N (%)	Ikere N (%)	N (%)
Availability	33(44.6)	34(45.3)	39 (52.0)	43 (57.3)	45 (60.0)	41 (54.7)	235 (53.3)
Organoleptic properties	29 (39.2)	17 (22.7)	24 (32.0)	23 (30.7)	14 (18.7)	28 (37.3)	135 (30.6)
Physical quality	0	7 (9.3)	0	1 (1.3)	3 (4.0)	3 (4.0)	14 (3.2)
Cost	10 (13.5)	13 (17.3)	6(8.0)	2 (2.7)	9 (12.0)	0	40 (9.1)
Nutritional value	2 (2.7)	3 (4.0)	1 (1.3)	6 (8.0)	4 (5.3)	1 (1.3)	17 (3.9)
Total	74 (100)	74 (100)	70 (100)	75 (100)	75 (100)	73(100)	441 (100)
Ability to identify different yam varieties N(%)							
Yes	53 (70.7)	39 (52.0)	60 (80.0)	64 (85.3)	62 (82.7)	67 (89.3)	348 (76.4)
No	22 (29.3)	36 (48.0)	15 (20.0)	11 (14.7)	13 (17.3)	8 (10.7)	105 (22.9)
Total	75 (100)	75 (100)	75 (100)	75 (100)	75 (100)	75 (100)	450 (100)
Source of yams for consumption							
Family farm	31 (41.3)	23 (30.7)	29 (38.7)	26 (34.7)	45 (60.0)	29 (38.7)	183 (40.7)
Market	38 (50.7)	42 (56.0)	28 (37.3)	39 (52.0)	20 (26.7)	30 (40.0)	197 (43.8)
Gifts	3 (2.7)	4 (5.3)	6 (8.0)	3 (4.0)	1 (1.3)	4 (5.3)	20 (4.4)
Farm and Market	4 (5.3)	4 (5.3)	11 (14.7)	6 (8.0)	9 (12.0)	8 (10.7)	42 (9.3)
Market and gifts	0	2 (2.7)	1 (1.3)	1 (1.3)	0	4 (5.3)	8 (1.8)
Seasonality and yam consumption							
Not affected	11(15.9)	12(16.0)	7(10.0)	4(5.5)	5 (7.1)	8 (11.1)	47 (11.0)
More during harvest	38(55.1)	42(56.0)	40(57.1)	45(61.6)	48 (68.6)	43 (59.7)	256 (59.7)
Eat certain products in dry season	20 (29.0)	21(28.0)	23(18.3)	24(32.9)	17 (24.3)	21 (29.2)	126 (29.3)
Total	69 (100)	75 (100)	70 (100)	73 (100)	70 (100)	72 (100)	429 (100)

Table 4.15: Varietal preferences during different seasons

	Ekiti Central		Ekiti North		Ekiti South		Total
	Ado N(%)	Ijero N(%)	Ikole N(%)	Ido/Osi/Osi N(%)	Gbonyin N(%)	Ikere N(%)	N(%)
Most preferred yam varieties during rainy season							
Gambari	24(32)	10(13.4)	33 (44)	33 (44)	41 (54.7)	23 (30.7)	164 (36.6)
Odo	8 (10.7)	1 (1.3)	1 (1.3)	8 (10.7)	4 (5.3)	11(14.7)	33 (7.4)
Others	14 (18.6)	19 (25.3)	13 (17.4)	8 (10.7)	19 (25.3)	15(20.0)	85 (19.1)
Indifferent	29 (38.7)	45 (60.0)	28 (37.3)	26 (34.6)	11 (14.7)	26 (34.7)	168 (36.9)
Total	75 (100)	75 (100)	75 (100)	75 (100)	75 (100)	75 (100)	450 (100)
Most preferred yam varieties during dry season							
Olo (yellow yam)	30 (40.0)	32 (42.7)	42(56.0)	52(69.3)	37 (49.3)	47 (62.7)	240 (53.7)
Water yam	2 (2.7)	0	1 (1.3)	0	4 (5.3)	2 (2.7)	9 (2.0)
Indifferent	32 (42.7)	39 (52.0)	24 (32.0)	18 (24.0)	26 (34.7)	20 (26.7	159 (35.3)
Others	11 (14.6)	4 (5.3)	8(10.7)	5 (6.7)	8 (10.7)	6 (7.9)	42 (9.0)
Total	75 (100)	75 (100)	75 (100)	75 (100)	75 (100)	75 (100)	450 (100)

Table 4.16: Ability to identify yam varieties and association with demographic factors

Variables	Chi Square	P value
LGA	**38.870**	**0.000**
Gender	0.244	0.621
Age	**6.682**	**0.035**
State of Origin	**20.353**	**0.002**
Marital Status	3.287	0.349
Educational Qualification	9.996	0.351
Occupation	**15.644**	**0.048**
HH Size	7.844	0.644
HH monthly income	3.229	0.665

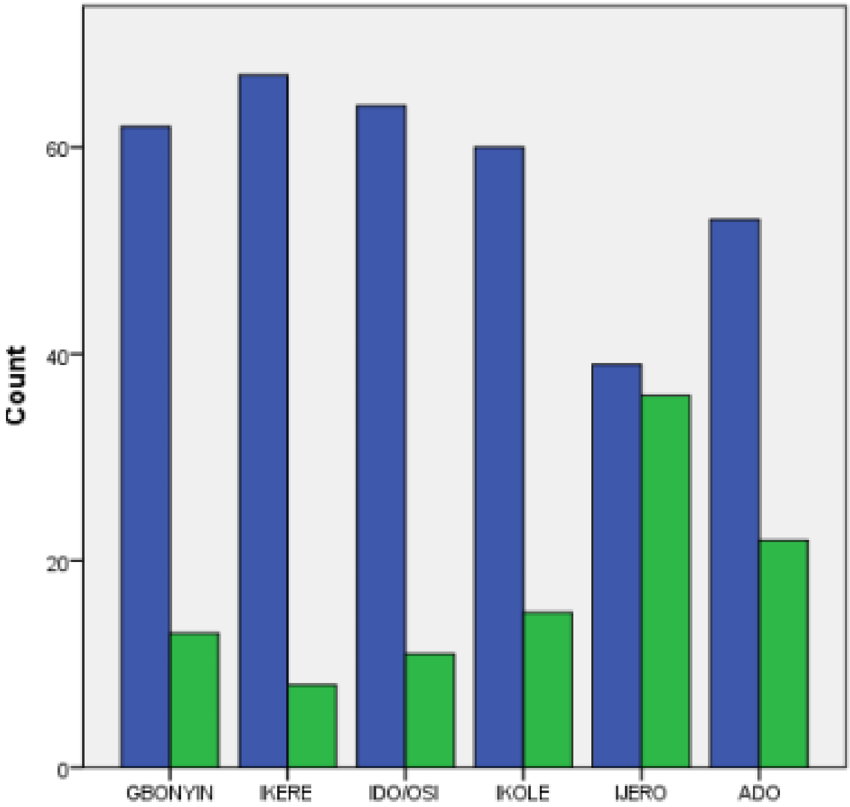
LGA- Local Government Area

HH- Household

Highlighted variables are significantly associated with the ability to identify yam varieties at $p<0.05$.

p=0.00

Number of Respondents

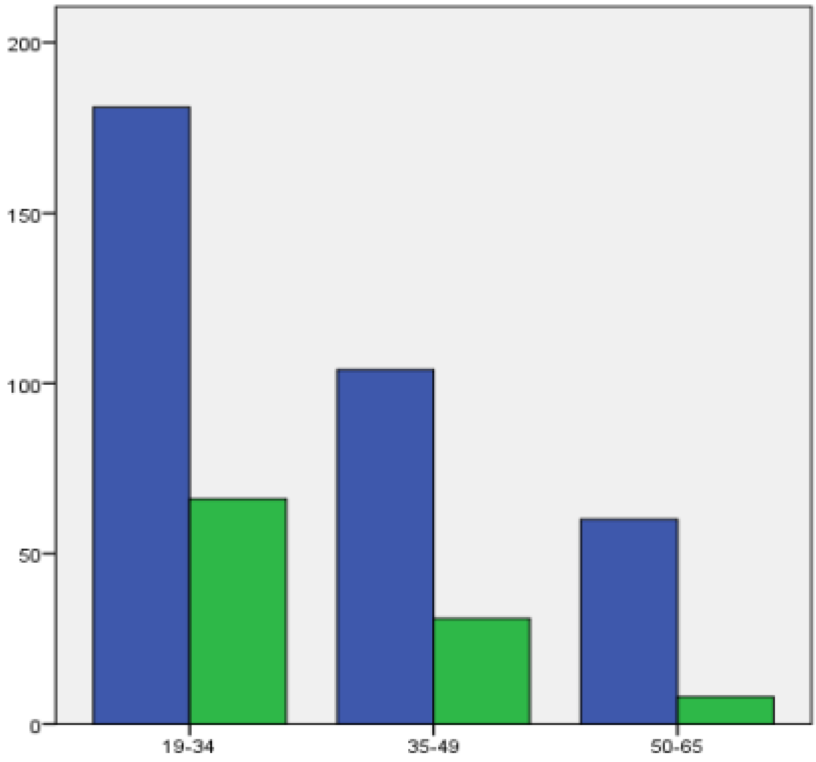


Local Government Areas

Figure 4.4: Ability to identify yams by Local Government Areas.

p=0.035

Number of Respondents



Age group (years)

Figure 4.5: Ability to identify yam varieties by age group

p=0.002

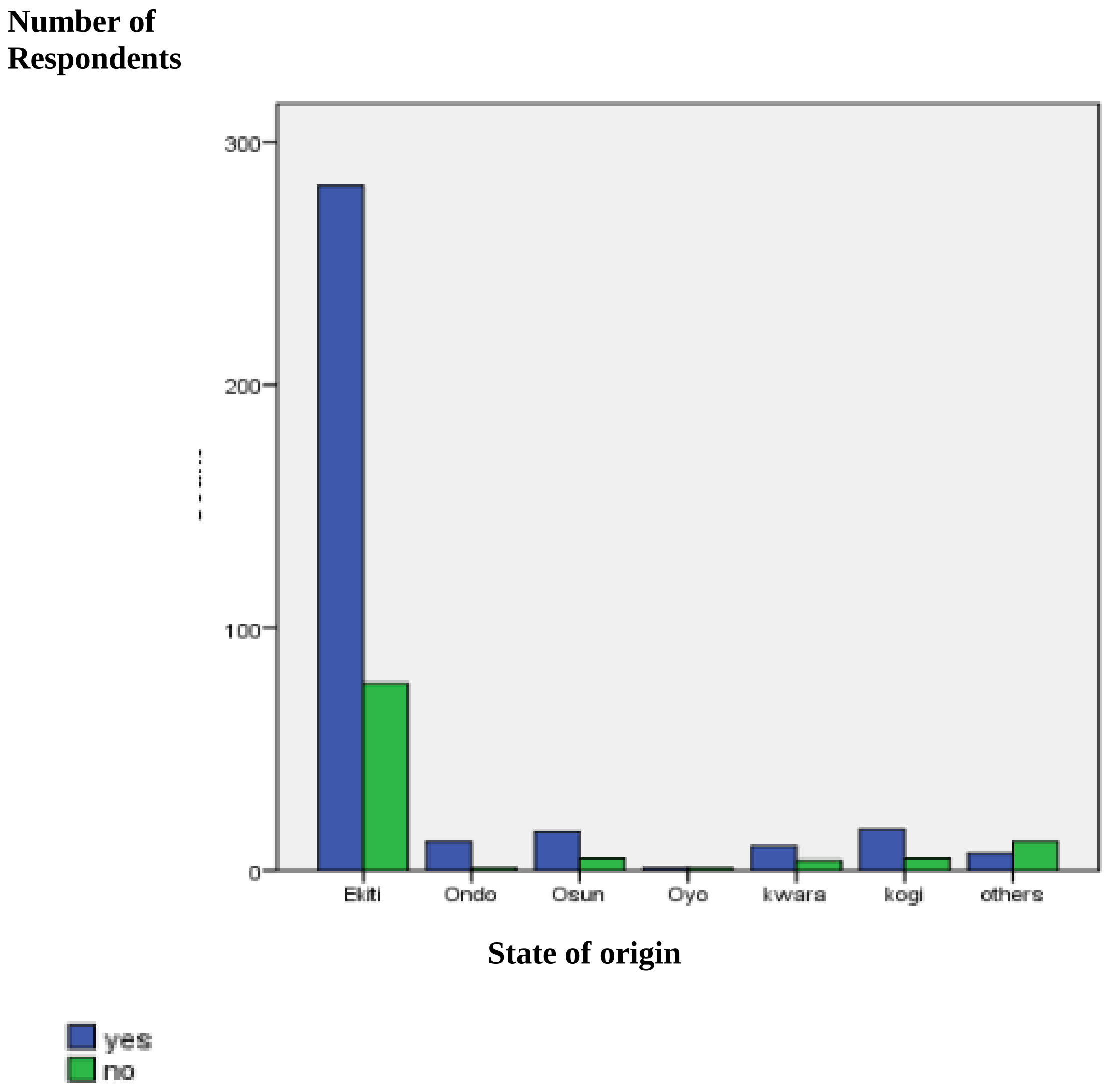


Figure 4.6: Ability to identify yam varieties by state of origin

p=0.048

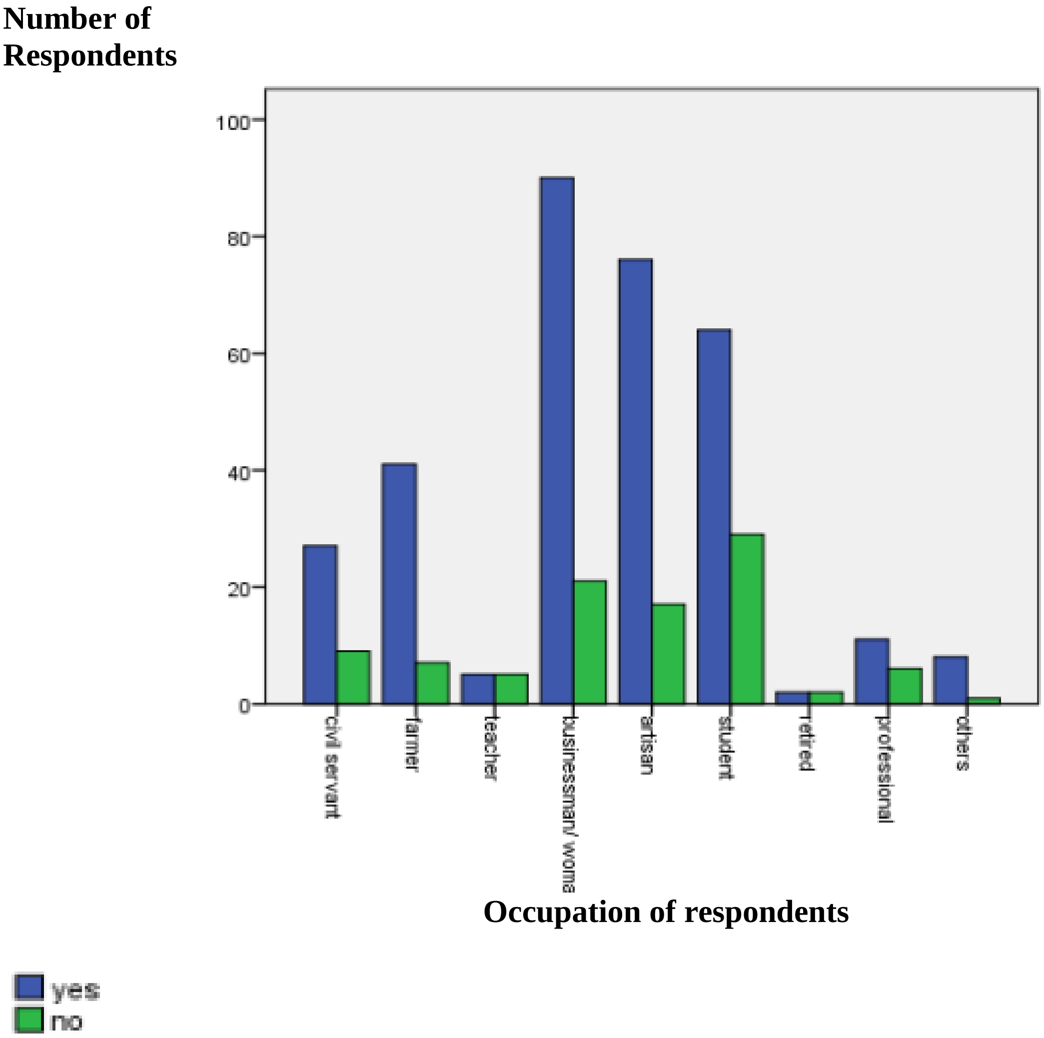


Figure 4.7: Ability to identify yam varieties by occupation of respondent

Table 4.17: Factors influencing choice of yam for consumption and association with demographic factors

	Chi Square	P value
LGA	**50.730**	**0.000**
Gender	3.444	0.486
Age	6.263	0.618
State of Origin	**43.419**	**0.009**
Marital Status	18.786	0.094
Educational Qualification	47.837	0.090
Occupation	**85.025**	**0.000**
HH Size	**62.070**	**0.014**
HH monthly income	**57.624**	**0.000**

LGA- Local Government Area

HH- Household

Highlighted variables are significantly associated with the ability to identify yam varieties at $p<0.05$.

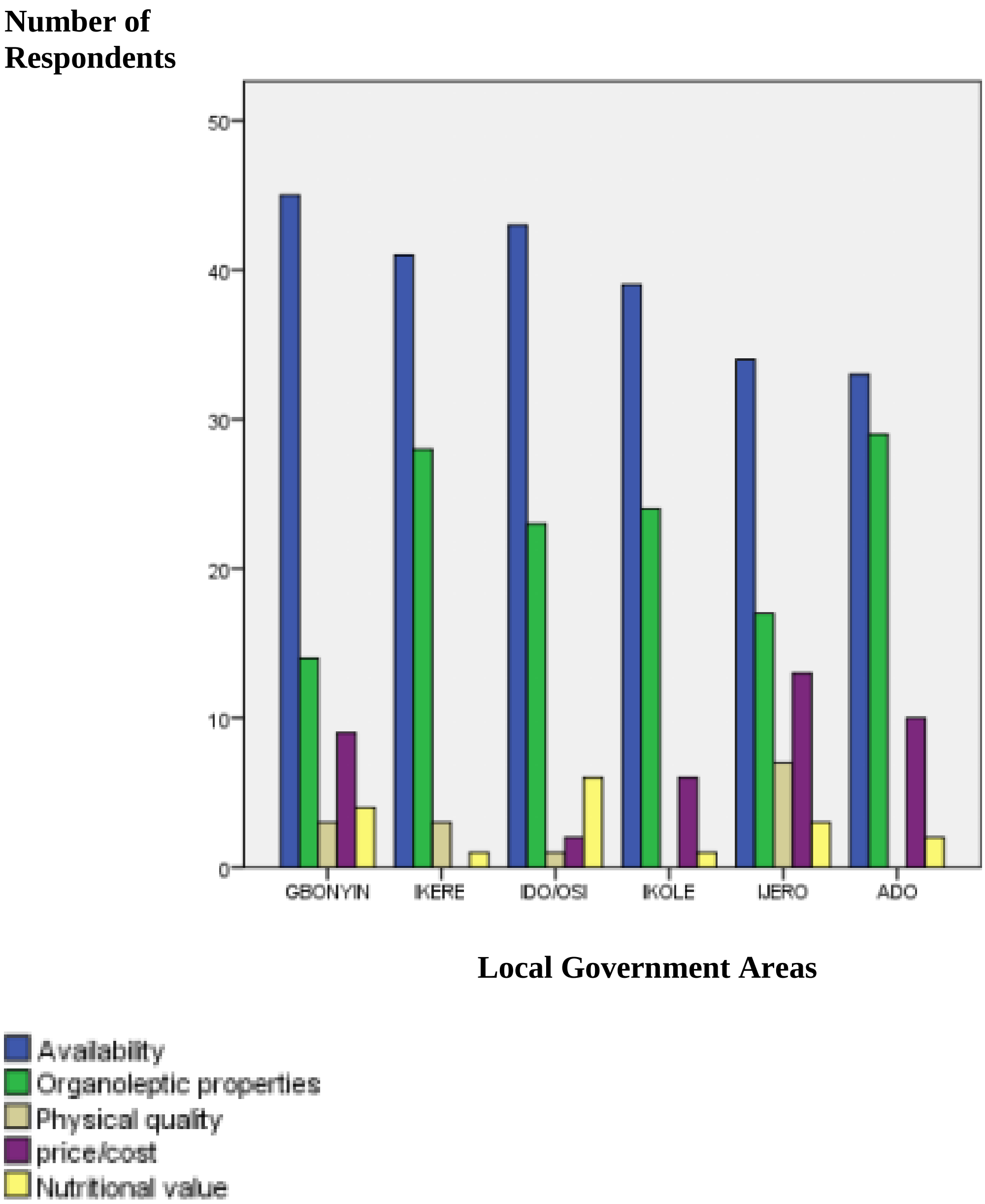


Fig 4.8: Factors influencing purchase of yam by LGA

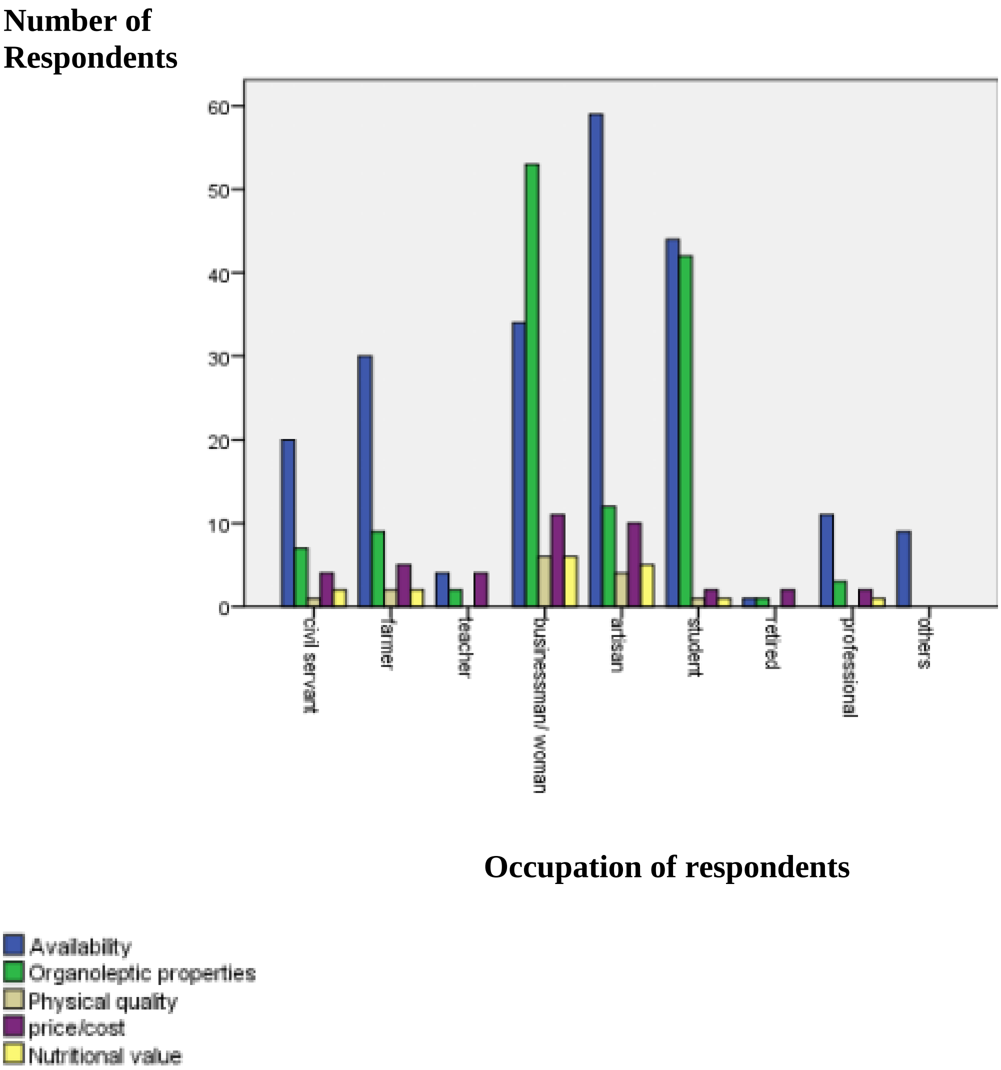


Fig 4.9: Factors influencing purchase of yam by occupation of respondents

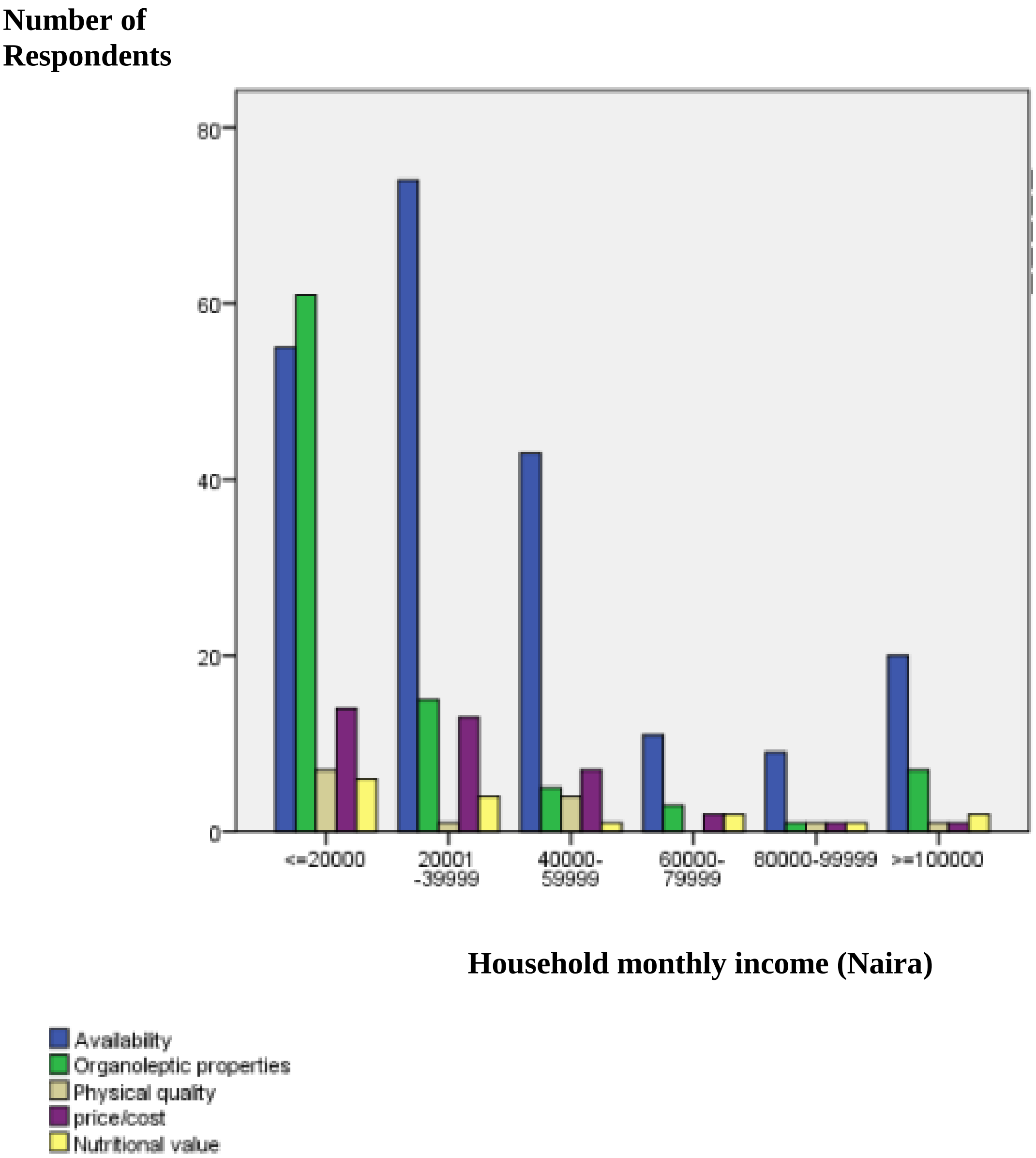


Fig 4.10: Factors influencing purchase of yam by household monthly income

Table 4.18: Seasonal influence on yam consumption and association with socio-demographic factors

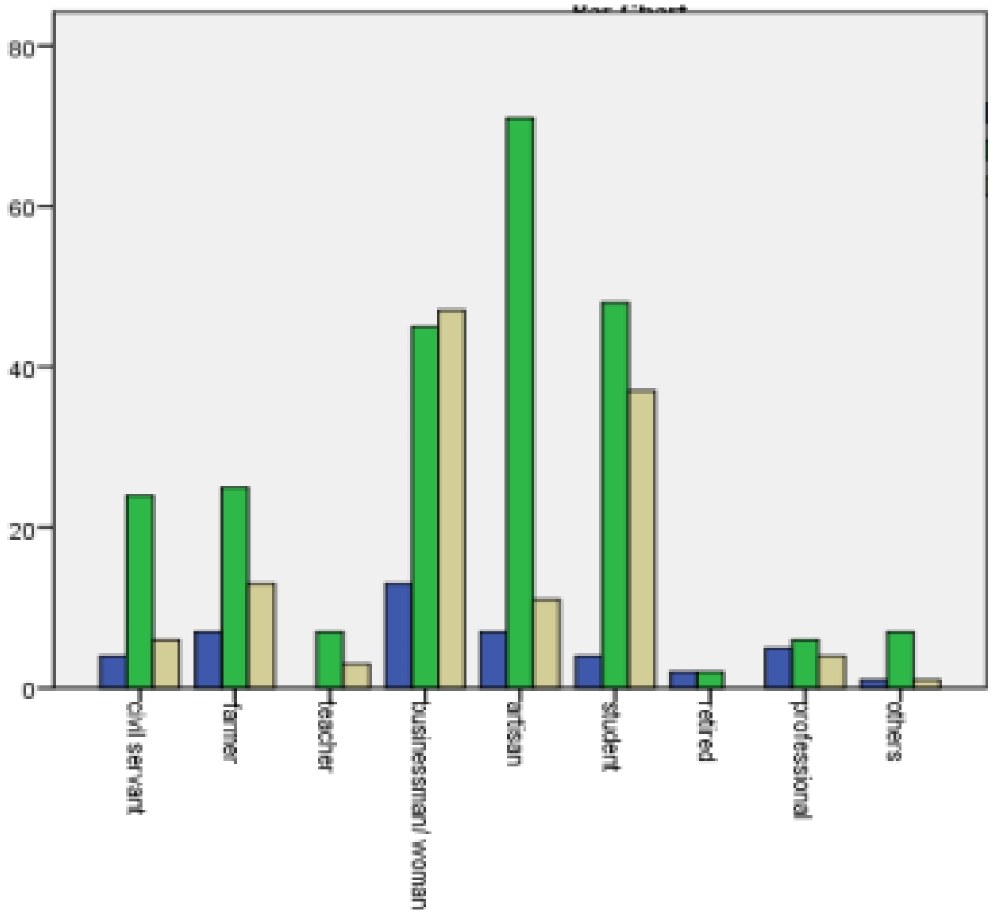
Variables	Chi Square	P value
LGA	9.025	0.530
Gender	3.933	0.140
Age	6.982	0.539
State of Origin	6.404	0.780
Marital Status	7.382	0.287
Educational Qualification	47.837	0.090
Occupation	**57.749**	**0.000**
HH Size	**43.092**	**0.002**
HH monthly income	**44.417**	**0.000**

LGA- Local Government Area

HH- Household

Highlighted variables are significantly associated with the seasonal influence of yam at $p<0.05$.

Number of
Respondents



Occupation of respondents

Fig 4.11: Seasonality influence on yam consumption by occupation of respondents

Number of Respondents

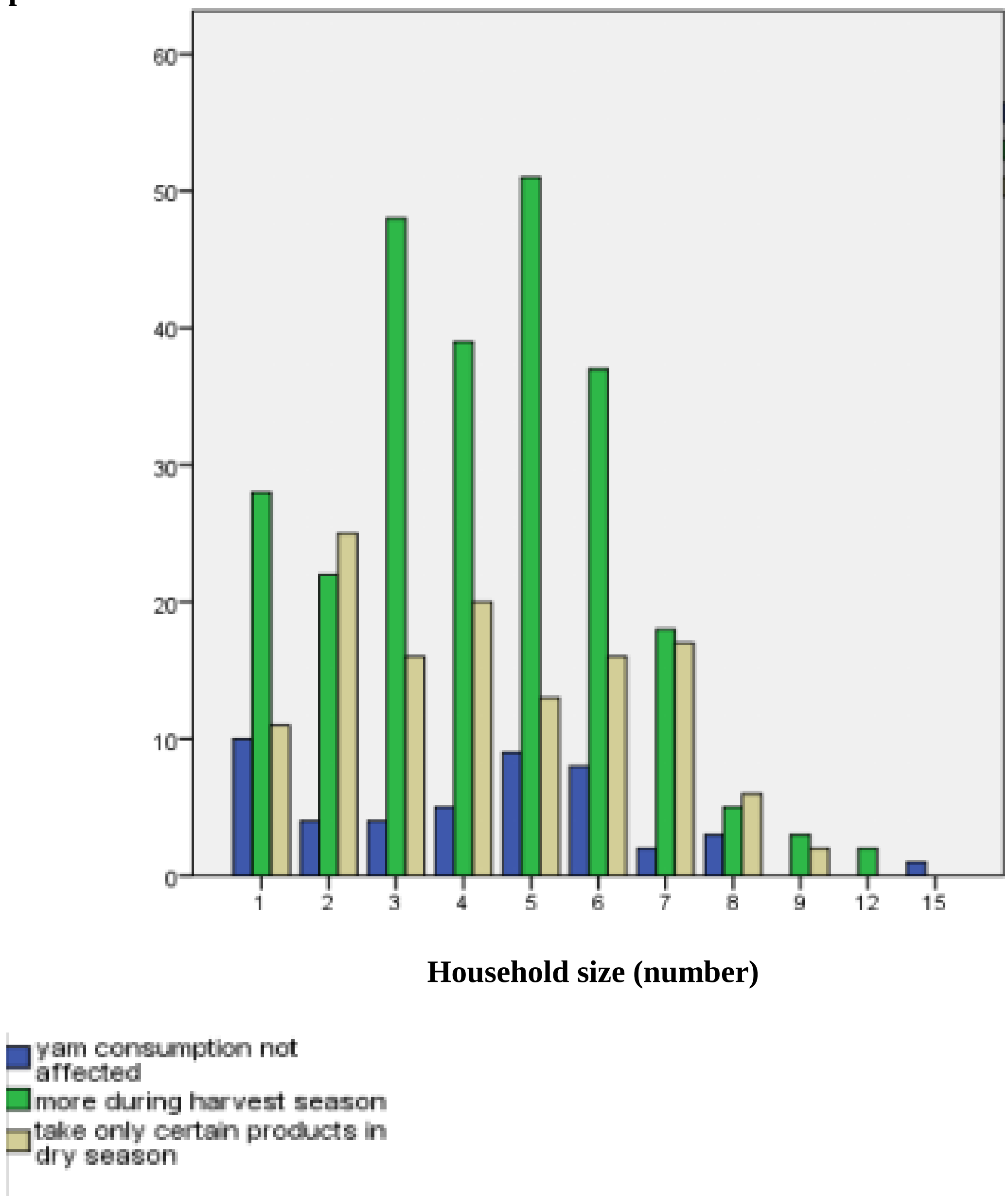


Fig 4.12: Seasonality influence on yam consumption by household size.

Table 4.19: Source of yam for consumption and association with demographic factors

Variables	Chi Square	P value
LGA	38.874	0.007
Gender	**17.687**	**0.001**
Age	**22.573**	**0.004**
State of Origin	21.725	0.596
Marital Status	**36.989**	**0.000**
Educational Qualification	**65.297**	**0.002**
Occupation	**83.246**	**0.000**
HH Size	36.261	0.639
HH monthly income	18.487	0.555

LGA- Local Government Area

HH- Household

Highlighted variables are significantly associated with source of yam for consumption at $p<0.05$.

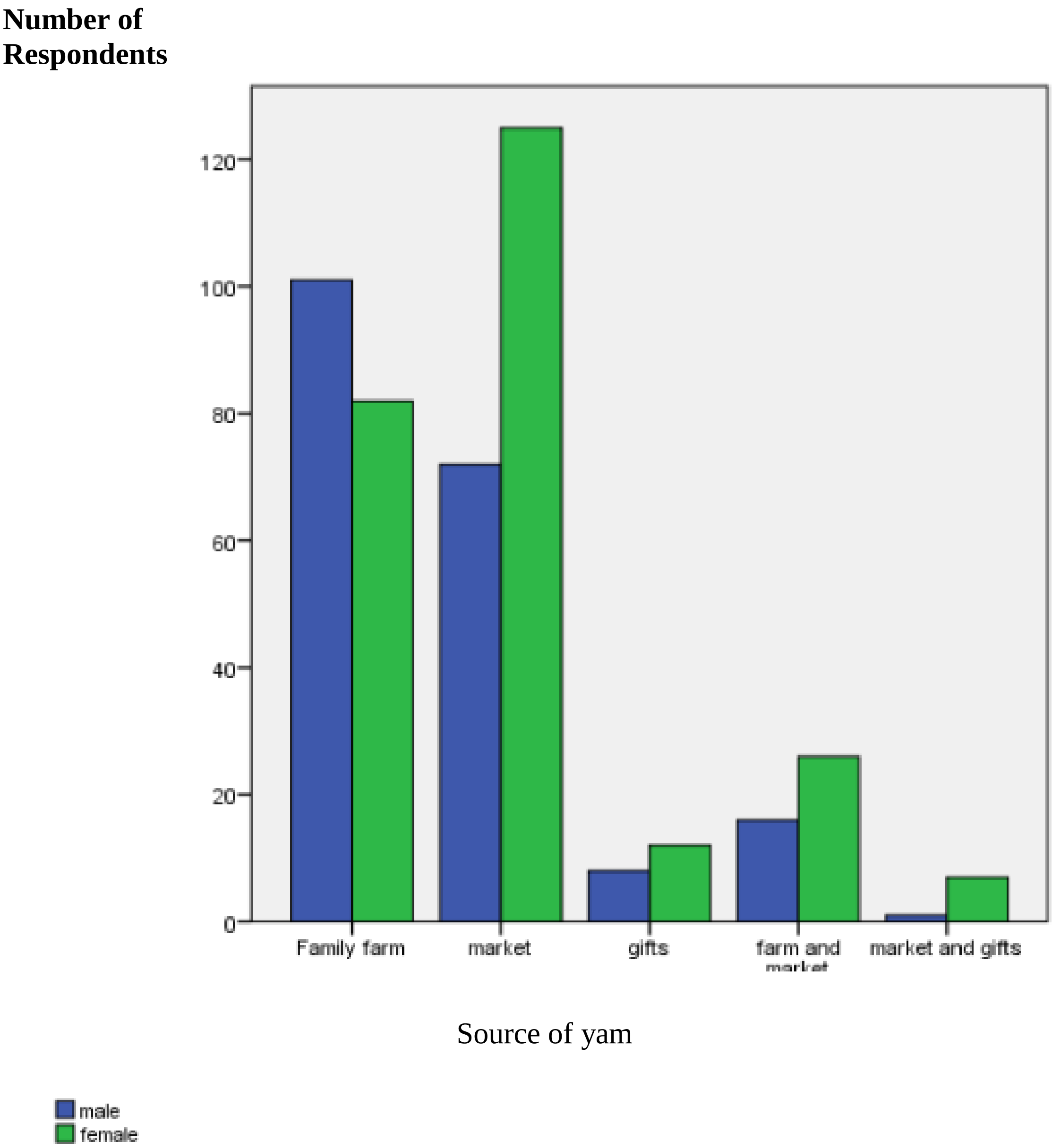


Figure 4.13: Source of yam by gender

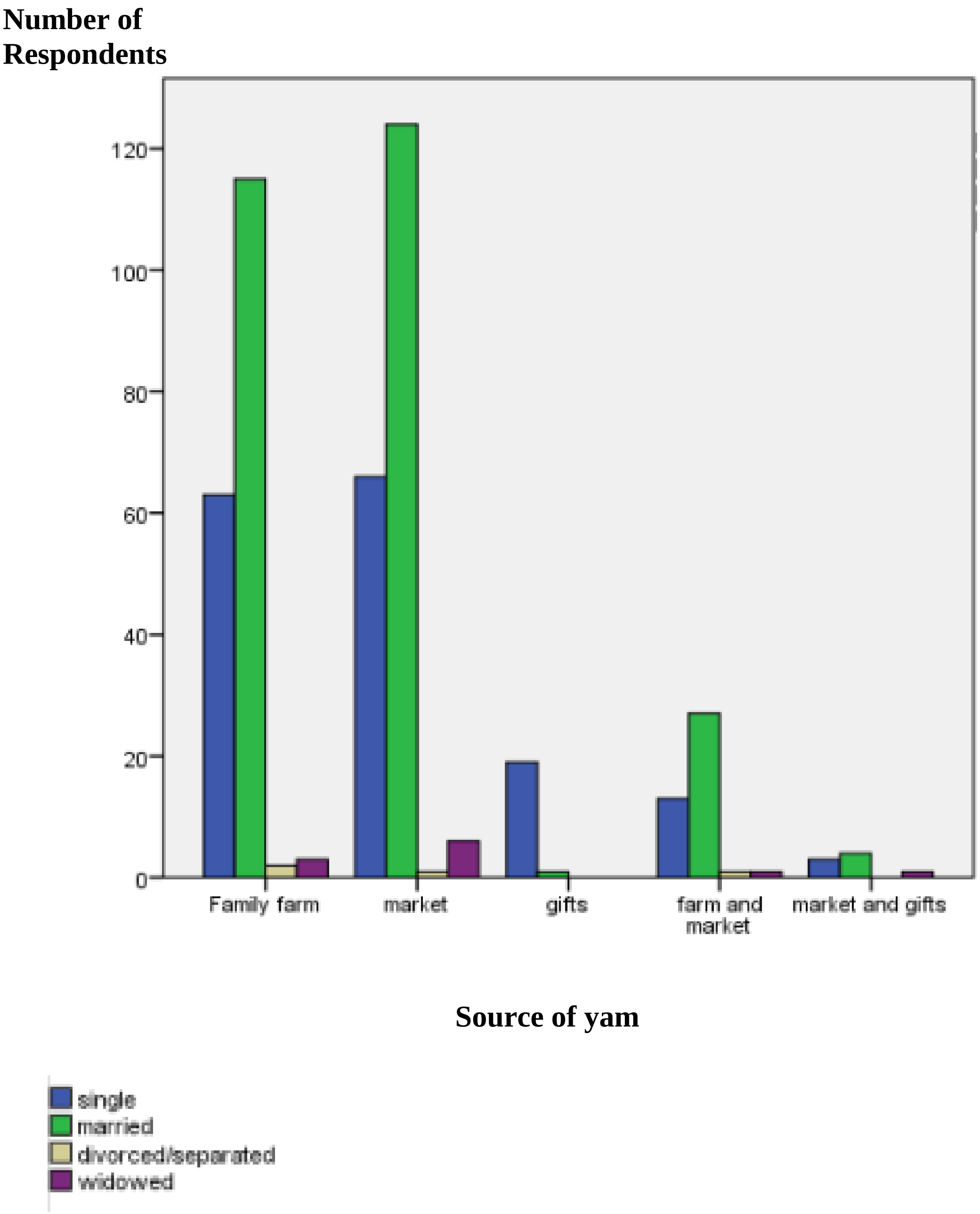


Figure 4.14: Source of yam by marital status

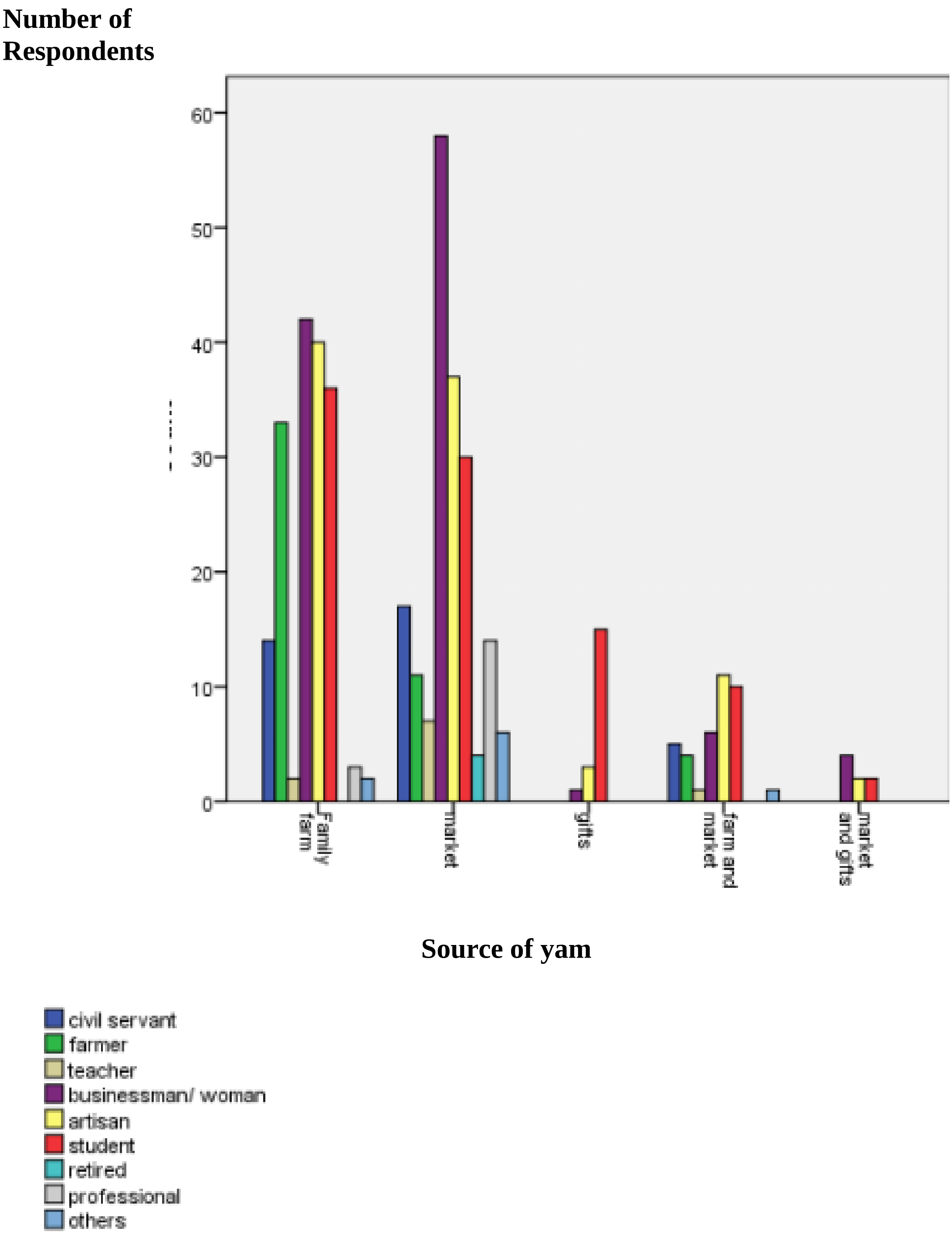


Figure 4.15: Source of yam by occupation of respondents

Objective four: Estimate the contribution of yam and its products to the nutrient intake of consumers in Ekiti State.

4.4 Yam and yam products consumption pattern

Yam consumption pattern (the frequency of consumption of yam and its products) of the respondents was assessed; the most preferred yam product by LGAs is presented in table 4.20 while the frequency of consumption of yam products is shown by table 4.21. The result of the yam consumption pattern assessment revealed that boiled yam and pounded yam are the most frequently consumed yam products. The mean consumption frequency for boiled yam and pounded yam was 3-4 days a week. Pounded yam was the most preferred yam product among majority (65.5%) of the respondents, followed by boiled yam (24.0%) and yam pottage (7%), more than half of the respondents (60.7%) consumed yam or its products daily, most respondents consume yam on a daily basis while 155 (39.3%) did not consume yam in any form at all. More than one-third (36.3%) of the respondents reported that they consumed pounded yams on a daily basis and even sometimes twice a day. More than a quarter (29.4%) of the respondents also reported that they consume boiled yams on a daily basis while only 1.9% of them reported that they never consume pounded yam and boiled yams. The least consumed yam product among the respondents was 'ojojo' (fried yam balls).

Table 4.22 reveals that pounded yam consumption frequency was significantly associated with gender, age, state of origin, educational qualification, occupation and household monthly income. In tables 4.23, 4.24 and figures 4.16, 4.17, 4.18, the interaction of the aforementioned variables with pounded yam consumption frequency is shown.

Table 4.20: Most preferred yam product

	Ekiti Central		Ekiti North		Ekiti South		
	Ado	Ijero	Ikole	Ido/Osi	Gbonyin	Ikere	Total
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Pounded yam	45 (60.0)	53 (70.7)	49 (65.3)	58 (77.3)	38 (50.7)	52 (69.3)	295 (65.5)
Boiled yam	19 (25.3)	19 (25.3)	19 (25.3)	12 (16.0)	20 (26.7)	19 (25.3)	108 (24.0)
Yam Pottage	2 (2.7)	2 (2.7)	0	2 (2.7)	1 (1.3)	0	7 (1.6)
Fried yam	0	0	1 (1.3)	0	2 (2.7)	1 (1.3)	4 (0.9)
Roasted yam	1 (1.3)	1 (1.3)	0	0	3 (4.0)	0	5 (1.1)
Amala	3 (4.0)	0	0	0	1 (1.3)	2 (2.7)	6 (1.3)
Ojojo	3 (4.0)	0	1 (1.3)	0	2 (2.7)	0	6 (1.3)
Indifferent	2 (2.7)	0	5 (6.7)	3 (4.0)	8 (10.7)	1 (1.3)	19 (4.3)
Total	75 (100)	75 (100)	75 (100)	75 (100)	75 (100)	75 (100)	450 (100)

Table 4.21: Frequency of consumption of yam products

	Pounded yam N (%)	Boiled yam N (%)	Yam Pottage N (%)	Fried yam N (%)	Roasted yam N (%)	*Amala* N (%)	Ojojo N (%)
Never	6 (1.4)	2 (0.5)	57 (13.1)	105 (24.1)	87 (20.1)	85 (19.5)	315 (72.4)
<1x per month	27 (6.2)	23 (5.3)	125 (28.7)	104 (23.9)	119 (27.5)	108 (24.8)	47 (10.8)
1-3 times per month	20 (4.6)	19 (4.4)	83 (19.0)	45 (10.3)	45 (10.4)	55 (12.6)	46 (10.6)
1-2 times per week	110 (25.3)	146 (33.6)	122 (28.0)	106 (24.4)	102 (23.6)	108 (24.8)	20 (4.6)
3-4 times per week	69 (15.9)	81 (18.7)	21 (4.8)	33 (7.6)	28 (6.5)	44 (10.1)	7 (1.6)
5-6 times per week	45 (10.3)	34 (7.8)	9 (2.1)	20 (4.6)	18 (4.2)	14 (3.2)	0
1x per day	80 (18.4)	84 (19.4)	12 (2.8)	14 (3.2)	16 (3.7)	12(2.8)	0
2 or more times per day	78 (17.9)	45 (10.4)	7 (1.6)	8 (1.8)	18 (4.2)	9 (2.1)	0
Total	**435**	**434**	**436**	**435**	**433**	**435**	**435**

Table 4.22: Pounded yam consumption frequency and association with socio-demographic factors

Variables	Chi Square	P value
LGA	48.46	0.065
Gender	**20.949**	**0.004**
Age	**30.048**	**0.008**
State of Origin	**58.818**	**0.044**
Marital Status	29.845	0.093
Educational Qualification	**102.876**	**0.001**
Occupation	**118.001**	**0.000**
HH Size	**94.965**	**0.025**
HH monthly income	**56.185**	**0.013**

LGA- Local Government Area

HH- Household

Highlighted variables are significantly associated with pounded yam consumption frequency at $p<0.05$.

Table 4.23: Pounded yam consumption frequency by gender

	MALE	FEMALE	TOTAL
Never	3(1.6)	3(1.2)	6(1.4)
<1x per month	6(3.1)	21(8.6)	27(6.2)
1-3 times per month	9(4.7)	11(4.5)	20(4.6)
1-2 times per week	39(20.3)	71(29.2)	110(25.3)
3-4 times per week	24(12.5)	45(18.5)	69(15.9)
5-6 times per week	25(13.0)	20(8.2)	45(10.3)
1x per day	46(24.0)	34(14.0)	80(18.4)
2 or more times per day	40(20.8)	38(15.6)	78(17.9)
Total	192(100)	243(100)	435(100)

Table 4.24: Pounded yam consumption frequency by state of origin

	EKITI	S/W STATES	OTHERS	TOTAL
Never	3 (0.9)	2(4.1)	1(2.5)	6(1.4)
<1x per month	19(5.5)	4(8.2)	4(10.0)	27(6.2)
1-3 times per month	13(3.8)	3(6.1)	4(10.0)	20(4.6)
1-2 times per week	90(26.0)	13(26.5)	7(17.5)	110(25.3)
3-4 times per week	56(16.2)	7(14.3)	6(15.0)	69(15.9)
5-6 times per week	42(12.1)	2(4.1)	1(2.5)	45(10.3)
1x per day	61(17.6)	7(14.3)	12(30.0)	80(18.4)
2 or more times per day	62(17.9)	11(22.4)	5(12.5)	78(17.9)
Total	346(100)	49(100)	40(100)	435(100)

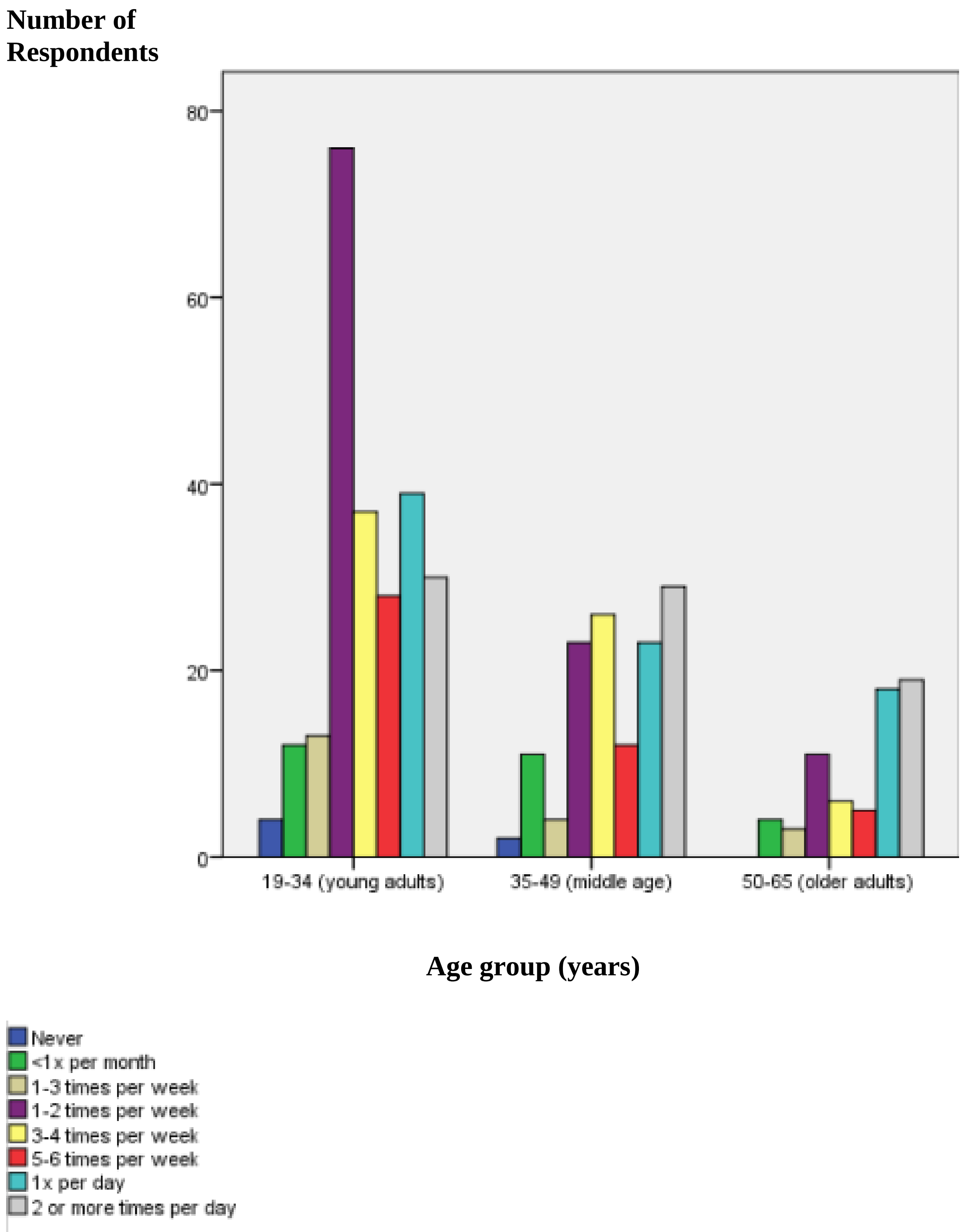


Fig 4.16: Pounded yam consumption by age group.

Number of Respondents

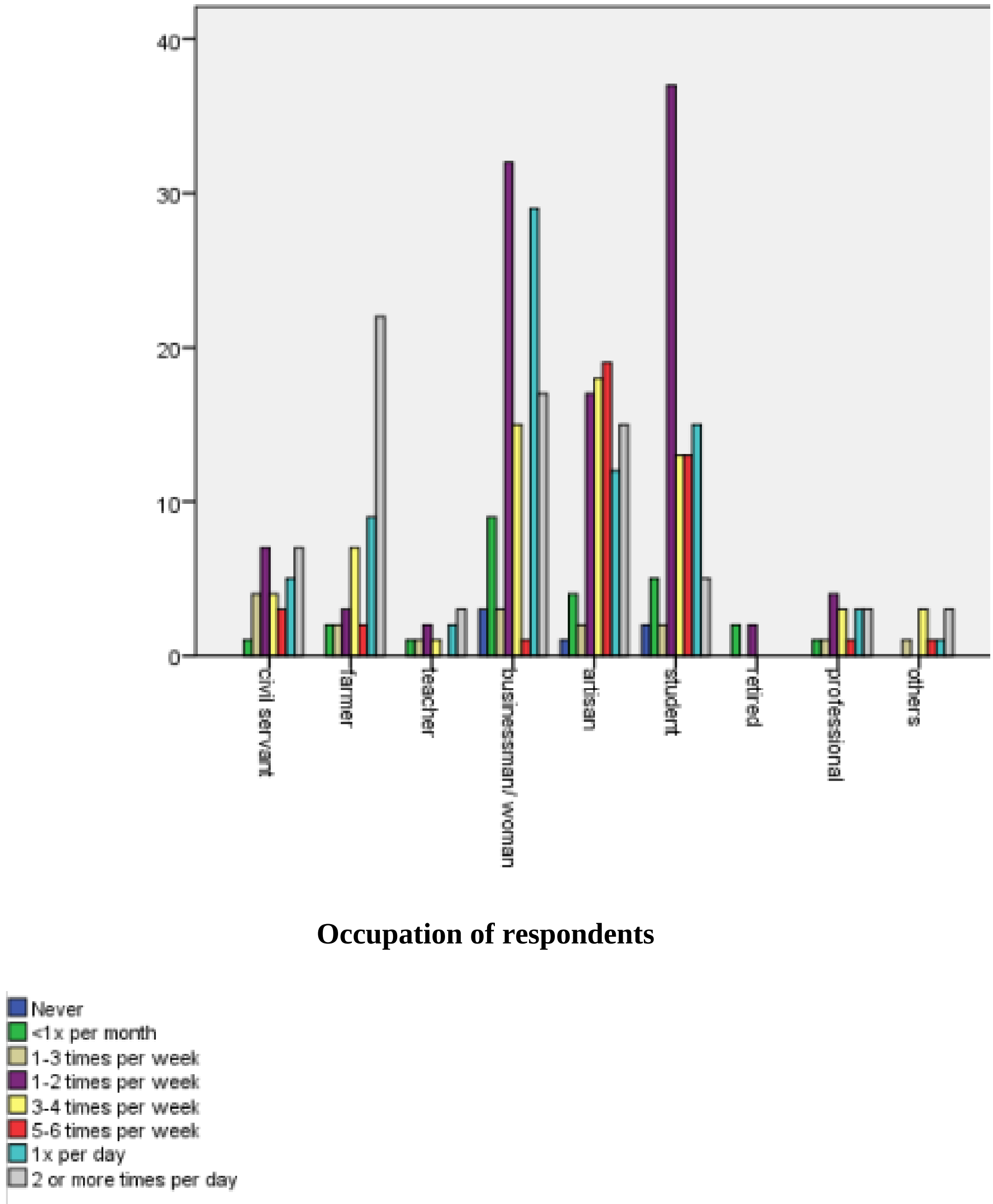


Fig 4.17: Pounded yam consumption by occupation.

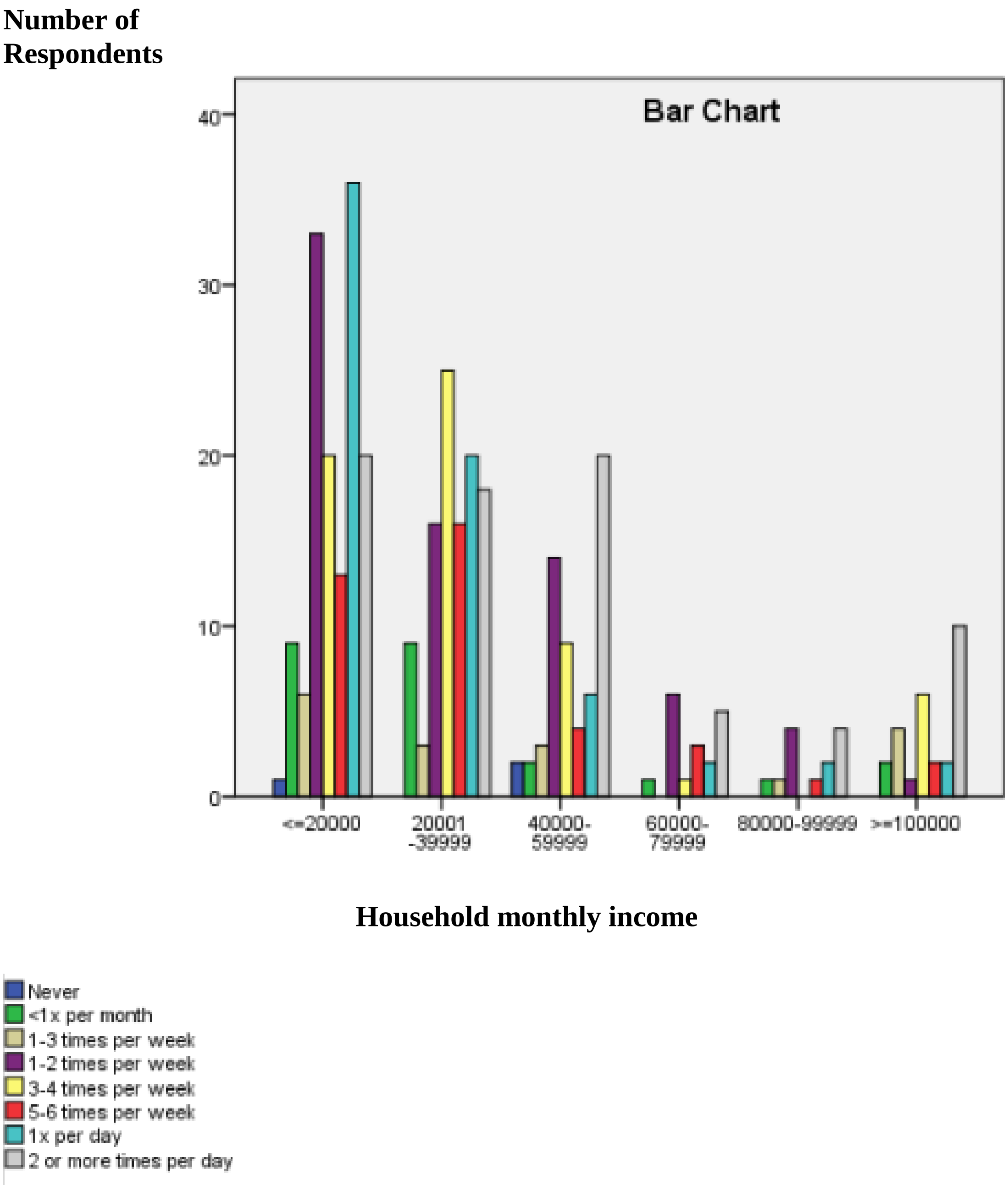


Fig 4.18: Pounded yam consumption by household monthly income.

4.4.1 Contribution of yam and its products to nutrient intake

The respondents' energy and nutrient intake is shown in table 4.25 while table 4.26 shows the contribution of yam and its products to daily nutrient intake. Daily energy, protein, carbohydrate, iron and magnesium intake were 1985.4±615.3 kcal, 55.1±27.3g, 422.5±117.3g, 15.3±5.8mg, and 251.9±86.0mg, respectively. Yam and its products contributed an average of 31.7%, 5.4%, 27.3% and 31.9% of total energy, protein, iron and magnesium intake, respectively. Yam contributed more than 50% of the daily energy intake of 58 (14.68%) of the total respondents. This means about 15% of the respondents get more than half of their total energy intake from yam products.

The contribution of yam consumed in the previous twenty-four hours to the Recommended Daily Allowance for males and females was also investigated and the results are presented in tables 4.27 and 4.28. The mean nutrient composition of the selected samples earlier analysed and their contribution to RDA according to Institute of Medicine (2006) are presented in Table 4.29.

Table 4.25: Respondents' energy and nutrient intake

Nutrients	**Mean (SD)**	**Maximum**	**RDA* (MALE)**	**RDA* (FEMALE)**
Energy (Kcal)	1985.42 (619.83)	4172.67	2204	1978
Protein (g)	55.12 (27.37)	299.83	56	46
Carbohydrate (g)	422.47 (117.25)	728.94	130	130
Fat (g)	32.81 (19.14)	146.38		
Dietary Fibre	6.42 (8.20)	86.39		
Vit A (RE)	4.26 (9.26)	88.34	900	900
Folate (mcg)	153.57 (157.49)	770.64	400	400
Iron (mg)	15.30 (5.81)	35.68	18	27
Mag (mg)	251.89 (86.01)	1032.81	420	320
Zinc (mg)	9.70 (8.58)	156.90	11	8
Calc (mg)	383.02 (160.89)	970.42	1000	1000
Phos (mg)	35.67 (10.14)	85.43	700	700
Sod (mg)	1114.29 (732.01)	4663.02	1500	1500
Potas (mg)	794.73 (94.47)	999.19	4700	4700

SD- Standard Deviation
Kcal-Kilo calories
RE-Retinol Equivalent
Mcg- microgram
Mg-milligrams
g- grams
RDA* according to Institute of Medicine. 2006.

Table 4.26: Contribution of yam and its products to total daily nutrient intake

Nutrient	Mean contribution (%)	Maximum contribution (%)
Energy	31.70	91.75
Protein	5.42	61.28
Carbohydrate	35.38	99.28
Calcium	21.69	99.96
Sodium	15.38	99.50
Potassium	18.56	99.90
Zinc	25.81	98.05
Iron	27.34	98.81
Magnesium	31.97	99.90

Table 4.27: Contribution of yam and its products to RDA for male respondents

Nutrient	Mean contribution (%)	Maximum contribution (%)
Calories	19.98	79.76
Protein	3.19	56.38
Carbohydrate	30.13	127.18
Calcium	2.71	41.89
Sodium	2.32	34.77
Phosphorus	1.25	79.71
Potassium	3.59	110.92
Zinc	20.83	120.58
Iron	37.13	204.70
Magnesium	13.16	92.66

RDA- Recommended Daily Allowance

Table 4.28: Contribution of yam and its products to RDA for female respondents

Nutrient	Mean contribution (%)	Maximum contribution (%)
Calories	14.74	85.67
Protein	1.93	32.67
Carbohydrate	24.02	133.70
Calcium	2.39	61.13
Sodium	2.99	97.65
Phosphorus	0.89	104.22
Potassium	1.19	66.99
Zinc	16.42	112.36
Iron	26.37	148.46
Magnesium	9.69	78.51

RDA- Recommended Daily Allowance

Table 4.29: Contribution of analyzed yam varieties per 100g to RDA

Nutrients	Mean analysed value/100g (SD)	RDA	Contribution (%)
Energy (Kcal)	151.52	2204	6.87
Protein (g)	2.41	56	4.30
Carbohydrate (g)	35.03	130	26.95
Fat (g)	0.09		
Iron (mg)	0.52	18	2.89
Magnesium (mg)	24.09	420	5.74
Zinc (mg)	1.52	11	13.82
Calcium (mg)	10.41	1000	1.04
Phosphorus (mg)	38.02	700	5.43
Sodium (mg)	12.01	1500	0.80
Potassium (mg)	235.85	4700	5.02

RDA- Recommended Daily Allowance
SD- Standard Deviation
Kcal-Kilo calories
RE-Retinol Equivalent
Mcg- microgram
Mg-milligrams
g- grams

OBJECTIVE FIVE: Assess the dietary diversity and nutritional status of adult men and women in Ekiti State

4.5 DDS and BMI of the respondents

Using the IDDS with a 9 food group, a DDS terciles for low, medium and high was constructed and most of the respondents (57.6%) fell within the medium (4-6) tercile. The DDS of the respondents is presented in table 4.30. The mean DDS was 3.63±0.93. With the dichotomous scale of the MDDW, the DDS for most of the respondents (78.8%) was inadequate irrespective of gender, LGA and other socio economic / demographic factors. Table 4.31 shows that only marital status was significantly associated with DDS and this relationship is shown by figure 4.19. Table 4.32 shows the proportion of DDS food groups consumed by the respondents and this is further graphically expressed by figure 4.20.

Table 4.33 shows the BMI of the respondents. Less than half of the respondents (42.8%) were of normal weight, 3.1% were underweight, while a large proportion of the respondents were overweight (38.7%) and obese (14.0%). Figure 4.21 shows that there was no significant association between DDS and BMI of respondents. While table 4.34 shows that only age and marital status were significantly associated with BMI of the respondents, figures 4.22 and 4.23 show these associations.

Table 4.30: Dietary Diversity Score of respondents (n=443)

	Ekiti Central		Ekiti North		Ekiti South		Total
	Ado	Ijero	Ikole	Ido/Osi	Gbonyin	Ikere	
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
MDDW CLASSIFICATION μ=3.79±0.99							
Inadequate (<5)	60 (80.0)	64 (85.3)	56 (82.4)	56 (74.7)	56 (74.7)	57 (76.0)	349 (78.8)
Adequate (>=5)	15 (20.0)	11 (14.7)	12 (17.6)	19 (25.3)	19 (25.3)	18 (19.1)	94 (21.2)
IDDS CLASSIFICATION μ=3.63±0.93							
Low (1-3)	31 (41.3)	30 (40.0)	25 (36.8)	34 (45.3)	32 (42.7)	34 (45.3)	186 (42.0)
Medium (4-6)	42 (56)	45 (17.5)	43 (63.2)	41 (54.7)	43 (57.3)	41(54.7)	255 (57.6)
High (7-9)	2 (2.7)	0	0	0	0	0	2 (0.5)

Table 4.31: Dietary Diversity Score and association with socio- demographic factors

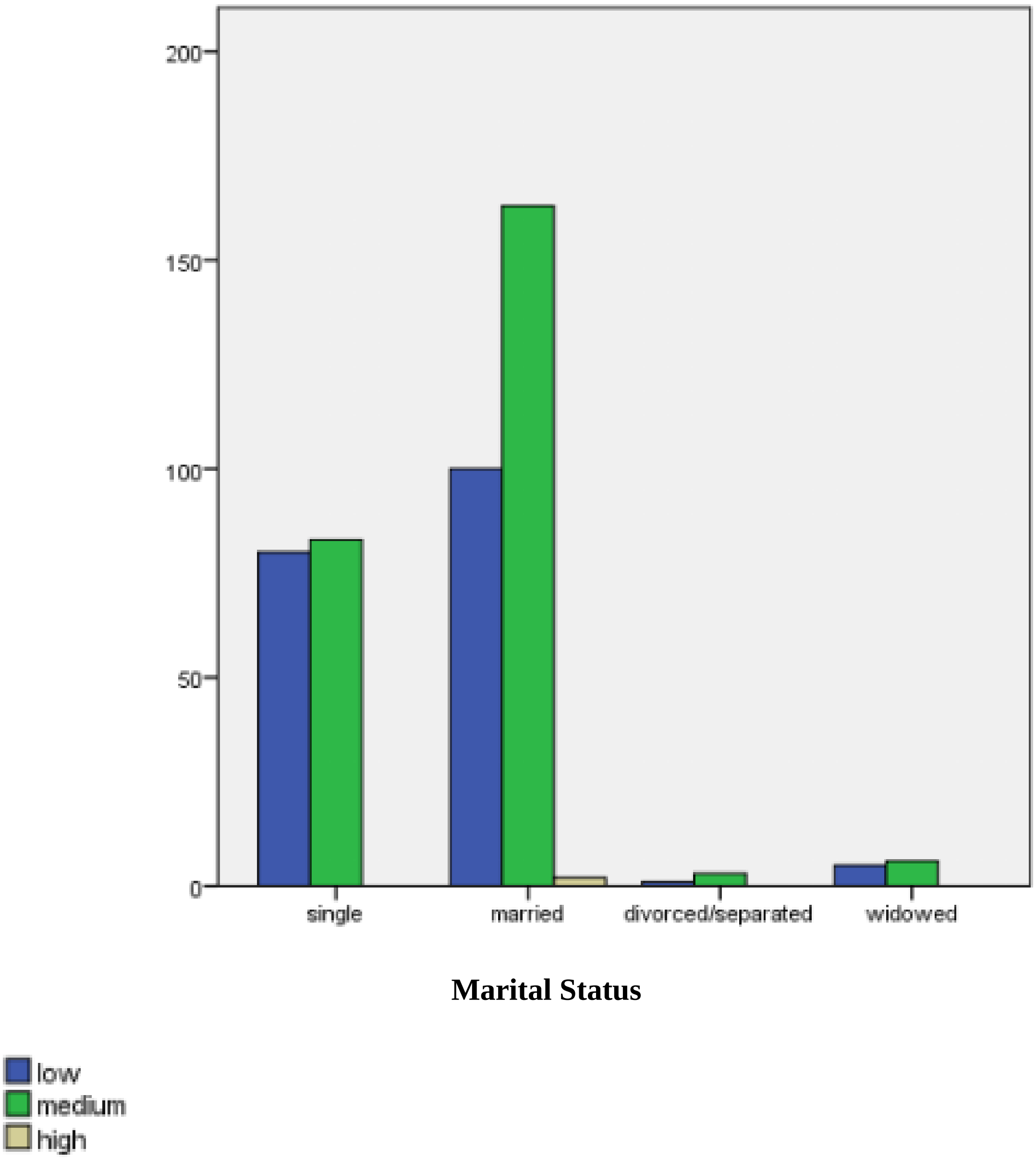
Variables	Chi Square	P value
LGA	4.265	0.512
Gender	4.378	0.708
Age Distribution	4.122	0.127
State of Origin	8.586	0.198
Marital Status	**8.174**	**0.043**
Educational Qualification	4.872	0.845
Occupation	9.606	0.294
HH Size	10.543	0.394
HH monthly income	9.280	0.098

LGA- Local Government Area

HH- Household

Highlighted variables are significantly associated with the DDS at p<0.05.

Number of
Respondents

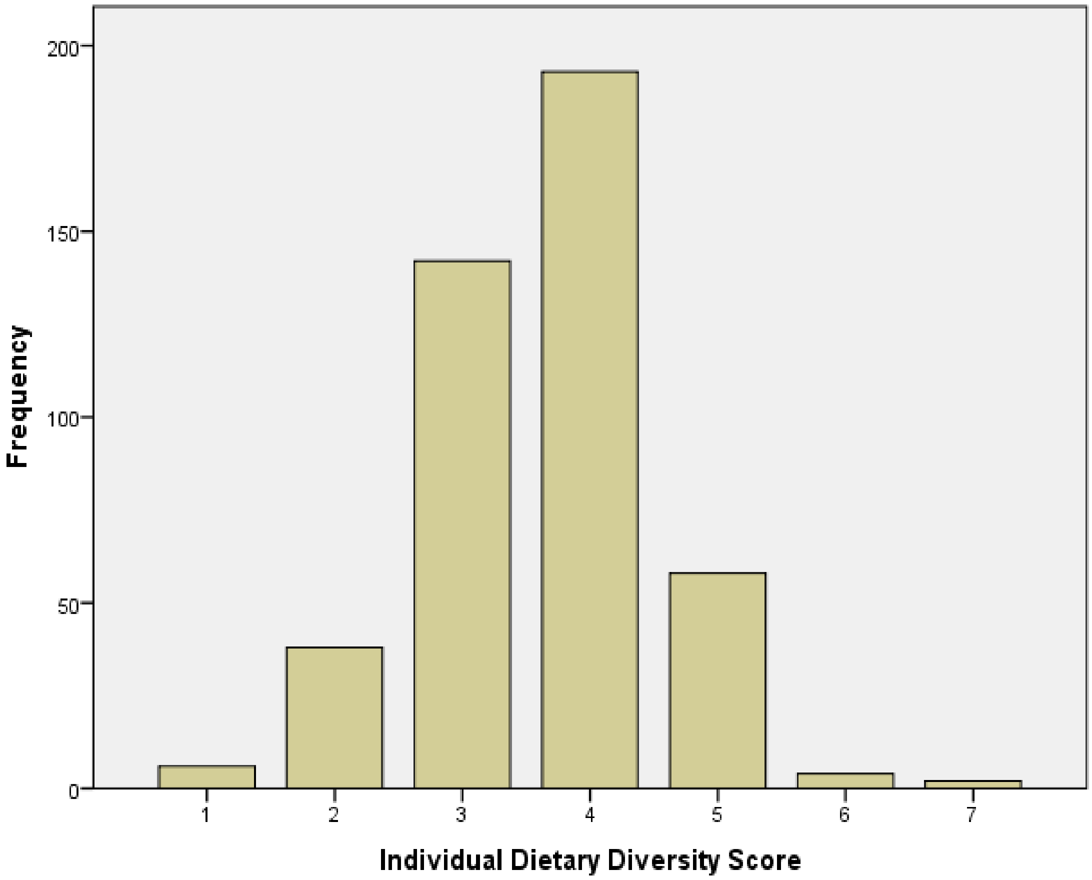


Marital Status

Figure 4.19 Dietary Diversity Score by marital status

Table 4.32 Proportion of DDS food groups consumed (n=443)

Food Group	Yes **N (%)**	No **N (%)**
Grains, white roots and tubers, and plantains	442 (99.8)	1 (0.2)
Pulses (beans, peas and lentils)	207 (46.7)	236 (53.3)
Nuts and seeds (melon locust bean)	137 (30.9)	306 (69.1)
Dairy (milk and milk products)	14 (3.2)	429 (96.8)
Meat, poultry and fish	357 (80.6)	86 (19.4)
Eggs	91 (20.5)	352 (20.5)
Dark green leafy vegetables	187 (42.2)	256 (57.8)
Other vitamin A-rich fruits and vegetables	57 (12.9)	386 (87.1)
Other vegetables	159 (35.9)	284 (64.1)
Other fruits	30 (6.8)	413 (93.2)



μ=3.63

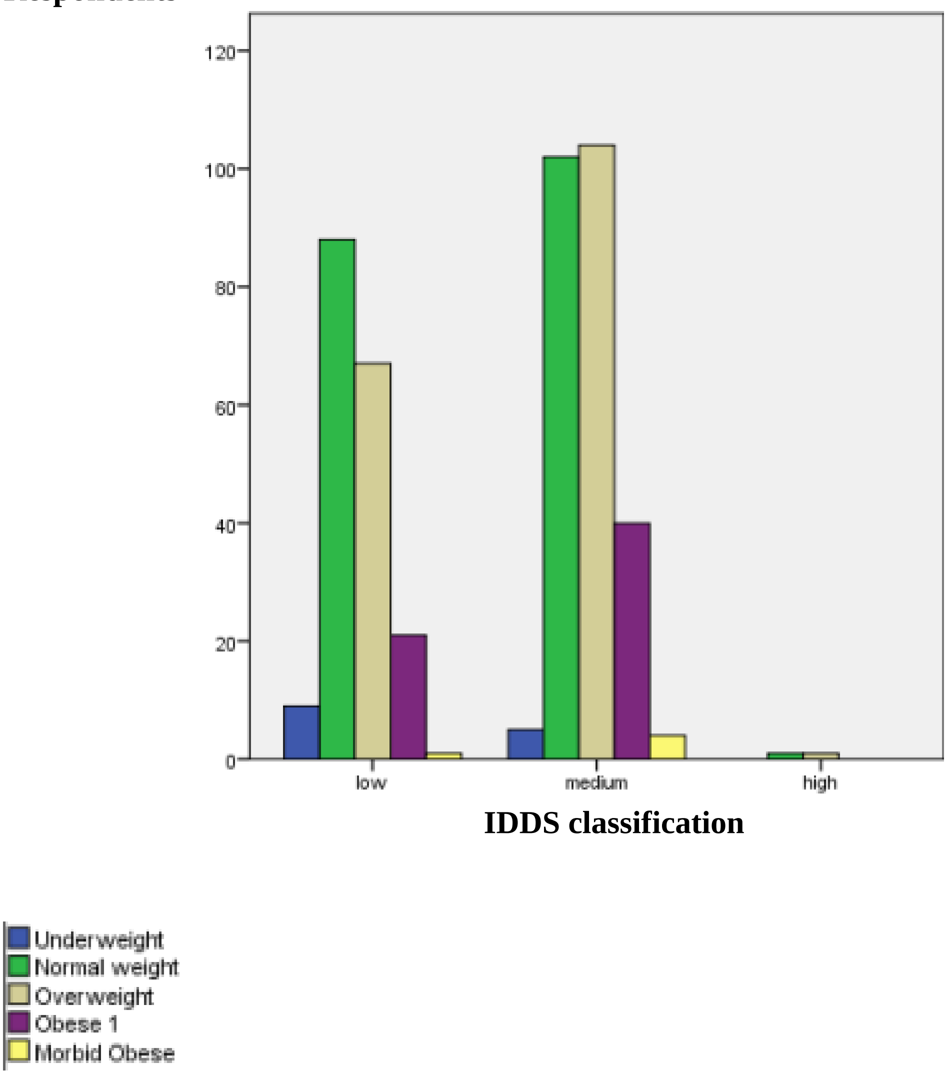
S.D. =0.93

Figure 4.20 Number of food groups consumed by respondents using the IDDS food grouping

Table 4.33: Body Mass Index of respondents

	Ekiti Central		Ekiti North		Ekiti South		Total
	Ado	Ijero	Ikole	Ido/Osi	Gbonyin	Ikere	
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Underweight (<18.5)	2 (2.7)	1 (1.3)	5 (6.7)	1 (1.3)	4 (5.3)	1 (1.4)	14 (3.1)
Normal weight (18.5-24.9)	32 (42.7)	31 (41.3)	31 (41.3)	32 (42.7)	36 (48.0)	32 (43.2)	195 (42.8)
Overweight (25.0-29.9)	27 (36.5)	29 (38.7)	33 (44.0)	26 (34.7)	24 (32.0)	35 (47.3)	174 (38.7)
Obese (30-39.9)	14 (18.9)	13 (17.3)	6 (8.0)	13 (17.3)	11 (14.7)	5 (6.8)	62 (13.8)
Morbidly obese (>40)	0	1(1.3)	0	3 (4.0)	0	1 (1.4)	5 (1.1)
Total	75	75	75	75	75	74	450 (100)

Number of
Respondents



IDDS classification

Figure 4.21 BMI by DDS classification

Table 4.34: BMI and association with DDS and socio demographic factors

Variable	Chi square	P
LGA	25.727	0.175
DDS (MDDW)	4.054	0.349
Gender	8.278	0.082
Age	**24.888**	**0.000**
State of Origin	23.046	0.517
Marital Status	**60.225**	**0.000**
Educational Qualification	37.236	0.412
Occupation	45.360	0.059
HH Size	34.350	0.722
HH monthly income	12.432	0.900

LGA- Local Government Area

HH- Household

BMI- Body Mass Index

DDS- Dietary Diversity Score

Highlighted variables are significantly associated with BMI at $p<0.05$.

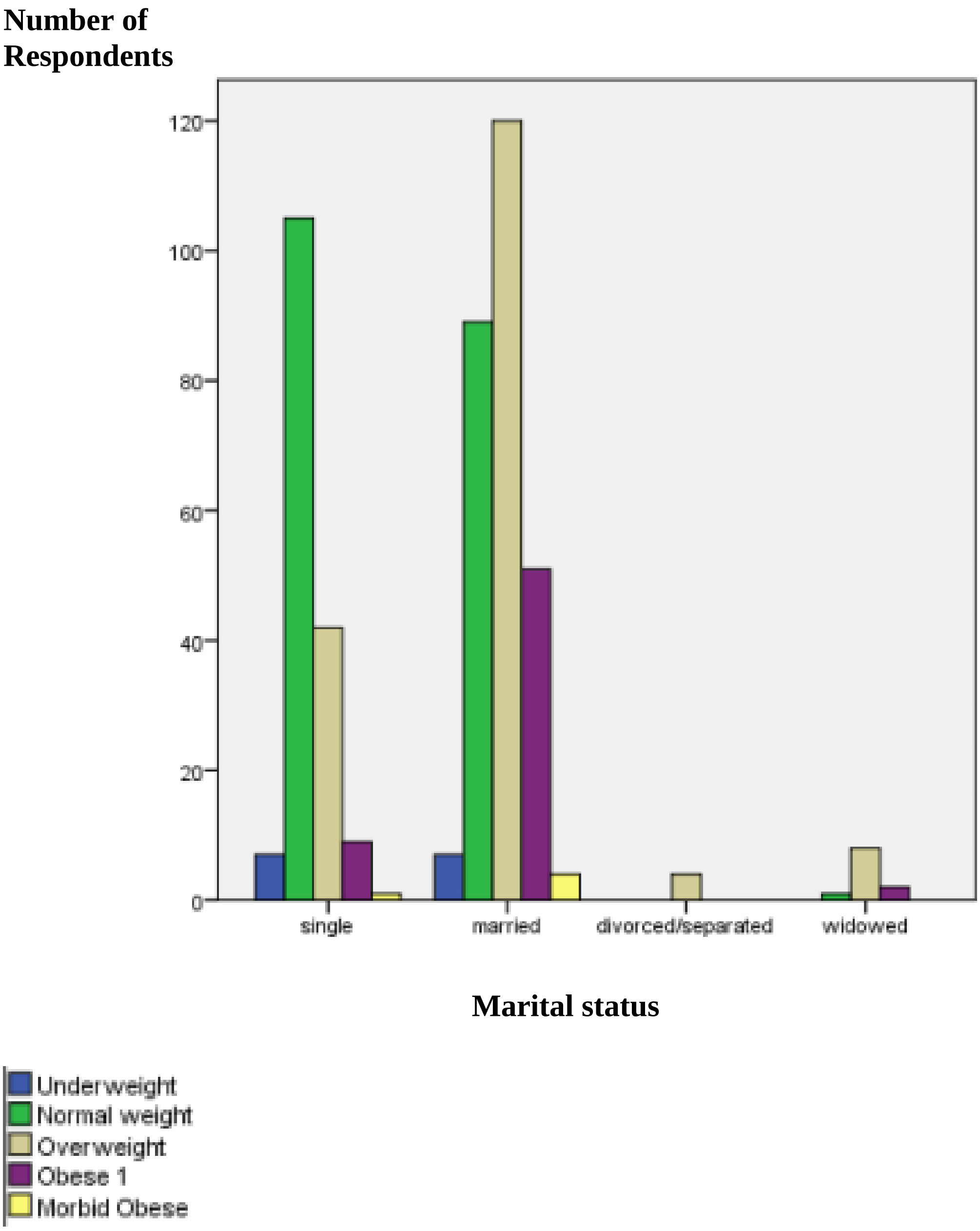


Figure 4.22 Body Mass Index by marital status

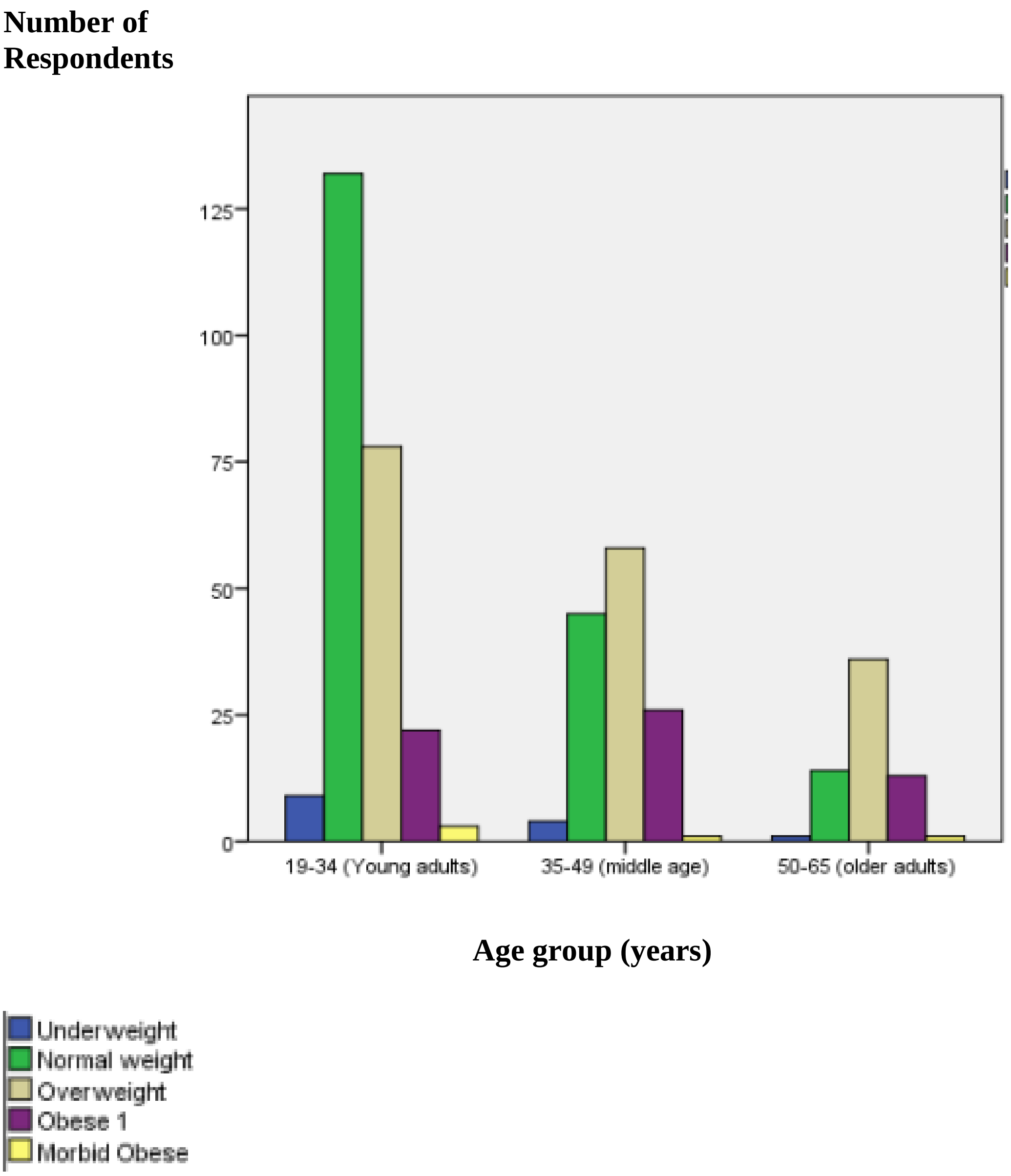


Figure 4.23 Body Mass Index by age

CHAPTER FIVE

DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

5.1 DISCUSSION

5.1.1 Proximate Composition of Yam Samples

The mean moisture content for *D. rotundata* was lower than that of *D. alata* and they were significantly different from each other. The values are similar with what was reported by Polycarp *et al.,* (2012) that the moisture contents of *D. alata* samples are higher than that of *D. rotundata*. The higher dry matter for *D. rotundata* is an indication of good eating and textural quality in food products (Izutsu and Wani, 1985; Otegbayo *et al.,* 2017). Varieties with high moisture content would be suitable for prolonged tuber storage and more efficient for industrial processing.

The carbohydrate contents of the varieties were significantly different ($p<0.05$). The values were comparable to values reported by Bhandari *et al.,* (2003); Shanthakumari *et al.,* (2008), Adepoju, (2012) and Polycarp *et al.,* (2012). The protein content in the studied varieties were significantly different ($p<0.05$). The mean protein value for the raw *D. alata* was greater than the mean value for *D. rotundata* in both the raw and boiled samples. These values are similar to those reported by Polycarp *et al.,* (2012) but different from the values reported by Otegbayo *et al.,* (2017). For both species, boiling significantly increased their mean protein content, this is contrary to the report by Ezeocha *et al.,* (2012) on *D. dumetorum* but similar to the report of Adepoju (2017). Processing has been reported to enhance nutrient availability in some processed foods compared to the raw (Oste, 1991; Adepoju, 2012).

All the yam varieties had low fat contents below 1.0% similar to values reported by Polycarp *et al.,* (2012) and Adepoju *et al.,* (2017). The crude fibre values reduced significantly with boiling for the *D. rotundata* samples but there was no significant difference between the values for raw and boiled *D. alata* samples. There were significant differences in the means of the proximate content of the varieties except for the fat content. Boiling significantly affected the proximate content and metabolisable energy. Boiling yam caused significant increase in moisture content of the samples with attendant decrease in lipid, crude fibre, carbohydrate, energy and ash content of the products compared with raw sample. This was an indication that some of these nutrients leached into the cooking water and that the yams contained significant amount of soluble fibre. This observation was in line with the findings of Adepoju *et al*., (2012 and 2017) who reported nutrient loss by cooking and soaking food items for a period of time through leaching. Ash contents of the varieties were significantly different ($p<0.05$).

5.1.2 Mineral composition of the yam samples

The result showed that the yam varieties are relatively good sources of both macro minerals (Ca, P, K, Na and Mg) and micro minerals (Fe, Cu and Zn) which are significant nutritionally. These values were comparable to values reported by Bhandari *et al.,* (2003); Shanthakumari *et al.,* (2008) and Polycarp *et al.,* (2012). There were significant differences in the means of the mineral content of the varieties. Generally, variations in mineral composition have been adduced to factors such as genetic component, environment effects, methods of estimation, seasonal changes, cultural practice, climate and soil and other factors and to a lesser extent whether or not it is cooked or raw (Oluwatosin, 1998; Eka, 1985: Otegbayo *et al.*, 2017). Minerals are important components of diets because of the physiological and metabolic roles they play in normal body functions. Though minerals are not lost due to heat, they are usually leached if cooked in boiling water (Akin –Idowu *et al.,* 2009; Lawal *et al.,* 2014).

Boiling significantly affected the Calcium, Sodium and Phosphorus content but did not affect Magnesium, Potassium, Zinc, Iron and Copper content. Boiling reduced the Ca, Na and P content. This is similar to the report of Assa *et al.,* (2014). Ezeocha and Ojimelukwe, 2012. Calcium as an important macro mineral functions as a component of skeleton and teeth where it occurs as a salt with phosphate. Calcium is also used in the activation of a number of hydrolytic enzymes. Assessing the 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; Dilworth *et al.,* 2012; Lawal *et al.,* 2014). It has also been implicated in significantly affecting the textural quality of food products. (Otegbayo *et al.,* 2012; Otegbayo *et al.*, 2017).

The most abundant mineral in all the yam varieties was Potassium. It ranged between 155-288mg/100g in the raw samples and between 201-257mg/100g for the boiled samples. This agreed with previous results (Baah *et al.* 2009; Polycarp *et al.* 2012; Adepoju 2012; Adepoju 2017). Potassium is a major intracellular cation which is involved in muscle contraction, transmission of nerve impulse and maintenance of fluid balance (Otegbayo *et al.,* 2017). It is important in the regulation of heart beat, neurotransmission and water balance in the body (Allinor and Akalezi, 2010). The potassium levels in all the samples however did not meet the WHO recommended daily allowance of 2000mg/day for adult and 1000mg/day for children. The sodium levels in the samples were higher than the WHO recommended daily allowance of 10mg/day for adult male and below the 15mg/day for female. Sodium is used to maintain blood pressure and chronic changes in salt nutrition can change blood pressure and influence the course of cardiovascular disease (Otegbayo *et al.,* 2012). The very low level of sodium compared with potassium is a good advantage for the yam to be suitable for consumption for hypertension patients where sodium: potassium ratio is expected to be low (Adepoju *et al.*, 2017).

The phosphorus content of the yam tubers ranged from 40.35-125.20mg/100g in the raw samples and between 33.29-72.87mg/100g for the boiled samples. The lower value of phosphorus in these yam tubers may be due to phytic acid in yams which binds the phosphorus and render it unavailable for biochemical and nutritional utilization. It could also be due to the fact that phytic acid and starch are capable of combining via phosphate linkages (Otegbayo *et al.*, 2017). Dietary phosphate deficiency is reported to be rare because phosphate concentration in plant and animal foods is well above requirement and because of the efficient absorption of phosphate 50 to 90% (Brody, 1994; Lawal *et al.*, 2014). Magnesium levels in the yam ranged from 22.55-27.56mg/100g in the raw samples and between 20.57-27.95mg/100g for the boiled samples. Most enzymes that utilize adenosine triphosphate (ATP) require magnesium and one of the enzymes using magnesium pumps sodium out of cells and potassium into cells (Wardlaw *et al.,* 2004). Magnesium also contributes to DNA and RNA synthesis during cell proliferation. The recommended daily allowance for magnesium is 320mg/day for adult females (Lawal *et al.,* 2014).

Iron concentration in the yam samples ranged from 0.12-0.27mg/100g in the raw samples and between 0.12-3.68mg/100g for the boiled samples which is lower than reported by (Afoakwa and Dedeh, 2001: Adepoju *et al.*, 2012). The recommended daily allowance (RDA) of iron is between 11 and 18 mg/day (USDA, 2015); most of these yam varieties have iron contents that can meet this RDA. Iron is an important oxygen carrier in haemoglobin in the blood and part of cytochromes a, b and c which are essential to the production of cellular energy by oxidative phosphorylation (Otegbayo *et al.*, 2017). Copper ranged from 0.25 to 1.76 mg/g in the raw samples and between 0.12-3.68mg/100g for the boiled samples. The RDA of Cu is 0.9 mg/day (USDA 2015), most of these yam varieties are able to meet this RDA when they are consumed above 200g. It is an important cell protective mineral.

5.1.3 Phytochemical content of the yam samples

The phytochemical composition of the samples is similar to that observed by Adegunwa *et al.*, (2011); Ezeocha and Ojimelukwe (2012); Alamu *et al.*, 2014. Values obtained for the phytochemical content of the yam varieties differed slightly. However, the differences in the means of saponin and alkaloid content of the yam varieties were not significant while there were significant differences in the total phenols, phytate and tannin content. Boiling significantly affected the phytochemicals tested except the phenolic component. The phytochemical components reduced upon boiling, this is in agreement with previous studies (Ezeocha and Ojimelukwe, 2012; Adepoju *et al.,* 2017).

The values of phytates in this study were similar to that of Dilworth et al., (2014). While phytate has mineral chelating properties, it is a potent hypoglycaemic compound and is shown to reduce total serum cholesterol as well as the incidences of multiple types of carcinomas (Dilworth *et al*., 2004; Lee *et al.,* 2006; Vucenik and Shamsuddin, 2006). Previous concerns regarding the mineral-chelating properties of IP6 were down played in light of the beneficial properties elucidated by new research. IP6 is recommended as a supplement and is found to be useful in treating some metabolic disorders including diabetes mellitus, hyperlipidaemias and endothelial dysfunction (Nascimiento *et al*., 2006; Lee *et al*., 2007). Some types of saponin are health friendly. They serve as natural antibiotics which help the body to fight infection and microbial invasion (Sodipo *et al.*, 2000). Saponin also inhibit the growth of cancer cells and help lower blood cholesterol hence are useful in the treatment of cardio vascular diseases and other health problems (Lawal *et al.*, 2014). Tannin levels in the raw and boiled yam were 0.41% and 0.38% respectively. The levels in the other diets were significantly ($P<0.05$) reduced ranging from 0.12% to 0.17%. Raw yam had the highest level of tannin. Tannins are water soluble compounds and can therefore be eliminated by cooking. Simple processing such as boiling removes the alkaloids present in most cultivated species of yams (Osagie and Opoku, 1992). The results of the alkaloid levels in raw and boiled yam were lower than the levels reported for five hybrids of *D. alata* by Udensi *et al.,* (2010). Most alkaloids according to Ogbuagu (2008) are toxic to animals and inspite of their medicinal uses can cause gastrointestinal upsets and neurological disorders (Lawal *et al.*, 2014). Phosphorus in phytic acid (Inositol hexaphosphate) is not usually available to man except through the activity of phytate, an enzyme which hydrolysis phytic acid into phosphoric acid and Inositol (Onigbinde, 2005).

5.1.4 Available varieties and factors influencing consumers' preference for different yam varieties in Ekiti State

More than 25 varieties were mentioned in all across the 6 LGAs. A study by Etchiha *et al.*, (2019) also identified an average of 22 cultivars per village in the Republic of Benin. This indeed underscores the fact that there exists a rich diversity in yams. The most preferred yam variety was '*Gambari'*, followed by *'Olo'*. However, it was observed that same varieties bear different names depending on the LGA or even state. For example, the variety *'Olo'* is also called *Iganganran* or *Aganra* or *Igangan* and it belongs to the *Dioscorea cayensis* species. Generally, it was said that '*Gambari*' is also called 'Abuja yam' in many areas of Nigeria, while it is also called '*Amula*' or '*Kishi´* or '*ako isu'* by some non- Ekiti indigenes. *Gbakumo* variety is also called *'Areyingbakumo'* or *'Igbakumo'* in some LGAs. Some yam names were peculiar to some areas, suggesting that they are called other names in some other areas. *Ikerikete* for instance was only named in Ijero LGA, *Ayigbiri* was only named in Gbonyin LGA, *Sogbe* was only named in Ido/Osi and Ijero LGAs while '*Eleyintu*' was only named in Gbonyin LGA. This suggests that the true identity of these varieties cannot be ascertained by their local names alone since they have different names depending on geographical location. Girma *et al.*, (2015) and Loko *et al.*, (2016) also alluded to the fact that "yam species or varietal differentiation is currently exclusively dependent on morphological descriptors which are prone to ambiguous and incorrect classifications, duplications and mix-up".

The choice of the most preferred yam varieties was significantly associated with LGA, age, educational qualification, occupation and household monthly income. Among the age group 35-49, a greater proportion of the respondents were indifferent about the choice of varieties. Also, those who had below N20000 as monthly income seemed to be stronger on their choice of *Gambari* as their most preferred variety. This could be because most famers belong to this group and they are able to identify the varieties more.

The factors influencing varieties or types of yam purchased and /or consumed by the respondents was found to be associated with LGA, occupation, household size and household monthly income. Availability was the strongest factor influencing purchase of yams among other occupational groups except business men/women among whom organoleptic properties was the strongest influencing factor. Availability as a factor influencing choice of yam varieties is greatly influenced by seasonality.

Majority of the respondents (76.4%) could identify different yam varieties and 53.6% had specific varieties they preferred for various yam products. Despite this, 53.3% of the respondents chose yams for consumption based on availability while only 30.6% choose their yams based on varieties best suited for their need in terms of organoleptic properties. This may be attributable to the fact that most (43.8%) purchase their yams from the market while only 40.7% have farms for yams. The most preferred yam varieties consumed during the rainy season were the '*Gambari*' and '*Odo*" varieties while '*Olo*' (yellow yam) and water yam (*ewura*) are mostly consumed during the dry season. Seasonal influence on yam consumption was significantly associated with occupation, household size and household monthly income. The least affected set of people by season are the retirees and the professionals such as doctors, engineers, nurses, lawyers etc. For the retirees, probably because they are elderly and will only consume a small portion of yam whether during its season or during off-season. The professionals are probably not affected because they have the purchasing power to buy yams whenever they want. A similar trend is found in the relationship of seasonal influence and household monthly income. Those earning above N100000 are the least affected by the seasonal influence. This shows that with higher purchasing power, Ekiti people will continue to consume yam and its products as often as possible even during the off-season once it is available.

5.1.5 Contribution of yam and products to nutrient intake of consumers in Ekiti State

More than half of the respondents (60.7%) consumed yam or its products daily, including pounded yam (65.5%) and boiled yam (24.0%) showing that most respondents consume yam on a daily basis while 155 (39.3%) did not consume yam in any form at all. The result of the yam consumption pattern assessment revealed that boiled yam and pounded yam are the most frequently consumed yam products. The mean consumption frequency for boiled yam and pounded yam was 3-4 days a week, this is slightly lower than the reported average yam consumption frequency of 5.7 days a week by Nweke et.al, 2013. Other yam products like roasted yam, yam pottage, fried yam, *amala,* had a much less average consumption frequency of 1-3 times a month while *ojojo* was hardly consumed at all. This reveals that even though it is postulated that Ekiti people consume yams a lot, their frequency of consumption seems lower than the average Nigerian yam consumer. However, the majority of their consumption is in the form of pounded yam and boiled yam.

Pounded yam was the most preferred yam product among majority (65.5%) of the respondents, followed by boiled yam (24.0%) and yam pottage (7%). More than one-third (36.3%) of the respondents reported that they consumed pounded yams on a daily basis and even sometimes twice a day. This further substantiates and strengthens the postulation that Ekiti people indeed like pounded yam and consume it a lot. More than a quarter (29.4%) of the respondents also reported that they consume boiled yams on a daily basis while only 1.9% of them reported that they never consume pounded yam and boiled yams. The least consumed yam product among the repondents was ‘ojojo’ (fried yam balls). The frequency of consumption of pounded yam was significantly associated with gender, age, state of origin, educational qualification, occupation, household size and household monthly income. Generally, the males reported a higher frequency of consumption than the females. Most of the females (29.2%) only consumed pounded yam one or two times a week and a lower proportion of the females (14.0%) compared to the males (24.0%) reported that they take pounded yam on a daily basis. This is probably because the women are the ones who do the cooking and most of the time simply cook for their husbands without they themselves necessarily eating out of it.

Majority (31.8%) of those aged 19-34years reported that they take pounded yam once or twice a week as against 17.7% and 16.7% among those aged 35-49 years and 50-65years respectively. While the largest proportions of the respondents aged 35-49 years (22.3%) and 50-65years (28.8%) reportedly take pounded yam twice a day as against 12.6% among the younger adults aged 19-34years. This is a sign of nutrition transition whereby the younger generation now consume the traditional food less frequently than the older generation as defined by Oyewole and Atinmo (2015) that 'Nutrition transition is a gradual and steady state of moving away from consumption of natural locally available foods Nutrition transition is a gradual and steady state of moving away from consumption of natural locally available foods'.

A higher proportion of the respondents from Ekiti, Ondo, Osun and Kogi reportedly take pounded yam on a daily basis while indigenes of Kwara and other non-South-Western states have a higher proportion of those who consume pounded yam one or two times a week. Farmers had the largest proportion of those who consume pounded yam twice a day.

Daily energy, protein, carbohydrate, iron and magnesium intake were 1985.4±615.3 kcal, 55.1±27.3g, 422.5±117.3g, 15.3±5.8mg, and 251.9±86.0mg, respectively. Yam and its products contributed an average of 31.7%, 5.4%, 27.3% and 31.9% of total energy, protein, iron and magnesium intake, respectively. This energy contribution is much higher than previous reports of 20% energy contribution (Grain de sel, 2010; Adepoju, 2012; Nweke et al., 2013). Yam contributed more than 50% of the daily energy intake of 58 (14.68%) of the total respondents. This means about 15% of the respondents get more than half of their total energy intake from yam products.

5.1.6 Dietary diversity and nutritional status of respondents

More than half (57.6%) of the respondents' DDS fell within medium and almost half (42.0%) had low IDDS. This shows that the micronutrient intake for most of the respondents was inadequate. Dietary diversity is a robust predictor of diet quality and micronutrient adequacy in both women and young children. Beyond food quantities, the importance of nutritional quality and diversity of foods consumed is increasingly recognized as essential for a healthy diet, as malnutrition has persisted in many populations despite sufficient food availability and access (Moursi *et al.*, 2008; Arimond *et al.*, 2010). The quality of diets has been shown to be directly related to dietary diversity and inversely related to malnutrition in terms of faltered growth in children, nutrient deficiencies and the risk of chronic diseases (Azadbakht *et al,* 2006; Styen *et al*, 2006). The DDS for most of the respondents (78.8%) was inadequate irrespective of gender, LGA and other socio economic / demographic factors. This implies that the issue of inadequate dietary diversity cut across all the LGAs assessed and was not affected by the socio demographic or socio economic status of the respondents, which means nutrition education will be needed by the people. This finding further strengthens the assertion by Sanusi (2010) and Sanusi *et al.,* (2014) that 'dietary diversity is poor in Nigeria and efforts to improve nutritional status must address the issue of dietary diversity'. Only marital status was significantly associated with DDS. This could be because more married people tend to eat more at home than outside and there is the tendency of them consuming foods from more food groups than their unmarried counterparts.

Most respondents (99.8%) consume foods from the 'grains, white roots and tubers" group and from the 'meat and poultry' group (80.6%) but ranked low in the consumption of foods from other groups. Majority of the people (78.6%) consumed food from less than five out of the ten food groups in the previous 24hours on the dichotomous scale of the MDDW. This is similar to reports from previous studies (Sanusi *et al.,* 2010; Nupo *et al.,* 2016) who also observed that majority of the studied population consumed foods from starchy grains, roots and tubers groups. This observation could be due to the fact that the majority of foods available in the study population (South west, Nigeria) were either starchy root and tubers or cereals.

Less than half of the respondents (42.8%) were of normal weight, 38.7% of respondents were overweight and 14.0% were obese. The relationship between BMI and DDS shows that a larger proportion of those who fell within the adequate category were also overweight. This may be attributable to the food groups they often eat from. Body Mass Index was significantly associated with age and marital status. A larger proportion of those who fell within the normal weight range were singles and they also belonged to the 19-34 years age group. There was also an interesting relationship between the frequency of consumption of pounded yam and BMI. The respondents who reported to eating pounded yam on a daily basis or even twice a day had the largest proportion of overweight individuals.

5.2 Summary of major findings

5.2.1 Key findings from objective one;

There were significant differences in the means of the proximate content of the varieties except for the fat content.

Boiling significantly affected the proximate content and metabolisable energy causing significant reduction in the carbohydrate and ash content while it significantly increased their mean protein content. Crude fibre values reduced significantly with boiling.

There were significant differences in the means of the mineral content of the varieties.

Boiling significantly reduced the Calcium, Sodium and Phosphorus content but did not affect the Magnesium, Potassium, Zinc, Iron and Copper content.

The inter-varietal differences, though statistically significant cannot be said to be nutritionally significant like some other studies carried out on varieties of potatoes (Ek *et al.,* 2013) and varieties of rice (Kennedy and Burlingame. 2003)

5.2.2 Key findings from objective two;

There were no significant differences in the means of saponin and alkaloid content of the yam varieties while there were significant differences in the total phenols, phytate and tannin content.

Boiling significantly affected the phytochemicals tested (decreased) except the phenolic component.

5.2.3 Key findings from objective three;

About twenty five yam varieties were identified in the state and the seven most commonly-consumed varieties were G*ambari* (29.2%), *Olo* (15.1%), *Aro* (7.8%), *Ileusu* (3.1%), *Dagidagi* (2.4%), *Gbakumo* (2.2%) and *Odo* (2.2%).

Factors influencing preference for yam varieties include availability, organoleptic properties, ability to identify yam varieties, etc. Other factors include; Ability to identify yam varieties, Source of yams for consumption and Seasonality. Availability was a major factor as reported by a majority (53.3%) of the respondents.

Ability to identify yam varieties was significantly associated with LGA, age, state of origin and occupation. The choice of the most preferred yam varieties was significantly associated with LGA, age, Educational qualification, occupation and HH monthly income. Seasonal influence on yam consumption was significantly associated with occupation and HH monthly income.

5.2.4 Key findings from objective four;

More than half of the respondents (60.7%) consumed yam or its products daily, including pounded yam (65.5%) and boiled yam (24.0%) showing that most respondents consume yam on a daily basis while 155 (39.3%) did not consume yam in any form at all.

Daily energy, protein, carbohydrate, iron and magnesium intake were 1985.4±615.3 kcal, 55.1±27.3g, 422.5±117.3g, 15.3±5.8mg, and 251.9±86.0mg, respectively. Yam and its products contributed an average of 31.7%, 5.4%, 27.3% and 31.9% of total energy, protein, iron and magnesium intake, respectively. The energy contribution from this study is higher than previous reports of 20% energy contribution.

Yam contributed more than 50% of the daily energy intake of 58 (14.68%) of the total respondents. This means about 15% of the respondents get more than half of their total energy intake from yam products.

5.2.5 Key findings from objective five;

Mean IDDS was 3.6±0.9, 57.6% fell within medium and 42.0% had low IDDS. The DDS for most of the respondents (78.8%) was inadequate irrespective of gender, LGA and other socio economic / demographic factors. Most respondents (99.8%) consume foods from the ‘grains, white roots and tubers” group and from the ‘meat and poultry’ group (80.6%) but ranked low in the consumption of foods from other groups. Marital status was significantly associated with DDS.

The nutrient intake assessment revealed that on the average, the respondents did not meet the RDA for all nutrients except carbohydrate and protein. Less than half of the respondents (42.8%) were of normal weight while a large proportion of the respondents (39.2%) were overweight and obese (14.0%). BMI was significantly associated with age and marital status.

5.3 Conclusion

Yam varieties had disparate macro- and micronutrient contents statistically, and largely contributed to energy, carbohydrate and magnesium intake. However, the differences are not wide enough to make a huge difference in their contribution to the RDA of most nutrients like what was observed in some other food crops like bananas, potatoes etc. (from literature).

Yam varieties differ not only in nutritional and physical characteristics but even in their names. Some are called different names across different LGAs hence it is a bit difficult to know the true identity of these varieties. Availability and organoleptic properties are strong factors that influences yam consumption hence if ‘nutritionally rich’ varieties of yams with acceptable organoleptic qualities are made available, Ekiti people will still consume it frequently.

The younger adults (19-35 years) consume yams less frequently than the older adults hence there may be a need to investigate their dietary pattern. The DDS of many of the respondents (42%) was low with majority of the respondents consuming foods majorly from two food groups- ‘Starchy staples’ and ‘meat and fish’ group followed by the ‘legumes’ and ‘dark green leafy vegetables’ groups. Hence the diets of the respondents were not diverse enough.

5.4 Contributions to knowledge

This study has been able to find that:

- The nutritional differences among the yam varieties though statistically significant, are not wide enough to make a huge difference in their contribution to the RDA of most nutrients
- Yam consumption is high in Ekiti with more than half (60.7%) of the respondents consuming yam and its products daily.
- Yam contributes an average of 31.7% of the total daily energy intake of Ekiti people.
- The energy contribution from this study is higher than previous reports of 20% energy contribution.

- The younger adults (19-35 years) consume yam less frequently than the older adults.
- The dietary diversity score of many of the respondents (42%) was low with majority of the respondents consuming foods majorly from two food groups- ‘Starchy staples’ and ‘meat and fish’ group followed by the ‘legumes’ and ‘dark green leafy vegetables’ groups.
- Despite the low DDS reported in Ekiti State, many of them are overweight and obese.

5.5 Public health implications

There are indications for an increase in the prevalence of double burden of malnutrition since many of the respondents did not meet the RDA for all nutrients except carbohydrate and protein. DDS (which is a proxy tool for micronutrient adequacy) also indicates that the micronutrient consumption in Ekiti is low. These have the potential of increasing the prevalence of diet related chronic diseases and affecting the overall health burden among adults in Ekiti State, Nigeria.

5.6 Recommendations

Yam (regardless of the variety) majorly largely contributes to energy, carbohydrate and magnesium intake hence there is a need to accompany yam consumption with soups that are very rich in other nutrients especially micronutrients.

Since the inter varietal differences are not wide enough to make a huge difference in their contribution to the RDA of most nutrients, consumption of foods from diverse food groups should be strongly advocated among Ekiti people.

DDS being a proxy for micronutrient adequacy indicates that the micronutrient consumption in Ekiti is low. Hence Nutrition education should be frequently done to emphasise the need for diverse diets in order to forestall a double burden of malnutrition since many of the respondents were overweight and obese despite not consuming an adequately diverse diet.

REFERENCES

A.O.A.C. 2010. Official Methods of Analysis, 18th edition *Association of Official Analytical Chemists*, Washington, DC.

Abioye, V.F., Ogunlakin, G.O., Babarinde, G.O. and Adeoti, B. 2008. Effect of drying temperatures and yam slices thickness on the quality attributes of yam flour. *Nigerian Food Journal. 26 (2):* 270-271.

Adegunwa M.O., Alamu E.O. and Omitogun L.A. 2011 Effect of processing on nutritional contents of yam and cocoyam tubers. *Journal of Applied Biosciences* 46: 3086– 3092

Adepoju O.T. and Etukumoh A.U. 2014. Nutrient composition and suitability of four commonly used local complementary foods in Akwa Ibom State, Nigeria. *African journal of Food, Agriculture Nutrition and Development* 14 (7), 9544 – 9560.

Adepoju O.T., Boyejo O. and Adeniji P.O. 2017. Effects of processing methods on nutrient and antinutrients composition of yellow yam *(Dioscorea cayenensis*) products. *Food chemistry* 238 ; 428-431

Adepoju, O. T., Adekola, Y. G., Mustapha, S. O. and Ogunola, S. I. 2010. Effect of processing methods on nutrient retention and contribution of local diets from cassava (Manihot spp) to nutrient intake of Nigerian consumers. *African Journal of Food, Agriculture Nutrition & Development, (AJFAND) 10(2):* 2099 – 2111.

Adepoju, O.T. 2012. Effects of processing methods on nutrient retention and contribution of white yam (*Dioscorea rotundata*) products to nutritional intake of Nigerians, *African Journal of Food Science Vol. 6(6),* 163-167

Afoakwa E.O. and Sefa-Dedeh S. 2001. Chemical Composition and Quality Changes associated with trifoliate yam Dioscorea dumetorum tubers after harvest. *Food Chemistry*, [75] 85 – 91.

Akin-Idowu P.E, Odunola O. A., Asiedu R., Maziya-Dixon B., and Uwaifo A.O.. 2009. “Variation in nutrient and antinutrient contents of tubers from yellow yam (*Dioscorea cayenensis*) genotypes grown at two locations,” *Journal of Food, Agriculture and Environment,* vol. 6, no. 3-4, pp. 95–100

Alamu E.O., Maziya-Dixon B., Okonkwo C.C. and Asiedu R.. 2014. Physicochemical and bioactive properties of selected white yam (*Dioscorea rotundata*) varieties adapted to riverine areas of Nigeria. *African Journal of Food Science* 8.7:402–9.

Allinor I. J. and Akalezi C.O., 2010. Proximate and mineral compositions of Dioscorea rotundata (white yam) and Colocasia esculenta (white cocoyam) *Pakistan Journal of Nutrition,* 9[10]: 998 – 1001.

Amani N.G, Buleon A, Kamenan A, Colonna P. 2004. Variability in starch and physico-chemical and functional properties of yam (*Dioscorea* spp.) cultivated in Ivory Coast. *Journal of Food and Agric Science* 84:2085–2096

Andre CM, Oufir M, Guignard C, Hoffmann L, Hausman JF, Evers D, Larondelle Y (2007) Antioxidant profiling of native Andean potato tubers (Solanum tuberosum L.) reveals cultivars with high levels of β-carotene, alpha-tocopherol, chlorogenic acid, and petanin. *Agriculture and Food Chemistry* 55:10839–10849

Aniszewski,T. 2015. Alkaloids: Chemistry, Biology, Ecology, and Applications: Second Edition

Argyri K., Athanasatou A., Bouga M. and Kapsokefalou M. 2016. The potential of an in vitro digestion method for predicting glycemic response of foods and meals. *Nutrients* 8.209: 1-12

Arimond M., Ruel M.T. 2004. Dietary Diversity is Associated with Child Nutritional Status: Evidence from 11 Demographic and Health Surveys. *Journal of Nutrition 134: 2579-85.*

Arimond M., Wiesmann D., Becquey E., Carriquiry A., Daniels M.C., Deitchler M., Fanou-Fogny N., Joseph M.L., Kennedy G., Martin-Prevel Y., Torheim L.E.

2010. Simple Food Group Diversity Indicators Predict Micronutrient Adequacy of Women's Diets in 5 Diverse, Resource-Poor Settings. *The Journal of Nutrition* 140: 2059S-2069S. DOI: 10.3945/ jn.110.123414.

Arvidsson-Lenner, R., Nils-Georg, A., Axelsen, M., Bryngelsson, S., Haapa, E., Jarvi, A., Karlstrom, B., Raben, A., Sohlström, A., Thorsdottir I., and Vessby B., 2004. Glyceamic index: relevance for health, dietary recommendations and food labelling. *Journal of Nutrition*. 48: 84-94

Asp N.G., Van Amelsvoort J.M.M., Hautvast J.G. 1996. Nutritional implications of resistant starch. *Nutrition research*, 9, 1-3

Assa, Cyrile D, Hubert K Konan, Martin K Djè, and Lucien P Kouamé. 2014. "Effect of Boiling Time on Some Biochemical Parameters of Yam Specie (*Dioscorea* Alata Variety " Bètè- Bètè ″) Tubers." *International Journal of Advanced Research 2(11): 40–50.*

Atkinson F.S., Foster-Powell K. & Brand-Miller J.C. 2008 International tables of glycaemic index and glycaemic load values: *Diabetes Care 31, 2281–2283*.

Atwater, W.O. and Woods, C.D. 1896. The Chemical Composition of American Food Materials. U.S. Department of Agriculture. Office of Experiment Station. Bulletin No. 28. Available at http://www.nal.usda.gov/fnic/foodcomp/Data/Classics/es028.pdf.

Awoniyi O.A and Omonona B.T. 2006 Production Efficiency in Yam Based Enterprises in Ekiti State, *Nigeria Journal of Central European Agriculture* Vol 7 No 4

Ayanwuyi, E., Akinboye, A. O. And Oyetoro, J. O. 2011. Yam production in Orire local government area of Oyo State, Nigeria: farmers perceived constraints. *World Journal of Young Researchers 1(2): 16–19*.

Azadbakht L., Mirmiran P.,Esmaillzadeh A., Azizi F. 2006. Dietary diversity score and cardiovascular risk factors in Tehranian adults - *Public health nutrition*, 2006

Baah, F. D., 2009. Characterization of Water Yam (*Dioscorea alata*) for Existing and Potential Food Products. A Thesis Submitted to the Department of Food

Science and Technology, Kwame Nkrumah University of Science and Technology in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy,. Pp. 20.

Bamigboye, A. Y. and Adepoju, O. T. 2015. Effects of processing methods on nutritive values of *Ekuru* from two cultivars of beans *(Vigna unguiculata* and *Vigna angustifoliata). African Journal of Biotechnology* 14.21: 1790 – 1795.

Barakat M.Z., Shahab S.K., Darwin N, Zahemy E.I. 1993. Determination of ascorbic acid from plants. *Analytical Biochemistry*. 53: 225-245.

Bassey E.E. 2017. Constraints and Prospects of Yam Production. *Nigeria European Journal of Physical and Agricultural Sciences* Vol. 5 No. 1,

Benzie, I.F., 2003. Evolution of dietary antioxidants. *Comparative Biochemistry and Physiology part A: Molecular and Integrative Physiology*, **136**(1):113-126. [doi:10. 1016/S1095-6433(02)00368-9]

Bhandari M. R., Kasai T., Kawabata J. 2003. Nutritional evaluation of wild yam (*Dioscorea* spp.) tubers of Nepal. *Food Chemistry*.;82 (4):619–623.

Bhandari, M. R., and Kawabata, J. 2005. Bitterness and toxicity in wild yam (*Dioscorea* spp.) tubers of Nepal. *Plant foods for human nutrition (Dordrecht, Netherlands)*, 60(3), 129–35.

Bhargava D, Shivapuri JN, Kar S, Pandit BR, Sidhiqie A, Upadhyay A, Thakur S, Mondal KC. 2012. Evaluation of antigonorrhoeal activity of saponins extract of *Sapindus mukorossi* Gaertn. *Research Journal of Pharm Biology ans Chemical Science*. 2012;3 (2):459-470.

Biesalski H., Dragsted L.O., Emadfa I., Grossklaus R., Mudler M., Shrenk P., Walter P. and Weber P. 2009. Bioactive compounds: Definition and assessment of activity. *Nutrition 1-4*

Bill & Melinda Gates Foundation (BMGF). 2014. Yam Improvement for Processing (Yip) Nigeria: Developed by Sahel Capital Partners and Advisory Limited.

Blasbalg, T. L., Wispelwey, B., and Deckelbaum, R. J. (2011).Econutrition and utilization of food-based approaches for nutritional health. *Food and Nutrition Bulletin, 32(1 SUPPL.) S4-S13*

Bohn, T., Davidsson, L., Walczyk, T., Hurrell, R.F., 2004. Phytic acid added to white-wheat bread inhibits fractional apparent magnesium absorption in humans. *American Journal of Clinical Nutrition*, **79**(3):418-423.

Booysen, L. 2010. Comparison of the eating quality of selected potato cultivars from two production regions in South Africa and a proposed classification system for the consumer. Master's Thesis. Department of Consumer Sciences. University of Pretoria. South Africa.

Burlingame B (2014) Grand challenges in nutrition and environmental sustainability. Front. Nutr. 1:3. doi: 10.3389/fnut.2014.00003 Available at: http://journal.frontiersin.org/Journal/10.3389/fnut.

Burlingame, B. and Toledo, A. (Eds) 2006. Special Issue: Biodiversity and Nutrition. *Journal of Food Composition and Analysis* 19: 6–7, 477–770.

Burlingame, B., Charrondiere, U.R. and Mouille, B. 2009. Food composition is fundamental to the cross-cutting initiative on biodiversity for food and nutrition. *Journal of Food Composition and Analysis* 22, 5: 361–365.

CBD-Convention on Biological Diversity Secretariat. 2016. Article 2: Use of Terms. https://www.cbd.int/convention/articles/default.shtml?a=cbd-02

Chan Y.-C., Hsu C.-K., Wang M.-F., Su T.-Y. 2004. A diet containing yam reduces the cognitive deterioration and brain lipid peroxidation in mice with senescence accelerated. *International Journal of Food Science and Technology*. 39.1: 99–107.

Chandrasekara A. 2018. Springer International Publishing J.-M. Mérillon, K.G. Ramawat (eds.), *Bioactive Molecules* in Food, Reference Series in Phytochemistry, https://doi.org/10.1007/978-3-319-54528-8_37-1

Chandrasekara A. and Kumar T.J., 2016. Roots and tuber crops as functional foods: A review on phytochemical constituents and their potential health benefits. *International Journal of Food Science*. .

Chen H.L., C.H.Wang, C.T.Chang, and T.C. Wang, 2003. Effect of Taiwanese Yam (*Dioscorea* japonica Thunb. Var pseudojaponica Yamamoto). on upper Gut

Function and Lipid Metabolism in Balbic Mice,Basic Nutritional Investigation *Nutrition*, 19, 646-651.

Chung K.T., Wong T.Y., Cheng-I W., Yao-Wen H. & Yuan L. 1998: Tannins and Human Health: *A Review, Critical Reviews in Food Science and Nutrition*, 38:6, 421-464

Corbiere C., Liagre B., and Bianchi A. 2003 Different Contribution of Apoptosis to the Antiproliferative Effects of Diosgenin and other Plant Steroids, Hecogenin and Tigogenin, on Human 1547 Osteosarcoma Cells, *International Journal of Oncology*., 22, 899-905.

Crozier A, Jaganath I.B. and Clifford M.N.2006 Phenols, Polyphenols and Tannins: An Overview in Plant secondary metabolites 1-24

De Clerck, F., Fanzo, J., Palm, C. and Remans, R. 2011 Ecological approaches to human nutrition. *Food and Nutrition Bulletin 32: S41-S50.*

De la Rosa L.A, Moreno-Escamilla J.O and Alvarez-Parrilla E. 2019 In Postharvest Physiology and Biochemistry of Fruits and Vegetables; Yahia E.M. Ed: Elsevier:

Dilek L.A., Turner N.D., McDonough C.M. and Rooney L.W. 2012 Effects of Sorghum [Sorghum bicolor (L.) Moench] Crude Extracts on Starch Digestibility, Estimated Glycemic Index (EGI), and Resistant Starch (RS) Contents of Porridges. *Molecules*, 17, 11124-11138

Dilworth, L., Brown, K., Wright, R., Oliver, M., Hall, S., & Asemota, H. 2012: Antioxidants , minerals and bioactive compounds in tropical staples. *African Journal of Food Science and Technology*, *3*(May), 90–98. Retrieved from http://www.interesjournals.org/AJFST

Diouf, J. 2005. ―Towards the World Food Summit and Millennium Development Goal Targets: Food Comes First‖ Foreword The State of Food Insecurity in the World 2005, FAO. pp. 4-5

Dolan L.C., Matulka R.A., Burdock G.A. 2010 Naturally Occurring Food Toxins. Toxins 2: 2289-332.

Dona A.C., Pages, G., Gilbert, R.G., Kuchel, P.W. 2010. Digestion of starch: In vivo and in vitro kinetic models used to characterise oligosaccharide or glucose release. *Carbohydrate Polymers. 80, 599-617*

Dorosh. P, 2000. The Economics of Root and Tuber crops in Africa. Resource and crop management program Research monograph No.ll I.I.T.A, Ibadan Nigeria. PP 31. 48

Dufie F., Manu W., Oduro I., Otoo Ellis W., Asiedu R., and Maziya-Dixon B. 2013. "Potential Health Benefits of Water Yam (*Dioscorea alata*)." *Food & function* 4(10):1496–1501.

Durazzo A., Turfani V., Azzini E.,Maiani G.,and Carcea M. 2012. Phenols, lignans and antioxidant properties of legume and sweet chestnut flours. *Food Chemistry 140(4): 666-671*

Durroux-Malpartida V. 2013 http://www.rtb.cgiar.org/yams-raising-the-profile-of-the-king-of-crops. Accessed January 18, 2015 vol.50.Rome, Italy.

Eckel R.H., Grundy S.M. and Zimmet P.Z. 2005. The metabolic syndrome. *Lancet 365, 1415–1428. 32.*

Egbe TA, Treche S 1984. Variability in the Chemical Composition of Yams grown in Cameroon. In: Terry ER, Doku EV, Arene OB, Mahungu NM (eds) Tropical root crops: Production and uses in Africa. IDRC, Ottawa, Canada, pp 153–157

Ek K.L., Wang S., Copeland L., and Brand-Miller J.C. 2013 Discovery of a low-glycaemic index potato and relationship with starch digestion in vitro.

Eka O.U. 1985, The chemical composition of yam tubers. In: G.Osuji[ed.]Advances in yam research: The biochemistry and technology of the yam tubers. Enugu: Biochemical Society of Nigeria, 51 – 74.

Eka, O. U. 1998. Roots and Tuber Crops. In: "*Nutritional Quality of Plant Foods.*" Osagie. A., and Eka, O. A. (Eds.) Postharvest research. Unit Publishers, University of Benin, pp 1-31.

Englberger, L., Aalbersberg, W., Fitzgerald, M.H., Marks, G.C., and Chand, K. 2003b. ‘Provitamin A carotenoid content of different cultivars of edible pandanus fruit tectorius’, *Journal of Food Composition and Analysis, 16. 2: 237–247.*

Englberger, L., Aalbersberg, W., Ravi, P., Bonnin, E., Marks, G.C., Fitzgerald, M.H., and Elymore, J. 2003a ‘Further analyses on Micronesian banana, taro, breadfruit and other foods for provitamin A carotenoids and minerals’, *Journal of Food Composition and Analysis, vol 16, no 2, pp.219–236.*

Englberger, L., Schierle, J., Aalbersberg, W., Hofmann, P., Humphries, J., Huang, A., Lorens, A., Levendusky, A., Daniells, J., Marks, G.C., and Fitzgerald, M.H. 2006. ‘Carotenoid and vitamin content of Karat and other Micronesian banana cultivars’, *International Journal of Food Science and Nutrition 57:399–418.*

Englberger, L., Schierle, J., Hoffman, P., Lorens, A., Albert, K., Levendusky, A., Paul, Y., Lickaneth, E., Elymore, A., Maddison, M., deBrum, I., Nemra, J., Alfred, J., Vander Velde, N., and Kraemer, K. 2009 ‘Carotenoid and vitamin content of Micronesian atoll foods: pandanus (Pandanus tectorius) and garlic pear (Crataeva speciosa) fruit’. *Journal of Food Composition and Analysis 22.1:.1–8.*

Englberger, L., Schierle, J., Kraemer, K., Aalbersberg, W., Dolodolotawake, U., Humphries, J., Graham, R., Reid, A.P., Lorens, A., Albert, K., Levendusky, A., Johnson, E., Paul, Y., and Sengebau, F. 2008 ‘Carotenoid and mineral content of Micronesian giant swamp taro (Cyrtosperma) cultivars’, *Journal of Food Composition and Analysis 21:93–106.*

Englberger, L., Schierle, J., Marks, G.C., and Fitzgerald, M.H. 2003c ‘Micronesian banana, taro, and other foods: newly recognized sources of provitamin A and other carotenoids’, *Journal of Food Composition and Analysis 16.1:.3–19.*

Englyst, K.N., Englyst, H.N., Hudson, G.J., Cole, T.J., and Cummings, J.H., 1999. Rapidly available glucose in foods: an in vitro measurement that reflects the glycaemic response. *American Journal of Clinical Nutrition 69: 448–454.*

Etchiha A. S. , Affokpon A. , Loko Y L., Agbangla C. and Dansi A. 2019. Yam (Dioscorea rotundata Poir and D. cayenensis Lam complex) in the Traditional Agriculture of Benin: Present-Day Cultivar Diversity and Farmers' Perception on their tolerance to Tuber Dry Rot caused by the Nematode Scutellonema bradys. *International Journal of Current Microbiology and Applied Sciences* 8(2): 1119-1138

Etejere, E. O. and Bhat, R. B. 1986. Traditional and Modern Storage Methods of Underground Root and Stem Crops in Nigeria. *Turrialba, 36(1), 33–37.*

Ezeocha, V C, and P C Ojimelukwe. 2012. "The Impact of Cooking on the Proximate Composition and Anti-Nutritional Factors of Water Yam (*Dioscorea* Alata)." 3(December): 172–76.

Faizal A, Geelen D.2013 Saponins and their role in biological processes in plants. Phytochemical Review; 12:877–893.

Fanzo J, Hunter D, Borelli T and Mattei F (eds). 2013. Diversifying Food and Diets: Using Agricultural Biodiversity to Improve Nutrition and Health. Routledge

FAO and FHI360. 2016 Minimum Dietary Diversity for Women: A Guide for Measurement. Rome: FAO. Rome, Italy. http://www.fao.org/3/ai5486e.pdf

FAO, IFAD, UNICEF, WFP and WHO. 2018. The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition. Rome, FAO.

FAO, IFAD, UNICEF, WFP and WHO. 2019. The State of Food Security and Nutrition in the World 2019. Safeguarding against economic slowdowns and downturns. Rome, FAO.

FAO. 2010 *Guidelines for Measuring Household and Individual Dietary Diversity*. Food and Agricultural Organization. Rome, Italy.http://www.fao.org/fileadmin/user_upload/wa_workshop/docs/FAO-guidelines-dietarydiversity2011.pdf.

FAO. 2018. Dietary Assessment: A resource guide to method selection and application in low resource settings. Rome 51-58

FAO/FANTA/IRD.2014 Meeting to Reach Consensus on a Global Dietary Diversity Indicator for Women, Washington DC. http:// www.fantaproject.org/sites/default/files/ resources/WDDP-Meeting-Report-Oct2014. pdf.

FAO/INFOODS 2013. Food Composition Database for Biodiversity (BioFoodComp 2.1). Retrieved February 2017 from http://www.fao.org/docrep/019/i3560e/i3560e.pdf

FAO/INFOODS 2013a. FAO/INFOODS Report on the Nutrition Indicator for Biodiversity – Global Progress Report. FAO: Rome. Retrieved February 2017 from http://www.fao. org/docrep/019/i3559e/i3559e.pdf

FAOSTAT. 2014. Food and Agricultural Commodities Production, available at: http://faostat.fao.org/site/339/default.aspx

FAOSTAT. 2015. Food and Agricultural Commodities Production, available at: http://faostat.fao.org/site/339/default.aspx [Accessed: 10 December 2018].

Farombi E.O., Britton G.,Emerole G.O. 2000. Evaluation of antioxidant activity and partial characterization of extracts from browned yam flour diet. *Food Research International* 33; 493-499

Farquer J.N., 1996. Plant sterols. Their biological effects in humans. Handbook of lipids in human nutrition. BOCA Raton FL CRC Press, pp. 101-105.

Fasaanu O.P, Oziegbe M. and Oyedapo O.O. 2013. Investigations of activities of alkaloid of trifoliate yam (*Dioscorea dumetorum, (kunth) pax*. *Ife Journal of Science* 15. 2

Fasanmade, A.A., and Anyakudo, M.M.C., 2007. Glycemic Indices of Selected Nigerian Flour meal Products in Male type 2 Diabetic subjects. *Diabetologia Croatica*. 36.2: 33 -38.

Feed the Future 2016: Early Generation Seed Systems Study -Building Capacity for African Agricultural Transformation Project (Africa Lead II) for the United States Agency for International Development

Fernandes G., Velangi, A., and Wolever, T.M.S., 2005. Glycaemic index of potatoes commonly consumed in North America. *Journal of American Dietetics Association 105, 557–562. 21.*

Food and Agriculture Organization of the United Nations, 2008. International year of the potato. http://www. potato2008.org/en/index.html (accessed March 2016).

Food and Agriculture Organization; World Health Organization. Carbohydrates in Human Nutrition; FAO: Rome, Italy, 1998; Volume 66, p. 1.

Gharib, A.G., Mohseni, S.G., Mohajer, M., Gharib, M., 2006. Bioavailability of essential trace elements in the presence of phytate, fiber and calcium. *Journal of Radioanalytical and Nuclear Chemistry*, 270 (1):209-215. [doi:10.1007/s10967-006-0330-3]

Gibson, N. 2006. Development of objective methods for the classification of potatoes. Honours thesis. BSc Nutrition and Food Sciences. Department of Food Science. University of Pretoria.

Gil A., Martinez de Victoria E. and Olza J. 2015. Indicators for the evaluation of diet quality. Nutrition Hospital

Girma G., Gedil M. and Spillane C. 2015. Morphological, SSR and ploidy analysis of water yam (*Dioscorea* alata L.) accessions for utilization of aerial tubers as planting materials

Glahn, R.P., Wortley, G.M., South, P.K., Miller, D.D., 2002. Inhibition of iron uptake by phytic acid, tannic acid, and ZnCl2: Studies using an in vitro digestion/Caco-2 cell model. Journal of Agricultural and Food Chemistry, 50(2):390-395. *doi:10.1021/jf011046u]*

Grain de sel 2010. Staple Crop Production and Consumption: Nigeria on the Way to Food Self-Sufficiency. *Inter-réseaux special report 51; 11-13*

Granfeldt Y, Bjorck, I, Drews, A., Tovar, J. 1992. An in vitro procedure based on chewing to predict metabolic response to starch in cereal and legume products. *European Journal of Clinical Nutrition* 46, 649–660.

Guerrero M.L. and Perez-Rodriguez F. 2017. Diet Quality indices for Nutrition Assessment: Types and Applications. In: Functional Food- Improve Health through Adequate Food. Pp 283-308

Ha M.A., Jarvis M.C. and Man J.L., 2000. A definition for Dietary Fibre. *European Journal of Clinical Nutrition.,* 54, 861-864.

Hamadina E.I., Craufurd P.Q., Asiedu R. 2009. Flowering intensity in white yam (Dioscorea rotundata). *The Journal of Agricultural Science,* 147 (04): 469-477.

Hamadina, E. I. 2011. The control of yam tuber dormancy: a framework for manipulation (pp. 1–60). Ibadan, Nigeria: International Institute of Tropical Agriculture.

Harborne J.B. 1973. Phytochemical methods. Chapman and Hall. London, p. 113

Hasjim J., Lavau G.C., Gidley M.J. and Gilbert R.G. 2010. In vivo and invitro starch digestion: are current in vitro techniques adequate? *Biomacromolecules, 11,* 3600-3608

Hoddinott J, Yohannes Y 2002. Dietary diversity as a food security indicator. FANTA, Washington DC, United States 1-50.

Hou W.C., Lee M.H., Chen H.J., Liang W.L.,Han C.H., LiuY.W. and LinY.H. 2001. Antioxidant Activities of Dioscorin, The Storage Protein of Yam (*Dioscorea* batatasDecne.) Tuber. *Journal of Agriculture and Food Chemstry.,* 49, 4956- 4960.

Huang, L. Tanudjaja, D. Lum.1999 *Journal of Food Composition and Analysis*, Vol. 12, No. 2, pp. 147–151

Ihediohanma, N.C., Onuegbu, N.C., Peter-Ikechukwu, A.I. and Ojimba, N.C. 2012. A comparative study and determination of glycemic indices of three yam cultivars (*Dioscorea rotundata, Dioscorea alata and Dioscorea domentorum) Pakistan Journal of Nutrition, 11: 547-552*

IITA (2013). Healthy yam seed production. IITA Publications.

Ike, P. C. and Inoni, O. E. 2006. Determinants of yam production and economic efficiency among small-holder farmers in South-eastern Nigeria. *Journal of Central European Agriculture*, 7(2): 337–342

International Food Policy Research Institute (IFPRI) 2019. *2019 Global Food Policy Report.* Washington, DC: International Food Policy Research Institute. https://doi.org/10.2499/9780896293502

Institute of Medicine. 2006. Dietary Reference Intakes: The Essential Guide to Nutrient Requirements. Washington, DC: The National Academies Press. https://doi.org/10.17226/11537.

Izutsu T, Wani K 1985. Food texture and taste: a review. *Journal of Texture Studies* 16:1–28

Jaacks, L. M., Slining M.M. and Popkin B. M. 2015. "Recent Underweight and Overweight Trends by Rural-Urban Residence among Women in Low- and Middle-Income Countries." *Journal of Nutrition* 145 (2): 352–357.

Jayawardena, R., Byrnel, N.M., Soares, M.J., Katulanda, P., Yadav, B. and Phills, A. 2013. High dietary diversity is associated with obesity in Sri Lankan adults: an evaluation of three dietary scores. *BMC Public Health* , 13:314

Jenab, M., and Thompson, L.U., 2002. Role of phytic acid in cancer and other diseases. In: Reddy, N.R., Sathe, S.K. (Eds.), Food Phytates. CRC Press, Boca Raton, FL, pp. 225–248. *Journal of Clinical Nutrition* 8, 64-74

Jenkins, D.J.; Wolever, T.M.; Taylor, R.H.; Barker, H.; Fielden, H.; Baldwin, J.M.; Bowling, A.C.; Newman, H.C.;Jenkins, A.L.; Goff, D.V. 2002 Glycemic index of foods: A physiological basis for carbohydrate exchange. *American Journal of Clinical Nutrition., 34, 362–366.*

Jimoh, A. K., Adediran, O. S., Adebisi S. A., Biliaminu S. A. and Okesina A. B. 2008. Glycemic Response to different preparations of yam in diabetic and Non-diabetic Nigerian. *Diabetologia Croatica 37(3): 67-71*

Kennedy GL, Pedro MR, Seghieri C, Nantel G, Brouwer I 2007. Dietary diversity score is a useful indicator of micronutrient intake in non-breast-feeding Filipino children. *Journal of Nutrition* 137: 472-7.

Kennedy, G.; Burlingame, B. 2003. Analysis of food composition data on rice from a plant genetic resources perspective. *Food Chemistry 80:589–596*

Khoury, C.K., Bjorkman, A.D., Dempewolf, H., Ramirez-Villegas, J., Guarino, L., Jarvis, A., Rieseberg, L.H., Struik, P.C. 2014 Increasing homogeneity in global food supplies and the implications for food security. Proc. Natl. Acad. Sci. USA 111, 4001–4006

Kintner, P. K. and VanBuen, J. K. 1982. 'Carbohydrate Interference and its correction in Pectin analysis using the m-Hydroxydiphenyl method'. *Journal of Food Science* **47**: 756-764.

Kuhnlein, H., Erasmus, B., Spigelski, D. 2009. Indigenous Peoples' Food Systems: the many dimensions of culture, diversity and environment for nutrition and health. FAO and CINE, Rome.

Kuhnlein, H., Erasmus, B., Spigelski, D., Burlingame, B. 2013. Indigenous Peoples Food and Wellbeing: Interventions and Policies for Healthy Communities. FAO and CINE, Rome.

Lawal, B., Ossai, P. C., Shittu, O. K. and Abubakar, A. N. 2014. Evaluation of phytochemicals, proximate, minerals and anti-nutritional compositions of yam peel, maize chaff and bean coat. *International Journal of Applied Biological Research 6(2): 21 – 37*

Lebot V., Malapa. R. and Jung M. 2013. Use of NIRS for the rapid prediction of total N, minerals, sugars and starch in tropical root and tuber crops. New Zealand *Journal of Crop and Horticultural Science. Vol 41(3); 144-153*

Lebot, V. and Malapa, R. 2012. Application of near infrared reflectance spectroscopy to the evaluation of yam (*Dioscorea alata*) germplasm and breeding lines. *Journal of the science of Food and Agriculture. 93.7: 1788-97*

Lister E and Wilson P. 2001 Measurement of total Phenolic sans ABTS Assay for Antioxidant Activity. Crop Research Institute , New Zealand

Liu Y.W., Shang H.F., Wang C.K., Hsu F.L., Hou W.C., 2007. Immunomodulatory activity of dioscorin, the storage protein of yam (*Dioscorea* alata cv. Tainung No 1) tuber. *Food Chemistry and Toxicology* 45:2312–2318

Loewus, F.A., Murthy, P.P.N., 2000. Myo-inositol metabolism in plants. Plant Science, 150(1):1-19. *[doi:10.1016/S0 168-9452(99)00150-8]*

Loko Y.L., Adjatin A., Dansi A., Vodouhe R., Sanni A., 2016. Participatory evaluation of Guinea yam (*Dioscorea cayenensis* Lam.–*D. rotundata* Poir. complex) landraces from Benin and agromorphological characterization of cultivars tolerant to drought, high soil moisture and chips storage insects. *Genetic Resources and Crop Evolution 62:1181–1192.*

Lott, J.N.A., Ockenden, I., Raboy, V., Batten, G.D., 2000. Phytic acid and phosphorus in crop seeds and fruits: A global estimate. Seed Science Research, 10(1):11-33.

Lott, J.N.A., Ockenden, I., Raboy, V., Batten, G.D., 2001. Phytic acid and phosphorus in crop seeds and fruits: A global estimate (Errata). Seed Science Research, 11(2):181.

Ludwig, D.D.S., 2002 The glycemic index – physiological mechanisms relating to obesity, diabetes, and cardiovascular disease. *JAMA 287, 2414–2423.*

Lutaladio, N., Burlingame, B., Crews, J. 2010. Horticulture, biodiversity and nutrition. *Journal of Food Composition and Analysis 23, 6:481–485.*

Markkar, A.O.S. and Goodchild, A.V., 1996. Quantification of tannins. A laboratory manual. International Centre for Agriculture Research in the dry areas (ICARDA), Aleppo, Syria, pp: 25.

Martin-Prével Y., Allemand P., Wiesmann D.,Arimond M., Ballard T., Deitchler M., Dop M.C., Kennedy G., Lee W.T.K., 2015. FAO, IRD. *Moving Forward on Choosing a Standard Operational Indicator of Women's Dietary Diversity*. FAO, Food and Agriculture Organization. Rome, Italy Rome, Italy. http://www.fao.org/documents/card/en/ c/678ab9d4-e7a8-4388-9f9f-1c709ea47752/

Martin-Prevel Y., Arimond M., Allemand P.,Wiesmann D., Ballard T.J., Deitchler M., Dop MC., Kennedy G., Lartey A., Lee WTK, Moursi M. 2017 Development of a dichotomous indicator for population-level assessment of dietary diversity of women of reproductive age. *Current Developments in Nutrition 1:e001701*.

Masset, E., L. Haddad, A. Cornelius, and J. Isaza-Castro. (2011). "Effectiveness of Agricultural Interventions That Aim to Improve Nutritional Status of Children: A Systematic Review." *British Medical Journal 344: d8222*.

Maswada H.F. 2013. Assessment of Total Antioxidant Capacity and Antiradical Scavenging Activity of three Egyptian wild plants. *Journal of Medical Sciences 13: 546-554*

McAnuff, M.A., Wayne W.H., Omoruyi F.O., Jacobs H., Morrison E.Y. and Asemota H.N. 2005. Hypoglycemic effect of steroidal sapogenins isolated from Jamaican bitter yam, *Dioscorea polygonoides*. *Food and Chemical Toxicology*., 43: 1667-1672

McCance, R.A., Widdowson, E.M., 1949. Phytic acid. *British Journal of Nutrition*, **2**(4):401-403. [doi:10.1079/BJN19480069]

Migap, J. P. And Audu, F. 2012. Empirical study on yam cultivation and economic development of Taraba State: Case study of Wukari local government area. *Journal of Business and Organizational Development 4: 32–52.*

Mignouna, D.B., Abdoulaye, T., Alene, A., Akinola, A.A., and Maroya. 2014. Baseline Protocols. The Case of Yam Improvement for Income and Food Security in West Africa (YIIFSWA) Project. *YIIFSWA Working Paper*

Series No. 4. Yam Improvement for Income and Food Security in West Africa, International Institute of Tropical Agriculture, Ibadan, Nigeria. 80 pp.

Mignouna, D.B., Akinola A.A., Suleman I., and Nweke F. 2014. Yam: A Cash crop in West Africa. *YIIFSWA Working Paper Series No. 3. Yam Improvement for Income and Food Security in West Africa, International Institute of Tropical Agriculture, Ibadan, Nigeria. 44 pp.*

Mignouna, H.O, Abana, M.M and Asiegbu, R 2004. Harnessing Modern Biotechnology for Tropical Tuber crops improvement. G.U. publication, Abuja, Nigeria

Moghimipour E. and Handali S. 2015. Saponin: Properties, Methods of Evaluation and Applications. *Annual Research & Review in Biology*, 5(3): 207-220

Moursi M. M., Arimond M., Dewey K.G., Treche S., Ruel M. T., et al. (2008) Dietary diversity is a good predictor of the micronutrient density of the diet of 6- to 23-month-old children in Madagascar. *Journal of Nutrition* 138: 12, 2448-2453.

Muzac-Tucker I, Asemota HN, Ahmad MH. 1993. Biochemical composition and storage of Jamaican yams (*Dioscorea* sp.). *Journal of Food and Agric Science* 62:219–224.

Nahapetian A, Bassiri A, 1975. Changes in concentration and interrelationship of phytate, P, mg, Cu, Zn, in wheat during maturation. *Food Chem. 32: 1179-1182*

Nascimento N. R. F., Lessa L. M. A., Kerntop M. R., Sousa C. M., Alves R. S., Queiroz M. G. R., Price J., Heimark D. B., Larner J., Du X., Brownlee M., Gow A., Davis C. and Fonteles M. C. 2006 Inositols prevent and reverse endothelial dysfunction in diabetic rat and rabbit vasculature metabolically and by scavenging superoxide. 218–223 PNAS vol. 103 no. 1

National Bureau of Statistics (NBS). 2012. LSMS – integrated surveys on agriculture: general household survey panel 2010/11. Available at: www.nigerianstat.gov.ng/pages/download/194.

National Nutrition and Health Survey (NNHS), Report. 2018. National Bureau of Statistics (NBS) and United Nations Children's Fund (UNICEF) Abuja, Nigeria. NBS and UNICEF

Nestor, K.K., Georges, G.T., Jacko, R.F.A., Cisse-Camara, M. and Amani, N.G. 2009. Influence of the variety and cooking method on glycemic index of yam. *Pakistan Journal of Nutrition*., *8: 993-999*

NNHS- National Nutrition and Health Survey Report. 2015. National Bureau of Statistics (NBS) and United Nations Children's Fund (UNICEF) Abuja, Nigeria. NBS and UNICEF

Nwankwo, I.I.M., Okeagu O.D., Egbo G.P., Uzoh E.J., Ekah E.O., and Eke-Okoro, O.N, 2017. Evaluation and Selection of white yam landraces (*Dioscorea rotundata* L .) clones for registration and release as varieties for farmers in Nigeria. *Agricultural Science Research Journal Vol.* 7.1: 1 – 8,

Nweke F., Aido, Osio R., & Okoye B. 2013.Yam Consumption Patterns in West Africa. Final Report for BMGF

Nweke, F.I. 2016. Yam in West Africa, Food, Money and More. Mchigan State University Press, East Lansing USA. pp112- 114.

Obadoni, B. O. and Ochuko, P. O. 2001. Phytochemical studies and comparative efficacy of the crude extracts of some homeostatic plants in Edo and Delta States of Nigeria. *Global Journal of Pure and Applied Science. 8:203-208.*

Oboh H A, Omofoma C.O. 2008 The effects of heat treated lima beans (Phaseolus lunatus) on plasma lipids in hypercholesterolemic rats. *Pakistan Journal of Nutrition.* 7(5):636-639.

Ogbuagu M.N., 2008. Nutritive and anti-nutritive composition of the wild (inedible) species of Dioscorea bubifera (Potato Yam) and Dioscorea dumentorum (Bitter yam). *Journal of Food Technology*, 6[5] 224 – 226.

Okwu D. E., Omodamiro O. D. 2005. Effects of hexane extract and phytochemical content of *Xylopia aethiopia* and *Ocimum gratissimum* on the uterus of guinea pig. *Biological Research 3*

Okwu, D E, and C U Ndu. 2006. "Evaluation of the Phytonutrients, Mineral and Vitamin Contents of Some Varieties of Yam (*Dioscorea* Sp.)." *International Journal of Molecular Medicine and Advance Sciences 2.2: 199–203.*

Oldewage-Theron, W. H., & Kruger, R. 2011. Dietary diversity and adequacy of women caregivers in a peri-urban informal settlement in South Africa. *Journal of Nutrition*, 27(4), 420- 427.

Oluwatosin O.B. 1998. Genetic and environmental variability in starch, fatty acids, and mineral nutrients composition in cowpea (Vigna unguiculata (L) walp). *Journal Science of Food Agriculture* 78:1–11

Omojola A. and Jegede A, 2010 The Problems of Bulk-Selling Yams in Harvest and Poverty of Farmers in Ekiti State, Nigeria. *African Research Review* Vol. 4(3b) 179-191

Onaolapo A.Y. and Onaolapo O.J. 2019. in Functional and Medicinal Beverages; Grumezescu A.M and Holban A.M., Eds: Elsevier: Academic Press 1: 313-349

Onigbinde A. O. 2005 Food and Human Nutrition [Biochemical Integration].Alva Corporate Organization, Benin City, Nigeria.2005, 289.

Onimawo I. 2010. Nigerian traditional food system and nutrition security. International scientific symposium biodiversity and sustainable diets. United against hunger

Onwueme I.C., 1978. The tropical tuber crops. John Wiley & sons ed, Chichester, New-York, Brisbane, Toronto, 234 pages.

Opara, L. U. 2003. YAMS: Post-Harvest Operation. In: AGST/FAO, D. Mejia, & F. (Technical), Eds. Palmerston North, New Zealand.

Osayande I., and Osarenren C.O. 2015. Effect of yam based production on food security status of farm households in Edo South Nigeria. *International Journal of Environmental & Agriculture Research 1 (6), 28-35*

Oste, R E. 1991. Digestibility of processed food protein *Advances in Experimental Medical Biology* 289: 371-388.

Otegbayo B.O., Oguniyan D.J. Olunlade B.A., Oroniran O.O., and Atobatele O.E., 2017. Characterizing genotypic variation in biochemical composition, anti-nutritional and mineral bioavailability of some Nigerian yam (Dioscorea spp.) land races. *Journal of Food Science and Technology*.

Otegbayo, B.O. 2004. Granule morphology, physicochemical and rheological characteristics of yam species as indicators of textural quality in pounded yam (*Dioscorea* spp.). *PhD thesis, University of Ibadan, Nigeria*

Otegbayo, B.O., Samuel, F.O., Kehinde, A.L., Sangoyomi, T.E., and Okonkwo, C.C. 2010. Perception of Food Quality in Yam by some Nigerian Farmers. *African Journal of Food Science. Vol. 4.8: 541- 549.*

Persson, H., Turk, M., Nyman, M., Sandberg, A.S., 1998. Binding of Cu2+, Zn2+ and Cd2+ to inositol tri-, tetrapenta, and hexaphosphates. *Journal of Agricultural and Food Chemistry*, 46(8):3194-3200. *[doi:10.1021/jf971055w]*

Polycarp D., Afoakwa E.O., Budu A.S., Otoo E. 2012. Characterization of chemical composition and anti-nutritional factors in seven species within the Ghanaian yam (Dioscorea) germplasm. *International Food Research Journal 19:985–992*

Poornima G.N. and Ravishankar Rai V.2009. Evaluation of phytonutrients and vitamin contents in a wild yam, *Dioscorea* belophylla (Prain) Haines. *African Journal of Biotechnology Vol. 8 (6), pp. 971-973, 20,*

Popkin B.M., Linda A.S., Shu NW 2012. Global nutrition and the pandemic of obesity in developing countries. *Nutrition Review* 2012, 70:3–21.

Popova A. and Mihaylova D. 2019. Antinutrients in Plant-based Foods: A Review. *The Open Biotechnology Journal, 13, 68-76*

Raboy, V., 2003. Myo-Inositol-1,2,3,4,5,6-hexakisphosphate Phytochemistry, 64(6):1033-1043. *[doi:10.1016/S0031-9422(03)00446-1]*

Ramiro Lopes da Silva 2013. Chair’s Round-up; Changing food systems for better nutrition. *UNSCN News 40: 4-5*

Rathnayake K.M., Madushani P and Silva K. 2012. Use of dietary diversity score as aproxy indicator of nutrient adequacyof rural elderly people in Sri Lanka. *BMC Research notes*

Rejinolda NS, Muthunarayanan M, Muthuchelian K, Chennazhi KP, Nair SV, Jayakumar R. 2011. Saponin-loaded chitosan nanoparticles and their cytotoxicity to cancer cell lines in vitro. Carbohydrate Polymers.:84:407–416

Rubiang-Yalambing, L., Arcot, J., Greenfield, H. and Holford, P. 2014 Aibika (Abelmoschus manihot L.): Genetic variation, morphology and relationships to micronutrient composition. *Food Chemistry*

Ruel M., Harris J., Cunningham K. 2001. Diet Quality in Developing Countries, in: V. R. Preedy, *et al.* (Eds.), *Diet Quality*, Springer New York. pp. 239–261.

Ryam M.K., Shattuck A.D. 1994. Treating aids with Chinese Medicine North Side HIV Treatment Centre Chicago U.S.A. Pacific View Press Berkeley USA., pp. 16-364.

Salawu, M.B, Ibrahim A.G, Lamidi, L.O, Salau M.A, Ogunleye B.T 2014. Economic Analysis of Yam Processing in Oyo State. *European Journal of Business and Management .Vol.6, No.39, pp 25-30*

Sanchez, P., Swaminathan, M.S., Dobie, P. and N. Yuksel. UN Millennium Project 2005. Halving Hunger: It can be done. Task Forces on Hunger.

Sanginga N. 2015 An action Plan for African Agricultural Transformation: Root and Tuber Crops. Background Paper for Feeding Africa.

Sanusi, R. A. 2010. An Assessment of Dietary Diversity in six Nigerian States. *African Journal of Biomedical Research 13; 161-167*

Sanusi, R. A., Ejoh S.I. and Yusuf F.K. 2014. Assessment of Dietary Diversity of In-School Adolescents in Ibadan, Oyo State, Nigeria. *West African Journal of Foods and Nutrition 12 (2) 69-77*

Sarah E. O’Connor.2010 In Comprehensive Natural Products II Chemistry and Biology; Mander, L., Lui, H.-W., Eds.; Elsevier: Oxford, volume 1,. 977–1007.

Sardesai, V.M. 2003 Herbal medicines. Poisons or potions? *Journal of. Lab. Clin. Med. 139: 343,*

Senavirathna, R.M., Ekanayake, S., Jansz, E.R., Welihinda, J. 2014. Proximate composition, glycemic indices and some factors affecting glycemic indices of underutilized tubers. *Starch/Starke 66, 1041-1048*

Shanthakumari S, Mohan V.R., Britto John D. E. 2008. Nutritional evaluation and elimination of toxic principles in wild yam (Dioscorea species). Trop Subtrop Agroecosyst 8:319–325.

Sibhatu, K.T. and Qaim, M. 2018. Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. *Food Policy*, 77: 1–18. Available at https://doi.org/https://doi.org/10.1016/j.foodpol.2018.04.013.

Sodipo O.A., Akiniyi J.A., Ogunbanosu. 2000. Studies on certain characteristics of extracts of bark of Pansinystalia macruceras (K.Schem) Piere. Exbeile. Global J. Pure Appl. Sci. 6: 83-87.

Steyn N.P., Nel J.H., Nantel G., Kennedy G., Labadarios D. 2006. Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? *Public Health Nutrition* (5):644-50. doi: 10.1079/phn2005912. PMID: 16923296.

Storcksdieck, S., Bonsmann, G., Hurrell, R.F., 2007. Iron-binding properties, amino acid composition, and structure of muscle tissue peptides from in vitro digestion of different meat sources. Journal of Food Science, 72(1):S019-S029. *[doi:10.1111/j.1750-841.2006.00229.x]*

Swindale, A. and Punam O. 2005. Measuring Household Food Consumption: A Technical Guide. Washington, D.C.: Food and Nutrition Technical Assistance (FANTA) Project, *Academy for Educational Development (AED).*

Tamiru M, Mass BL, Pawelzik E. 2008. Characterizing diversity in composition and pasting properties of tuber flour in yam germplasm (*Dioscorea* spp.) from Southern Ethiopia *Journal of Food and Agric Science* 88:1675–1685

Teshome A, Amenti C 2010. On farm participatory evaluation and selection of sweet potato (Early, Medium and Late set) varieties at Adami Tulu Jiddo Kombolcha District. *International Journal of Agriculture. 2.4: 1-5.*

Toledo, A. And Burlingame, B. 2006. Biodiversity and nutrition: a common path toward global food security and sustainable development. *Journal of Food Composition and Analysis 19: 477–483.*

Toluwase, S.O.W. and Sekumade, A.B. 2017. Resource Use Efficiency of Yam Production in Ekiti State, Nigeria. *Advances in Social Sciences Research Journal*, *4(2) 20-34.*

Trease, G. E. and Evans, W. C. 1989. Pharmacognosy. 11th ed. Brailliar Tridel and Macmillian Publishers, London, pp. 48-65.

Trivedi P.D, Kilambi P., Shivprakash R., and Karishma S.S., 2007. A Validated Quantitative Thin Layer Chromatographic Method for Estimation of Diosgenin in Various Plant Samples, Extract, and Market Formulation, *Journal of AOAC International*, 90(2), 358-363.

Trowel H., 1976. Definition of Dietary Fibre and Hypothesis that it is a Protective Factor for Certain Diseases. *American Journal of Clinical Nutrition*, 29, 417-427.

Udensi E. A., Oselebe H. O., Onuoha A. U..2010 Antinutritional assessment of D. alata varieties. *Pakistan Journal of Nutrition* 9[2]; 179 – 181.

Van Soest, P.J. and Wine, R. H. 1968. Determination of lignin and cellulose in acid detergent fibre with permanganate. *Journal of Assoc. Off. Anal. Chem.*, ***51**: 780 - 785*

Venn, B.J. and Green, T.J. 2007 Glycemic index and glycemic load: Measurement issues and their effect on diet-disease relationships. *European Journal of Clinical Nutrition., 61, S122–S131.*

Verter N. and Becvarova V. 2015. An Analysis of Yam Production in Nigeria. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 63(2): 659–665.

Verter N. and Becvarova V.2014. Yam production as pillar of food Security in logo local government area of Benue state. *Nigeria European Scientific Journal 10(31), 27-42*

Vucenik, I., Shamsuddin, A.M., 2006. Protection against cancer by dietary IP6 and inositol. *Nutrition and Cancer,* 55(2):109-125. [*doi:10.1207/s15327914nc5502_1]*

Vucenik, I., Shamsuddin, A.M., 2006. Protection against cancer by dietary IP6 and inositol. Nutrition and Cancer,55(2):109-125. *doi:10.1207/s15327914nc5502_1]*

Wardlaw G.M., Hampl J.S., DiSilvestro R.A., Perspective in Nutrition. Mcgraw Hill Press, USA. 2004.

Wheeler, E. l. and Ferrel, R. E. 1971. A method for phytic acid determination in wheat fractions. *Cereal Chemistry, 48: 312 – 320.*

Whitney E. and Rolfes S. R., 2008. Understanding Nutrition, Thomson Learning, Belmont, Calif, USA, 11th edition.

WHO 2015. World Health organization, and Secretariat of the Convention on Biological Diversity. “Connecting Global Priorities :Biodiversity and Human Health.”

WHO. 2012. Our Planet, Our Health, Our Future. Human Health and the Rio Conventions. Discussion paper. Geneva: World Health Organization. http://www.who.int/ globalchange/publications/reports/health_rioconventions.pdf.

WHO/UNICEF. (2010) Indicators for assessing infant and young child feeding practices. Part 3, in: W. L. C.-i.-P. Data (Ed.), WHO, Geneva. Woodhead Publishing 1: 253-271

Williams, P.C., Kuzina, F.D., Hiynk, I. 1970. A rapid colorimetric procedure for estimating the amylose content of starches and flour. *Cereal chemistry. 47.4: 411-421*

Wireko-Manu, F. D., Ellis, W. O., Oduro, I., Asiedu, R. and Maziya-Dixon, B. 2011. 'Physicochemical and Pasting Characteristics of Water Yam (*D. alata*) in Comparison with Pona (*D. rotundata*) from Ghana'. *European Journal of Food Research & Review, 1. 3: 149 – 158.*

Yang C. R., Zhang Y, Jacob M.R., Khan S.I., Zhang Y.J., Li X.C. 2006 Antifungal activity of C-27 steroidal saponins. *Antimicrobial Agents Chemotherapy*; 50 (5) :1710–1714.

York, J.D., 2006. Regulation of nuclear processes by inositol polyphosphates. *Biochimica et Biophysica Acta (BBA)-Molecular and Cell Biology of Lipids*, 1761(5-6):552-559.[doi:10.1016/j.bbalip.2006.04.014]

York, J.D., Odom, A.R., Murphy, R., Ives, E.B., Wente, S.R.,1999. A phospholipase C-dependent inositol polyphosphate kinase pathway required for efficient messenger RNA export. *Science*, **285**(5424):96-100. [doi:10.1126/science.285.5424.96]

Zaknayiba D.B., Tanko L. 2013 Costs and returns analysis of yam production among small scale farmers in Karu Local Government Area, Nasarawa State, Nigeria. PAT; 9(1): 73-80

Ziegler J. and Facchini P. J., 2008 *Annual Review of Plant Biology*, 59, 735–769.

APPENDICES

INFORMED CONSENT FORM FOR RESPONDENTS

This research is being conducted by OLAWUYI Yetunde, a Postgraduate Student of the Department of Human Nutrition, Faculty of Public Health, College of Medicine, University of Ibadan. The purpose of this study is to carry out yam consumption survey and assess the contribution of yam to the nutrient intake of consumers in Ekiti State. The information obtained in this study will enable us to know what varieties of yams are commonly consumed in Ekiti State, the contribution of yams to the diet and assess the dietary diversity of diets consumed by adults in Ekiti State. Interaction will be for about 25 minutes and we may return another time if further information is needed or to provide feedback.

Your identity, responses and opinion will be kept strictly confidential and will be used for the purpose of this research only. Kindly answer the questions below as accurately as possible to make the research a success. However, your participation is voluntary and you may request to withdraw at any time.

Statement of person obtaining informed consent:

I have fully explained this research to ______________________________________ and have given sufficient information to make an informed decision.

DATE: _________SIGNATURE: ____________

NAME: _______________________________

Statement of person giving consent:

Now that the study has been well explained to me and I fully understand the content of the study process, I hereby agree to be part of the study.

DATE: ________SIGNATURE/ THUMBPRINT: ______________________________

NAME:____

Detailed contact information:

If you have any question about your participation in this research, you can contact the principal investigator, Mrs Olawuyi Yetunde in Department of Human Nutrition, Faculty of Public Health, University College Hospital, Ibadan. Telephone: 08033518935, E-mail: yetundeoluolawuyi@gmail.com.

QUESTIONNAIRE

Office Use Only
Interviewer's name: ______________________ Date: ___________
Questionnaire Identification: ☐☐☐☐☐☐☐☐

	Name/No
LGA	
Sector Codes: Rural (01), Urban (02)	
Household head	
Address	
No. of persons in HH	

Section A: Socio-Demographic/ Socio-economic Characteristics

S/N	QUESTIONS	
1	Gender: (1) Male (2) Female	
2	Age of respondent:	
3	How long have you been living in Ekiti State? 1) I was born here 2) More than 10 years 3)less than 10 years	
4	Religion: (1) Christianity (2) Islam (3) Traditional	
5	State of Origin: …………………..	
6	Ethnicity: (1) Yoruba (2) Igbo (3) Hausa (4) Others (pls specify)………..	
7	Marital Status: (1) Single (2) Married (3) Divorced/Separated (4) Widowed	
8	Household family size: (1) 1 (2) 2 (3) 3 (4) 4 (5) 5 (6) 6 (7) 7 (8) 8 (9) 9 Others…………	
9	Relationship to the household head: (1) Self (2) Wife (3) Son (4) Daughter (5) Relative (6) Grandchild (7) Others Specify ………………	

10	Highest Educational Qualification of Household Head: (1) No formal education (2) Primary (3) Secondary (4) NCE (5) OND (6) Diploma (7) HND (8) First Degree (9) Masters (10) PhD (11) Others………………..	
11	Highest Educational Qualification of Respondent: (1) No formal education (2) Primary (3) Secondary (4) NCE (5) OND (6) Diploma (7) HND (8) First Degree (9) Masters (10) PhD (11) Others………………..	
12	Primary occupation of Household head: (1) Civil Servant (2) Farmer (3) Teacher (4) Businessman/woman (5) Artisan (6) Student (7) Retired (8) Professional (Health worker [ ], Lawyer [ ], Engineer [ ], Accountant [ ], Nurse [ ].(9) Others (please specify)…………..	
13	Secondary occupation of Household Head:	
14	Primary occupation of Respondent: (1) Civil Servant (2) Farmer (3) Teacher (4) Businessman/woman (5) Artisan (6) Student (7) Retired (8) Professional (Health worker [ ], Lawyer [ ], Engineer [ ], Accountant [ ], (9) Others (please specify)…………..	
15	Secondary occupation of Respondent:	
16	Household monthly income: 1) ≤N20,000 2) N20,001 – N39,999 3) N40,000 – N59,999 4) N60,000 –N79,999 5) N80,000 –N99,999 6) >/=N100,000	
17	Primary energy source: 1) No electricity (2) Benin Distribution Electric Company (BDEC) (3) Personal generator (4) Solar energy	
18	Major source of water for domestic use: 1) Pond/lake (2)Spring/river (3)Well (4)Bore hole (5)Pipe-borne water (6)Rain water harvest (7)Others (specify)	
19	Major source of water for drinking: 1) Pure(satchet) water (2)Spring/river (3)Well (4)Bore hole (5)Pipe-borne water (6)Rain water harvest (7)Others (specify)	
20	Main type of toilet: 1) Bush 2) Pit latrines 3)Water system 4) Rivers	
21	Method of refuse disposal 1) Bush 2) State waste management agency 3) Burning 4) Refuse dump 5) Others (specify)……………………	

22	Source of energy for cooking 1) Firewood 2)Coal 3)Kerosene 4)Electricity 5) Gas cooker 6) Others(specify)…………………….	

SECTION C: REPORTED HEALTH STATUS OF RESPONDENTS

Do you or any of your parents suffer from any of the following diseases?

S/N	Variables	Yes (1)	No (2)	Code
1	High blood pressure			
2	Diabetes			
3	Cancer			

SECTION D: YAM CONSUMPTION

S/N	QUESTIONS	
1	What is the source of the yams you consume in your household? 1) Family farm (2) Market (3) Gifts (4)Others (Specify)	
2	Are you able to distinguish the different types of yams? 1) Yes 2) No	
3	If yes, mention some types of yam you know ________________________________ if No, go to question 9	
4	Are you particular about the type (variety) of yam you consume? 1) Yes 2) No	
5	If yes, mention three of your most preferred varieties 1)_____________ 2) _________________ 3) ____________________	
6	How are you able to distinguish the varieties? 1) Size 2) external features like hair 3) colour 4) others (specify)______________________________________-	
7	What varieties do you usually consume during the rainy season (at the start of yam harvest)?________________________________	
8	What varieties do you usually consume during the dry season?___________________	

9	What influences the yams you purchase/ consume? 1)Availability 2) Price/ cost of yam 3) Taste 4) Texture 5) Nutritional value 6) Others ____________________	
10	In what forms do you consume yam? ______________________________	
11	Do you have specific varieties preferred for different yam products? 1) Yes 2) No	
12	If yes, mention the preferred varieties for the yam products listed in 10 above	
13	What do you usually take with the yam products mentioned above? 1)Boiled yam _______________________2)Pounded yam _____________________ 3)Yam pottage _______________________4)Fried yam ___________________________ 5)Roasted yam ________________________6)Amala _______________________ 7)Ojojo ___________________________ 8) Others ( )________________________	
14	What is your most preferred form of yam consumption? _________________	
15	How does seasonality affect the frequency of your consumption of yam and its products? 1)Season does not affect my yam consumption 2) I eat more yams during the harvest period and less during the dry season 3) I only eat certain products during the period of harvest 4) Others____	
16	What vegetables do you usually consume? ________________________	
17	What fruits do you usually consume? _____________________________	

SECTION E: FOOD FREQUENCY QUESTIONNAIRE

	Never	<1x per Month	1-3 x times per month	1-2 x times per wk	3-4 x per wk	5-6 x per wk	1x per day	2 or more times per day
Boiled yam								
Pounded yam								
Roasted yam								
Fried yam								
Yam pottage								
Amala Isu								
Amala Ogede								
Amala Lafun								
Mixed Amala								
Eba								
Garri								
Cocoyam								
Potatoes								
Fufu								
Boiled plantain								
Fruits								
Vegetables								

SECTION E: TWENTY FOUR-HOUR DIETARY RECALL

Now I would like you to tell me everything you had to eat and drink after you woke up yesterday morning. Include everything you ate and drank at home and away, even snacks, tea, or coffee.

DATE……………………… DAY OF THE WEEK…………………

QUESTIONNAIRE NO………………… NAME OF SUBJECT………………………

Item No (a)	Food/Drink Addition (b)	Description of Food or Drink (use volume, size or prize) (c)	Place taken (d)	Time (e)	Amount (how much did you actually eat/drink?) (f)	Weight equivalent (g)

1.) Was the food intake usual? (Y /N) If no, how was it unusual?	4.) Probe for supplements (iron, antimalarial, vitamins and other supplements) If yes, specify
2.) Was it a feast day? (Y/N)	
3.) Probe for sickness (Sickness) (Y/N): if yes, did sickness affect appetite (Y/N) If yes, how? Increase of decrease?	5)Probe for fermented beverages consumed

SECTION F: ANTHROPOMETRIC ASSESSMENT

Weight (kg)		Waist circumference (cm)	
Height (cm)		Hip circumference (cm)	

INDIVIDUAL DIETARY DIVERSITY SCORE (IDDS) QUESTIONNAIRE

Question Number	MDDW	Examples	YES=1 NO=0	Food group IDDS	Examples	YES=1 NO=0
1	Grains, white roots and tubers, and plantains (all starchy staples)	Corn/maize, rice, wheat, sorghum, millet or any other grain of foods made from these (e.g bread noodles, porridge or other grain products)		STARCHY STAPLES	+ *insert local foods e.g eba, amala, pounded yam*	
2	Pulses (beans, peas and lentils)	Dried beans, dried peas, lentils, nuts, seeds or foods made from these (e.g. hummus, peanut butter)		DARK GREEN LEAFY VEGETABLES	Dark green leafy vegetables, including wild forms+ locally + locally available vitamin A Rich leaves such as amaranth, cassava leaves, kale, spinach	
3	Nuts and seeds			OTHER VITAMIN A VEGETABLE RICH FRUIT	Ripe mango, apricot (fresh or dried), ripe papaya, dried peach, and 100% fruit juice made from these + other locally available vitamin A. Rich fruits	
4	Dairy	Milk, cheese, yogurt or other milk products		OTHER FRUIT & VEGETABLES	Other vegetables (e.g. tomato, onion, eggplant)+ locally available vegetables. Other fruits, including wild fruits and 100% fruit juice made from these	
5	Meat, poultry and fish			ORGAN MEAT	Liver , kidney, heart or other organ meats or blood – based foods	
6	Eggs			MEAT & FISH	Beef, pork, lamb, goat, rabbit, game, chicken, duck, other birds,	

					insects, fresh or dried fish or shell fish.	
7	Dark green leafy vegetables			EGGS	Eggs from chicken, duck, guinea fowl or any other egg	
8.	Other vitamin A-rich fruits and vegetables			LEGUMES, NUTS AND SEEDS	Dried beans, dried peas, lentils, nuts, seeds or foods made from these (e.g. hummus, peanut butter)	
9	Other vegetables			MILK AND MILK PRODUCTS	Milk, cheese, yogurt or other milk products	
10	Other fruits					
TOTAL						

Adapted from FAO, 2013

INSTITUTE FOR ADVANCED MEDICAL RESEARCH AND TRAINING (IAMRAT)

College of Medicine, University of Ibadan, Ibadan, Nigeria.

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UI/UCH EC Registration Number: **NHREC/05/01/2008a**

NOTICE OF FULL APPROVAL AFTER FULL COMMITTEE REVIEW

Re: Nutritional Characterisation of Yam Varieties and Contribution of Yam to Nutrient Intake.

UI/UCH Ethics Committee assigned number: UI/EC/19/0298
Name of Principal Investigator: **Yetunde O. Olawuyi**
Address of Principal Investigator: Department of Human Nutrition,
College of Medicine,
University of Ibadan,
Ibadan.

Date of receipt of valid application: 05/08/2019
Date of meeting when final determination on ethical approval was made: **N/A**

This is to inform you that the research described in the submitted protocol, the consent forms, and other participant information materials have been reviewed and *given full approval by the UI/UCH Ethics Committee.*

This approval dates from **06/02/2020 to 05/02/2021.** If there is delay in starting the research, please inform the UI/UCH Ethics Committee so that the dates of approval can be adjusted accordingly. Note that no participant accrual or activity related to this research may be conducted outside of these dates. *All informed consent forms used in this study must carry the* UI/UCH EC *assigned number and duration of* UI/UCH EC *approval of the study.* It is expected that you submit your annual report as well as an annual request for the project renewal to the UI/UCH EC at least four weeks before the expiration of this approval in order to avoid disruption of your research.

The National Code for Health Research Ethics requires you to comply with all institutional guidelines, rules and regulations and with the tenets of the Code including ensuring that all adverse events are reported promptly to the UI/UCH EC. *No changes are permitted in the research without prior approval by the* UI/UCH EC *except in circumstances outlined in the Code. The* UI/UCH EC *reserves the right to conduct compliance visit to your research site without previous notification.*

UI/UCH EC
06 FEB 2020
APPROVED
COLLEGE OF MEDICINE, U.I.

Professor O. G. Ademowo
For: Director, IAMRAT
Chairperson, UI/UCH Research Ethics Committee
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