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EVALUATION OF TEN GENOTPYES OF SWEETPOTATO FOR FRIES

BY

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DECLARATION

I hereby declare that this submission is my own work towards the MSc. and that, to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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Abstract

Several genotypes of sweetpotato are being developed by breeders due to its nutritional and economic potentials. In order to ensure increased consumption and constant demand creation, its potential use in several food types need to be ascertained. Moisture, fat, colour, starch and betacarotene content of fries from ten sweetpotato genotypes: *Apomuden, Bohye, Nanungungun, Otoo, CIP442162, Patron, CIP440390, Obare, Dadanyuie* and *TU-Purple*, were determined by standard methods. Sensorial properties of the fries were further evaluated by an in-house consumer panel of 8 using standard methods. The starch content of the genotypes before frying, ranged from 10.12% in *Apomuden* (orange-fleshed variety) to 19.79% in *Bohye* (orange-fleshed variety), dry matter from 24.05% in *Apomuden* to 38.25% in *Dadanyuie* (white-fleshed) and beta-carotene from 330.76 in *Bohye* to 6205.07 µg/100g in *Apomuden*. After frying, fat content was highest in *CIP442162* and low in *Dadanyuie*. Beta-carotene content reduced by 44.27% in *Bohye* and 13.20% in *Nanungungun.* Browning index was highest in the orange-fleshed and purple genotypes but this was mostly due to their flesh colours and not the frying conditions. Fries from orange-fleshed genotypes, *Apomuden* and *Nanungungun,* were considered to be sweeter than the other genotypes. Detection of caramel and starch (rawness sensation) was very low for all genotypes assessed. Oily mouthcoat, moistness and sogginess were detected in mostly the orange-fleshed genotypes; particularly, *Apomuden* and *Nanungungun*. *TU-Purple*, *Bohye* and *CIP440390* produced moderately crunchy fries, and had the highest score for desirable attributes compared with the other genotypes. *TU-Purple*, *Bohye* and *CIP440390* could be explored in commercial production of fries for enhanced utilization of developed sweetpotato genotypes.

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INTRODUCTION

1.0 Background to the study

Sweetpotato (*Ipomoea batatas* L.) is a dicotyledonous plant, belonging to the morning glory family, Convolvulaceae (Watson and Dallwitz, 2000). They are large root vegetables that are starchy and have a sweet taste. Sweetpotato is part of the top seven staples in the world following wheat, rice, maize, potato, barley and cassava (Tan, 2015). Sweetpotato is an indispensable profitable crop and is able to adapt successfully to a wide range of habitats including marginal regions (Aina *et al*. 2009). Comparing sweetpotato to other staple crops, the root also has positive properties such as short production cycle, increased nutritional value and sensory versatility in terms of flesh colour, texture and taste (Truong and Avula 2010). Artificial selection and the eventuality of natural hybrids and mutations of sweetpotato has led to the existence of an increase in varying amount of cultivars based on their properties which range from physical appearance and texture of the tuber to structure-function properties of the starch (Aina *et al*., 2009).

As an important economic crop, over 104 million tons of sweetpotatoes are currently being produced in the world (FAOSTAT, 2014). Central America and the western coast of South America are the original home of sweetpotato (Tan, 2015). However, sweetpotato is largely cultivated in China with more than 3.5 million hectares which makes up 43% of the world total (Tan, 2015). Ghana produced 131,990 metric tonnes of sweetpotato in 2012 according to MoFA (2012).

In Ghana, sweetpotatoes are mostly fried when yams are either out of season, or are dried and not very palatable when boiled (Danquah *et al*., 2000). They can be processed into different food products which include confectionery, snacks, noodles, breads, chips and fries (Kimberly, 2015).

Sweetpotato genotypes with increased amounts of provitamin A (beta-carotene) and ascorbic acid will have an added advantage of nutrition when used in snack foods. In the United States, there has been an increase in consumer demand for sweetpotato fries and many processing companies are venturing into its production (US sweetpotato council, 2013). This has led to the development of new genotypes that possess qualities suitable for the production of fries as part of the sweetpotato breeding program of the US Sweetpotato Council.

In Ghana, several genotypes of sweetpotato including orange-fleshed sweetpotatoes (high in betacarotene) have been produced by the International Potato Centre (CIP-Ghana), however their potential use as fries is yet to be investigated. It is necessary to understand the characteristics of the sweetpotatoes produced, their potential use for fries, in order to inform processors and consumers on which genotypes to process into fries.

Dry matter content in sweetpotato which mainly consists of carbohydrate is very important for the selection of a particular genotype for fries and accounts for the taste and texture of the product (Gao *et al.* 2014). It is important to look out for superior characteristics in dry matter, good product colour, lower oil absorption and increased crop yield (Abong *et al*. 2010) to produce fries preferred by consumers and that will also increase sales for sweetpotato farmers.

In spite of its great potential, the consumption of the sweetpotato root is still limited in Ghana although it is regularly being promoted (Adu-Kwarteng *et al*., 2002). In Ghana, the crop is given less attention in our menu planning as compared to other roots and tuber such as yam, cassava or cocoyam mainly because of its sweetness. Low consumption of sweetpotato which both reflects and results in low demand and low commercial value can be attributed to the poor utilization of sweetpotato in popular food products that have mass-market appeal, and its lack of use in large

industrial applications. This study therefore seeks to evaluate 10 genotypes of sweetpotato to select the most suitable to be used as fries.

1.1 Problem statement

The International Potato Centre (CIP-Ghana) has produced several genotypes of sweetpotato through its breeding program, with some genotypes already released. These genotypes have good yield, resistance to pest and diseases, with some genotypes having high beta-carotene and vitamin C contents. However, there is limited information on the end-uses of these sweetpotato genotypes.

1.2 Justification

Selecting the sweetpotato roots for fries will help processors in choosing which kind of roots from the many genotypes available to be used. This will help increase consumption of sweetpotato roots, diversify their use and make available the nutrients in sweetpotato for consumers.

1.3 Main Objective

To evaluate the physicochemical and sensory properties of sweetpotato genotypes for use as fries

1.3.1 Specific Objectives

1. To determine the dry matter and starch content of 10 genotypes of sweetpotato
2. To conduct descriptive sensory analysis on the fried sweetpotatoes
3. To determine fat, moisture, colour and β-carotene content of the sweetpotato fries

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1.0 Sweetpotato

Sweetpotato is a tuberous root belonging to the family convalvulaceae. It is an important crop for the alleviation of hunger and is cultivated in over 100 countries (Ali *et al.*, 2015). Sweetpotato as an edible root tuber is long and tapered with smooth skin and colour ranging from red, purple, brown and beige. The flesh colour of the crop is also ranged from white through orange, pale cream and purple (Dapaah *et al.*, 2005). Sweetpotato is considered as a food security crop, mainly due to its reliable yields. It is an essential crop that is widely utilized in terms of consumption in SubSaharan Africa (Woolfe, 1992).

Worldwide, sweetpotato is ranked the 6th most important food crop after rice, wheat, potatoes, maize, and cassava, whiles in developing countries it is ranked 5th (CIP, 2013). Annually, over 133 million tons of sweetpotatoes are being produced globally (Warammboi *et al*., 2011), of which 95% are grown in developing countries (FAOSTAT 2014). Asia is known to be the world's largest producer of sweetpotato with 92.5 million tonnes with china producing 85.2 million tonnes which amounts to 77% of the world sweetpotato production (FAOSTAT 2008), whiles in Sub-Saharan Africa, sweetpotato production is 13.7 million tonnes per annum representing only 12.4% of the world's production (FAOSTAT, 2008).

Sweetpotato is ranked fifth in profitable value production, sixth in dry matter production, seventh in energy production, ninth in protein production in developing countries and has excellent pliability of utilization as food, animal feed and industrial products (Gregory, 1992). Sweetpotatoes can be harvested any time after a significant amount of the tuber crop has reached a weight of marketable size. The crop can be harvested just before frost to increases yields in case it should be

stored. A fall in soil temperature below approximately 13°C can cause damage to the quality of the root and also reduce their worth for storage and result in slip production (Brandenbeger *et al.*, 2014).

Ghana, ranked the 4th largest producer of sweetpotato in West Africa (FAO, 2010) has climate conditions that is conducive for growing and cultivating root and tuber crop such as sweetpotato (Graffham *et al.*, 1998) with extensive production at almost all agro-ecological zones in the country yielding 1.75t/ha on average all year round (Amoatey *et al.*, 2016) . However, inadequate all year supply of tubers, agro-ecological barriers to crop cultivation, high tuber perishability, high per capita consumption, low crop yield and dry matter are the major challenges that limit the exploitation of sweetpotato for food processing (Graffham *et al.*, 1998).

Despite its great potential to attenuate food insecurity, malnutrition and poverty, sweetpotato remains an underutilized crop in Ghana. It is for instance, rare to find sweetpotato being made available to consumers in public locations such as local restaurants, canteens and schools (Baafi *et al*., 2015). However, sweetpotato is increasingly becoming the 3rd most important root and tuber crop after cassava and yam in Ghana which can be attributed to its increased yielding ability, outstanding energy and nutrient content (vitamin A in orange fleshed) and its potential to grow in marginal soils (Sossah *et al*., 2014) with an estimated all year round production of 135,000 tons representing only 0.6% of all root and tuber crop produced in Ghana (FAOSTAT, 2013). This however, is low when compared to the output of the country's main staple crops such as cassava (9.7 million Mt), yam (3.1 million Mt) and maize (1.3 million Mt) in 2003 (MOFA, 2013). It is used a substitute for rice, cassava, yam, plantain and other staples in various food preparations

(Ellis *et al*., 2001; Meludu *et al.*, 2003). Meanwhile, it is relatively less important in the Ghanaian diet as compared to other roots and tubers such as yam, cassava, and cocoyam (Opare-Obisaw *et al*., 2000).

Sweetpotato roots should be stored between 12.8 °C and 15.6 °C. Temperatures below 12.8 °C can cause chilling injury. The roots should also be kept at relative humidity between 75% and 80% to prevent uncontrolled water. Exposure of the crop to the sun can cause sunscald and this affects the quality of the product (Brandenbeger *et al*., 2014).

2.1.1 Genotypes of Sweetpotato

Sweetpotato is an outcross species that is vegetatively propagated and each cultivar is a clone. Artificial selections of sweetpotatoes, as well as the occurrence of natural hybrids and mutations, have emerged in the existence of a myriad amounts of genotypes, which vary in properties, ranging from the visible qualities and texture of the root to structure-function properties of the starch (Zhang and Oates, 1999). In the past three decades, research efforts have triumphed in developing early maturing genotypes that yields more than 20 t/ha with satisfactory measure of resistance to diseases and pests (Doku, 1984). The new cultivars that are being released are possess low sweetness compared to the old cultivars and are more suitable for use as staples (Martin, 1987) even though, there are still myriad cultivars that possess high level sweetness to assent to their use as staple like cassava or yams (Danquah *et al*., 2000).

Sweetpotato comes with colours ranging from white, cream, yellow, orange and purple based on flesh colour. After the discovery of the nutritional and economic significance of sweetpotato the international potato center (CIP) in 1996, launched a project to ameliorate human health and income generation. The development and adoption of new sweetpotato genotypes with improved

postharvest qualities, and executing virus cleanup exercises to produce healthy planting materials in low-input subsistence farming systems all confirm the project launch (CIP, 2013).

The Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI) in Ghana has developed several genotypes of sweetpotato since 1998. *Sauti, Okumkom, Faara* and *SantomPona* that were produced in 1998, have already been widely adopted by farmers in Ohawu in the Akatsi District found in the Volta region and in some parts of the Central and Western regions. These genotypes are disease-resistant, high-yielding, and early-maturing,and conatins high amounts of protein (GNA, 2002). Hi-Starch, *Ogyefo, Otoo* and *Apomuden* are some other genotypes that were unleashed in 2005. The aforementioned genotypes possess high yield qualities, are resistant to pests and diseases and also acceptable for food and industrial production. *Apomuden*, an orange-fleshed genotype, has the highest mean fresh tuber yields followed by *Otoo*, *Ogyefo* and High-Starch (CSIR-CRI, 2005). It is also known to have more β-carotene compared with the other genotypes. However, the challenge associated with it is the high moisture content.

Common sweetpotato diseases that affects the quality of the various genotypes are scurf, stem rot (wilt), nematodes, black rot and soft rots. Field loss and losses during storage can be recorded if the crop is attacked by the aforementioned diseases as well as other diseases (Brandenbeger *et al*., 2014). These diseases can be averted or managed by adopting certain recommended practices in selecting resistant genotypes, selecting seed stock, producing transplants, selecting fields and growing practices. However, Scurf, black rot and stem rot mostly emanate from disease-infested seed stock and can be controlled by dipping the seed root in fungicide dip before bedding (Brandenbeger *et al*., 2014).

2.2 Chemical composition and utilization of sweetpotato

2.2.0 Nutritional components

The roots, vines, young leaves and all other parts of the sweetpotato plant are being utilized in production of food and also as feeds for animals worldwide. The nutrient composition of the crop varies widely and is dependent on the cultivar, growing conditions, maturity, and storage (Troung *et al*., 2011). Comprehensively, sweetpotatoes contain have a high amounts of moisture with an average dry matter (DM) content of 25-30%. Generally, DM content in sweetpotato widely ranges from 13% to 45% (Aina *et al*., 2009; Mensah *et al*., 2016). Hageninmana *et al* (1998) reported that general dry matter content in orange-fleshed sweetpotato (OFSP) and purple-fleshed sweetpotato (PFSP) ranged from 20.4% to 27.8% and 20.3 to 30.2% respectively when they analysed DM content of sweetpotato with different flesh colours. A study by Tsou and Hong (1992) recorded a wide range of dry matter content (13-41%) from a sweetpotato germplasm collection. Most of the DM in sweetpotatoes is made up of carbohydrates, basically starch and sugars and to a lesser extent pectin, cellulose and hemicellulose. During storage, DM content reduces due to the metabolic activity and the utilization of carbohydrate present in the sweetpotato root as an energy source and also because of respiration and transpiration of the root (Troung *et al*., 2014).

Meanwhile, starch comprises 60-70% of the total dry matter but values are dependent on the type of cultivar. The starch content in sweetpotato ranges from 6.9% to 33.5%. Sweetpotato starch granules consists of up of amylose (20%) and amylopectin as with other starches (Woolfe 1992). Amylases present in the raw root act on gelatinized starch to form maltose when cooking sweetpotatoes. In a study carried out by Truong *et al*. (1986) on a Filipiano and Louisiana cultivar it was found that total sugars varied from 5.6% to 38% respectively on a dry weight basis (db). Majority of sugars in raw sweetpotato roots were found to be sucrose, glucose, and fructose.

Sweetpotato provides excellent nutrition and health benefits because of the abundant β-carotene present, and other nutrients such as complex carbohydrates, the B and C vitamins, vitamin E (nonfat source), antioxidant micronutrient, minerals and dietary fibers (Woolfe, 1993; BonvellBenjamin, 2007). The carotenoids in sweetpotato roots exist in an all Trans configuration, which shows the highest provitamin A activity among the carotenoids. Carotenoids found in the orange fleshed sweetpotato have attracted great interest to their values as antioxidants which has a connection with its ability to reduce cancer and other degenerative diseases, apart from being a source of vitamin A.

The sweetpotato roots also have anti-diabetic effects and are regarded as eminently functional low calorie foods (Padmaja, 2009). It has been reported that phytochemicals present in the roots help reduce the risk of chronic diseases, such as cardiovascular diseases, cancer and age-related degenerative diseases due to the high free radical scavenging activity of phenols (Kurata *et al*., 2007; Scalbert *et al*., 2005). Comparing the orange-, white- and yellow-fleshed sweetpotato to the purple-fleshed sweetpotato, it contains anthocyanins which exists in mono- or diacylated form of cyanide and peoridin and thereby contributes to the high antioxidant activity of the purple-fleshed genotypes (Teow *et al*, 2007). Van Jaarsveld *et al*., (2005) advocated that a successful way to ameliorate vitamin A nutrition in developing countries is to increase the consumption of orangefleshed sweetpotato (OFSP).

Purple-fleshed sweetpotato roots have attractive reddish-purple color with high levels of anthocyanin and phenolic compounds. Also, dietary fiber in the root ranges from 2 to 4% of fresh weight (Huang *et al*., 1999). The ash content of sweetpotatoes is approximately 3% of the dry weight (dw) or between 0.3% and 1.0% of the fresh weight (fw). Potassium was the component with the greatest concentration in sweetpotato roots with an average of 396mg/100g fw.

Phosphorous, calcium, magnesium, iron. Copper, and magnesium all exist in notable amounts (Woolfe 1992). The orange fleshed genotypes are also tastier and attractive and therefore have the potential of addressing caloric and vitamin A deficiency situations in children among the poorest communities (Stathers *et al*., 2005; van Jaarsveld *et al*., 2006; Low *et al*., 2001). Meanwhile, majority of the cultivars found in sub-Saharan Africa are white-fleshed. These cultivars low yielding and also lack beta-carotene, (Stathers *et al*., 2005).

2.2.1. Uses of sweetpotato

The roots of sweetpotato and other parts of the plant can be used as food for human consumption, for animal feed, and for processing into raw materials in industries. Starch, sugars, and natural colorants are intermediary products that can be utilized in processing industries that produce edible and inedible products. Cultivars that have high amounts of dry matter (35-41 %), total starch (2527%), and extractable starch (20-23%) can be used to process starch (Brabet *et al*., 1998). In Japan, the orange-fleshed and purple-fleshed sweetpotatoes genotypes have been used to produce natural β-carotene and anthocyanin pigments in beverages and other food products for commercial purposes. Sweetpotatoes have less significance in the Ghanaian diet than some roots and tubers, such as yam, cassava or cocoyam, due to its high sugar content. It is used to sweeten porridges and some maize products, such as Aboloo (sweetened fermented maize dough that has been steamed or baked) (Osie-Opare and Adjei-Poku, 1977). The crop is progressively becoming well known to street food vendors to make sweetpotato into fries, especially during the times when yams are dwindling or when they are dry and not as palatable. Sweetpotato can also be used for traditional Ghanaian dishes such as Mpotompoto (mashed sweetpotato) (Danquah *et al*., 2000).

2.3 Processing of Sweetpotato fries

2.3.0 Pre-treatment of sweetpotato

There are several ways of treating sweetpotato before frying. These include blanching, pre-drying, sulphiting, to mention but few. Blanching is a thermal treatment commonly practiced in processing of a genotype of vegetable products including French fries. Blanching also reduces sugars that cause undesirable color and acrylamide formation due to Maillard reaction during frying (Truong *et al*., 2014).

Oluwole *et al* (2015), studied the effects of processing pre-treatment on polyphenol oxidase activity of sweetpotato and sensory properties developed chips. Three different pre-treatments were applied i.e. hot water blanching, sliced samples were immersed in water at 60 °C held in a water bath to maintain the temperature and steam generated from boiling water for 10 mins to avoid loss of product firmness; sulphiting, sliced samples were soaked in sodium metabisulphate solution 0.75 g/100 ml of distilled water for 5 mins at room temperature and pre-frying; samples were deep fried at 150 °C for 30 secs. The study revealed that sulphiting treatment had the least enzyme activity and was overly accepted by sensory panelists than the other pre-treatments. Blanching treatment caused a reduction in dry matter content because the sugars and other watersoluble materials were partially extracted by the hot water (Walter and Hoover 1986; Truong *et al*., 2014). Crust hardness was the highest when purple-fleshed SP strips were not blanched and par-fried during processing although strips without blanching had poor texture quality which was hard or felt like rubber (Oner and Wall 2012). They reported that purple-fleshed sweetpotato French fries (SPFF) with 10 min blanching had lower peak force than those of 0 and 5 min blanching although SPFF with a combination of 10 min blanching and par-frying significantly increased peak force. Sweetpotato crisps produced from drying pretreatment had the highest

Vitamin C content (35.25 mg/100 g) while samples without pretreatment had the lowest (22.42 mg/100 g) (Fetuga *et al*., 2016).

2.3.1 Vacuum frying

Important factors that may affect the stability of phytochemicals/nutraceuticals are the duration for frying and the frying method (Shirsat and Thomas, 1998). A very effective way to decreasing the oil content in fried snacks, sustain quality of the product and also lessen the decomposition of oil is by vacuum frying. Food is heated under reduced pressure [<60 Torr~8kPa] which causes a decrease in the boiling points of the oil and the amount of water in the foods, in vacuum frying (Shyu *et al*., 1998). French fries processed in a vacuum fryer can reach the necessary degree of moisture loss without being excessively darkened or scorched (Da Silva and Moreira 2008). A study on the quality attributes of some fruits and vegetables (sweetpotato chips, blue potato chips and mango) under vacuum conditions revealed that the vacuum fried products were able to maintain more of their natural colours and flavours due to reduced oxidation and low frying temperature (Da Silva and Moreira, 2008). A study by Garayo and Moreira (2002) also revealed that vacuum fryers are able to produce potato chips with low oil content (30% less) and the similar texture and color qualities of those fried using the conventional (atmospheric) method.

Yang *et al* (2012), studied the effects of vacuum frying and atmospheric frying on the physical and chemical properties and quality characteristic of deep-fat fried orange-fleshed and purple-fleshed sweetpotato cultivar. Vacuum fried snacks showed about 50% lower values regarding the moisture and fat contents compared to atmospheric fried snacks. There was considerable reduction in total carotenoid and anthocyanin contents of snacks compared to the raw sweetpotato root, and were greatly higher in vacuum-fried snacks compared to atmospheric-fried snacks. For the sensory

evaluation of snacks, vacuum-fried snacks were highly accepted in terms of colour and flavour, whiles that of texture was higher in atmospheric fried snacks due to a higher degree of crispiness.

2.3.2 Sweetpoato French fries

Deep-fat frying is one of the oldest and most general ways of processing food. It has been used in producing different processed foods like potato chips, French fries, doughnuts etc., because of the distinctive flavour and texture it gives to food (Da Saliva and Moreira, 2008). In the last decades, there has been an increase in the Consumption of deep fried foods since the consumption of frozen foods is becoming a growing market need (Matthäus 2006). Sweetpotatoes are well suited for use in many types of structured products than any other high beta-carotene vegetables. It would be particularly desirable to use sweetpotatoes as a substitute for the extremely popular American French fry product made from Potatoes (Walter *et al*., 2002).

Sweetpotato roots can be processed into products with improved qualities and extended shelf-life (Ali *et al*, 2012) and is therefore increasingly becoming a favoured raw material for French fries and crisps production (Gracia *et al*., 1998). They are mostly consumed fresh mainly due to the trouble in storing the high moisture roots after harvest (>70%) (Fasina, 2006). Sweetpotato chips and French fries are popular in many countries. In years past, most food processing industries in the United States have ventured into the production of sweetpotato chips and French fries with using genotypes with high beta-carotene content in response to the growing demands of consumers on healthy foods (Troung *et al*., 2011).

Cultivars that contain high amounts provitamin A (β-carotene) and vitamin C made into French fries and crisps can be used as potential nutritional snacks (Ali *et al*., 2012). The raw and cooked roots contain invert sugars ranging between 25% and 27% and 24% and 26% respectively which

makes it suitable for use as desserts or snacks when made into fries (Danquah *et al*., 2000). The use of the red fleshed and orange fleshed sweetpotato for the production of French fries and crisps would further improve nutrition of the consumers (Ali *et al*., 2012).

Researchers have carried out several studies on the preparation of high quality fried chip product (Walter and Hoover 1986). One major problem by these studies was discolouration which arises from two different sources. The first caused by reaction between o-dihydrioxyphenol and iron III which forms a gray discolouration and the second type of discolouration is non-enzymatic browning as a result of a condensation reaction between reduced sugar and amino acid group (Walter and Hoover 1986). However, the commercial production of sweetpotato French fries has been ventured into by many food processing companies due to the increase in market demand (Truong *et al*., 2014). The quality of fried chips and French fries are affected by sweetpotato cultivar, postharvest handling, and the condition for storing (Troung *et al*., 2011). The high reducing sugar content in sweetpotato would produce sweetpotato French fries with an undesirable brown colour when frying temperatures are above 170 °C (Friedman and Levin, 2008; Palazoğlu and Gökmen, 2008).

A study carried out by Odeningbo *et al*. (2012) assessed the quality changes during deep fat frying of five cultivars of sweetpotato 'Ginseng Red', 'Beauregard', 'White Travis', 'Georgia Jet clone #2010' and 'Georgia Jet'. The roots were peeled, sliced into cylindrical shape and deep fried in canola oil at 180 °C for 5 mins. 'Ginseng Red' was singled out as an acceptable cultivar for the processing French fries due to its low fat absorption, attractive color, and textural properties developed during frying. Any alterations in reducing sugars, amino acids, and other vital elements involved in the discolouration of sweetpotatoes affect the color of this product type (Troung *et al*., 2011).

Another study carried out by Akpapunam and Abiante (1991) showed that sliced sweetpotato roots blanched in water and 1% sodium metabisulfite solution, respectively, prior to the dehydration (at 70°C for 165 min) and frying (at 190°C for 2 min) significantly enhanced the color and overall acceptability of the chips compared to those dipped in water, only. Onigbogi *et al*. (2011) also fried sweetpotato slices in groundnut and melon seed oils and observed that chips fried with fresh melon seed was favoured than sweetpotato chips fried using groundnut oil. The color of sweetpotato chip fried with second frying oil and the sweetpotato chips fried with the fourth frying oil were significantly better than the other samples. The taste of chips fried with the fourth groundnut oil was notably better than the other samples. The crispy nature of sweetpotato chips fried with fresh melon seed oil and the one fried with the fourth frying oil was more favoured than the other samples ($P<0.05$).

It was observed that melon seed oil degraded the most compared to the other oils. Taiwo and Baik (2007) also carried out a study on the outcome of various pre-treatments (blanching, freezing, air drying, osmotic dehydration and control) on the shrinkage and textural properties of fried sweetpotatoes. Sweetpotato discs were pre-treated and fried in canola oil at 170 °C for 0.5–5 mins, respectively. There was a reduction in bulk density and an increase in porosity which was dependent on the duration of frying. The outcome of pre-treatment was insignificant on bulk density, but rather on the porous nature of the product. Samples that were used as control showed less shrinkage than the pre-treated samples. Utmost change in thickness of samples ranged between 6.7% and 10.2% and this is dependent on pre-treatment used. Utmost change in the diameter of the sample was noticed by 120 s of frying and the highest value was 18.3%. There was a vast difference in diameter between Pre-treated samples and the control samples. Variations in sample size increased with frying duration reaching a maximum at 120 s after which it either reduced or

leveled off. Generally, the pre-treatment enhanced the textural properties of fried samples in terms of hardness, springiness, chewiness, cohesiveness and, adhesiveness.

Ali *et al*. (2012), studied the effects of cultivar on quality attributes of sweetpotato fries and chips. The three different cultivars namely; Lovers Name, Black Vine and Red Big were washed, peeled, cut into French fries strips and deep fried in soy bean oil at 185 °C for 5 minutes. Lovers Name recorded higher appearance scores, this was however due to its orange colour which masks the grey colour of the other two cultivars. Meanwhile, Black Vine and Red Big recorded significantly better scores than Lovers Name in terms of taste and overall acceptability because of low sugar content of these cultivars. Texture characteristics and fat content of the fries are influenced by dry matter and starch content. An unsegregated approach including selecting acceptable genotypes, growing conditions, and proper postharvest handling and storage conditions should be considered in order to produce sweetpotato chips and French fries with consistent quality all year round (Troung *et al*., 2011).

Leksrisompong *et al* (2012) also assessed the effect of sweetpotato colour on consumer preference using various colours of sweetpotato (white, yellow, orange, purple). It was reported that the orange-fleshed sweetpotatoes had higher surface moisture and a softer texture against the other flesh colours. The orange and purple-fleshed sweetpotatoes had higher aroma values. Also, the purple-fleshed sweetpotatoes were thought to be more fibrousness and had a more firm texture. The orange-flesh was most accepted based on the flesh colour. It was found that the flesh colour could not be the major driving force of acceptability but the flavor and texture were the major drivers of acceptability. Consumers accepted the unique flesh colors only if the flavor and textural attributes were also well accepted.

2.4 Product quality attributes

2.4.0 Oil content

The choice for a particular cultivar can significantly influence the uptake of oil in French fries and this happens due to the cellular structures of different genotypes which affect decrease in moisture content and subsequently oil uptake in the final product (O'Connor *et al*, 2001). A food product is denied its typical appealing taste and odour when too little oil is used in frying. Likewise, increased levels of oil absorption in a fried product leaves it with an oily taste. Basically, the absorption of oil in fried potato products has been linked to the moisture, starch and dry matter content of the raw root and also temperature of the frying oil (Kita, 2002; Basuny *et al.*, 2009). Walter and Hoover (1986) reported 15.6 to 19.6% oil content in Sweetpotato French Fries fried at 175°C for 2.5 mins while Oner and Wall (2012) reported 9.5 to 37.9% dw (dry weight) oil content in purplefleshed Sweetpotato French Fries fried at 180°C for 3 mins.

Esan *et al* (2015), researched on process optimization by response surface methodology and quality attribute of vacuum fried yellow-fleshed sweetpotato chips. Sliced samples were deep fried using a vacuum fryer at a temperature range of 108 °C - 136 °C at time range of 3-9 mins and vapour pressure ranging from 4.91-19.9 cmHg. it was realized that, the fat content of the fried yellow-fleshed sweetpotato samples increased at lower vapour pressure and lower frying temperature whiles the a higher frying temperature and low vapour pressure there was a reduction in the fat content of the fried samples. However, at higher frying temperature and lower vapour pressure on one hand and higher vapour pressure and lower frying temperature the oil content of the fried samples reduced.

Moreira *et al*. (2009) recognized that just 14 % of the total oil content (TOC) is internal oil content (IOC) while 86 % is surface oil content (SOC) in fried potato chips. Almost 34 % of the IOC and

0.7 % of the SOC are taken up during the first 20 s of frying operation. The bulk density and porosity values for the centrifuged (surface oil removed) chips were 564 kg/m^3 and 0.6, respectively, while these values were 800 kg/m^3 and 0.36 for the non-centrifuged ones (surface oil not removed). The amount of oil absorption was raised with increasing moisture content of the raw strips (Walter and Hoover 1986). Prolonged blanching time marred the surface of the strips, increasing water evaporation and thereby raising oil uptake (Oner and Wall, 2012). Processing treatment before final frying also influences oil content. O'Connor *et al*. (2001) reported strips processed without blanching, drying and freezing contained only 5.8% oil while WPFF processed with blanching, drying, par-frying and freezing contained 7.1-10.9% oil. Moreover, increase of frying time increases oil content and decrease moisture content (Du Pont *et al*. 1992).

Fetuga *et al* (2013), observed high oil content in sweetpotato crisps that pre-treated using drying than in blanched samples. The study revealed that the high oil content could be attributed to the thin slice used and amongst other factor including the type of oil used.

2.4.1 Moisture content

A study by Farinu and Baik, (2007) revealed that the initial moisture content of the sweetpotato sample decreased during frying. At the initial stage of frying there was increased moisture loss. However, the moisture loss rate reduced as frying progressed. They also noticed an increase in moisture loss rate for smaller sample size as well as a higher oil temperature.

Fetuga *et al*, (2016) observed lower moisture content in fried sweetpotato crisps (1.13 and 4.93%) as compared to previous studies. The low values reported in the study was attributed to the lower slice thickness as well as differences in frying conditions and pre-treatment.

2.4.2 Texture

Texture is a very essential quality attribute for foods since it has a dominant impact on acceptability and the quality of the product (Kayacier and Singh, 2003). It can be assessed by instrumental analysis and sensory evaluation (Steffe, 1996). The determination of texture by instrumental analysis is easier, more accurate, and less time consuming (Kayacier and Singh, 2003). There have been several publications on the textural properties of sweetpotato French fries. Lima and Singh (1995) employed compression, puncture and three-point bending, which are instrumental methods to explain the texture of the outer and inner parts of white potato French fries.

Du Pont *et al*. (1992) compared the sensory properties with objective instrumental methods to be able to understand and quantify the outcome of deep-fat frying on the characteristics of white potato French fries. Oner and Wall (2012) noted that the perceived softness of SPFF due to weak crust and moist interior was related to low DM and low oil contents. Changes in WP texture during processing are associated with water loss, damage of potato tissue and non-starch polysaccharide and lignin contents. The cells of the outer layers of WPFF were much smaller that of the unprocessed potato strips due to water evaporation. The ultimate texture of French fries was developed during frying by oil penetration into the outer layer of strips (Lisińska and Gołubowska 2005).

Kita and Lisińska (2005) reported that increase of frying temperature decreased oil content resulting in decrease of instrumental hardness and interior sensory oiliness, and increase of sensory crispness. The reason for this phenomenon was not revealed. Walter *et al*. (1992) studied the effect of tissue acidification on firmness of SPFF and reported that starch hydrolysis would be inhibited by tissue acidification resulting in firmer tissue. Laurie *et al*. (2013) studied the instrumental and sensory characteristics of boiled SP as affected by the chemical components. They reported poor

correlation coefficients between sensory firmness and instrumental firmness (r = 0.47), sensory wateriness with starch (r = –0.54) and DM (r = –0.60), maltose content with sweet flavor (r = 0.51). They also found that sweet flavor was positively correlated with consumer acceptability (r = 0.73). Walter *et al.* (2002) studied the texture of restructured SPFF made from SP puree mixed with alginate and calcium sulfate. Descriptive sensory test and instrumental measurements including puncture, three-point bending and Kramer shear tests were conducted. Four sensory attributes, including springiness, hardness, density and mastication shear, were highly correlated with instrumental measurement (r = 0.80-0.91). On the other hand, cohesiveness, oiliness, moistness and compression while chewing were negatively correlated with instrumental measurement (r = –0.80 - –0.92).

A study by Gao *et al*. (2014) revealed that high dry matter content and starch content of sweetpotato negatively affects the texture qualities of fried sweetpotato chips. They also noted that the ratio of starch to dry matter contents in sweetpotato significantly correlated with peak fracture forces of blanched chips (r = 0.623, P = 0.023) and those that were not blanched (P = 0.151).

Teruel *et al* (2015) studied the quality of French fries by deep fat frying and air frying. There were no variations between the 2 frying methods for the outer part of the fries at different frying times with regard to the effect of frying method. However, with the internal region, the air fried samples showed higher hardness work values ($P<0.05$) than the deep fat fried samples. They stated that the differences in the internal texture could be as a result a smaller degree of gelatinization occurring in air fried samples, associated with the prevalence of lower temperatures inside the product.

2.4.3 Starch content

Sweetpotatoes possess a number of physical and chemical characteristics. Generally, they are made up mainly of carbohydrates (80% to 90% dw), with starch being the greater portion forming 50% - 80% of the roots' dry matter (Woolfe, 1992). The use of starch in food systems are basically controlled by gelation, gelatinization, pasting, solubility, swelling, colour and digestibility. The high carbohydrate content of sweetpotato and its wide availability makes it an excellent source of starch for both domestic and industrial uses in tropical Africa (Chibuzo, 2012). Sweetpotato starch is made up of a mixture of amylose and amylopectin which possesses the A-type (high swelling) pattern and, its starch granules are medium sized with a smooth round oval shape like those possessed by other roots and tubers (Woolfe, 1992). Starch from sweetpotato can be used in making products such as noodles, cakes, bread, biscuits, desserts, alcoholic and non-alcoholic drinks, puddings and confectionery products.

The starch content in sweetpotato ranges from 6.9% to 33.5%. Many sweetpotato genotypes possess an active system of amylolytic enzymes which degrades starch at a very fast rate once its reaches its gelatinization temperature and produces a dextrinous material which makes it however rare to find textural properties of French fries made from sweetpotatoes being similar to those of fries made from white potatoes (Walter *et al*., 1997). During frying, starch granules in WP are rapidly gelatinized, fragmented and compacted into one mass which occupies the whole volume of the cell (Aguilera *et al*., 2001). Sensory properties and shelf life of potato products depend on the molecular interactions of starch with non-starch polysaccharides (Lisinska and Leszczynski, 1989). Komiyama *et al*., (2002), stated that the high starch content WPFF had a softer and flourier texture. They also reported that WPFF with 16% starch in raw WP were preferred by consumers.

2.5 Effects of frying on β-carotene

Reports have showed in recent years that during preparation a decrease in the β-carotene content occurs in sweetpotato and vegetables (van Jaarsveld *et al.*, 2006). A study done by van Jaarsveld *et al*. (2006) on the true retention (TR) of β-carotene in boiled, mashed OFSP revealed that there was a difference in the true retention of β-carotene with respect to the mode of preparation. They also observed that the sweetpotato boiled in a pot of water and covered with a lid for a short period (cooking to just doneness) was able to preserve its β- carotene content. In the process of frying, degradation of β-carotene due to oxidation and/or trans–cis-isomerization of β-carotene may occur, thereby decreasing its biological activity. Wu *et al*. (2008) researched on the outcome of preparation on β-carotene content in sweetpotato cultivars from China. Comparing boiling, steaming and microwave cooking to frying, there was no observed decrease in the β-carotene content of the peeled, steamed and mashed sweetpotato, however, there was a 6% increase in βcarotene content of the fried sweetpotato cake. This might be because of the higher extractability of β-carotene due to changes in the structure of the cell wall during the short frying time. A study by Kidmose *et al*. (2007) after boiling and roasting sweetpotato recorded true retention (TR) values > 100% for some genotypes. They also observed that the degree of stability of all-trans-β-carotene during heating seemed to be dependent on the genotype.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1.0 Source of Raw Materials

The ten different genotypes (*Bohye, TU-Purple, Nanungungu, Dadanyuie, Apomuden, CIP440390, CIP442162, Patron, Otoo, and Obare*) of sweetpotato were obtained from the farms of International Potato Center (CIP), Tamale and transported to the CIP laboratory in Fumesua.

Yam which was also used as control was obtained from Ayigya market center.

Table 3.1: The ten genotypes and their flesh colours Genotype
Flesh colour

Apomuden	Deep orange
Bohye	Pale orange *Nanungungun*gu
Pale orange	
Otoo	Pale yellow
CIP442162	Pale yellow
Patron	Pale yellow
CIP440390	Pale cream
Obare	White

Dadanyuie	White TU-Purple	Purple

CIP, 2017.

3.2.0 Dry matter determination of fresh roots

Two root tubers were selected at random from each of the ten genotypes and transported to the Department of Food Science and Technology laboratory, KNUST. The samples were washed, peeled, grated and 5g of each of the ten genotypes weighed into a petri dish, and dried using a hot air oven (Binder Heating and Drying Oven, serial no: 15-18440, Tuttingen, Germany) at 80°C for 24 hours. The dried samples were transferred into a desiccator and allowed to cool to ambient temperature and then weighed (Kathabwalika *et al*., 2016). The analysis was conducted in triplicate. The percentage dry matter was then calculated for each of the ten genotypes.

3.3.0 Starch Determination of fresh roots

Three raw roots from each genotypes were sampled at random, washed under running tap water and peeled. The peeled samples were grated and 200g of each genotype was weighed. The samples were blended with enough water for 1-2 minutes after which they were transferred into bowls and stirred. The mixture was strained using a fine cheese cloth into another plastic container. This was allowed to settle for 12 hours and the water at the top decanted, leaving the starch at the bottom. The starch was then dried in the hot air oven (Binder Heating and Drying Oven, serial no: 1518440, Tuttingen, Germany) at 60°C for 18 hours to remove more moisture from the starch. The weight of the dried starch was taken and the percentage starch was calculated (Kathabwalika *et al*., 2016).

3.4.0 Frying Experiment

Four sweetpotato root tubers were selected at random, washed under running potable tap water and manually peeled using a stainless sweetpotato peeler. The roots were then cut, manually into a French-fry strip (0.7cm × 0.7cm × 7.5cm) using a stainless steel knife. The cut strips were rinsed under running tap water and patted with tissue paper to remove surface water and deep-fried in sunflower oil (2.5 L) at 175°C for 5 minutes using a domestic fryer (Akai Deep Fryer; model DF006A-388, China). An average of 15 strips were fried for each batch of sweetpotato genotype. Fries obtained were placed in zip lock bags and then used in sensory evaluation, moisture, fat, colour and beta-carotene analysis.

3.5.0 Sensory Evaluation of fried samples

Quantitative descriptive analysis was conducted using 8 trained panelists. Panel members were trained for 3 times within a week for 2 weeks. They were taken through basic tasting for sweetness, sourness and bitterness using sugar solution, lime juice and quinine at different concentrations respectively. Afterwards, they were taken through texture and colour training using fruits, crackers and crips. Fried sweetpotatoes were introduced to participants and asked to come up with attributes that can best describe the fried sweetpotatoes or fries in general. A scale was designed based on these attributes and panelists were asked to assess the fried sweetpotatoes. The attributes were colour, crunchiness, hardness, moisture, sogginess, caramel, starch/rawness, oily mouth coat, all on a scale of 1-9 with 9 indicating highest and 1 as lowest. The evaluations were done between the hours of 10 am and 12.30 p.m at the International Potato Centre (CIP-Ghana) postharvest laboratory.

3.6.0 Moisture, Fat, Colour and Beta-carotene of Sweetpotato fries

3.6.1 Moisture determination of sweetpotato fries

Petri dishes were washed clean and dried in an oven at 103°C for 20 minutes and allowed to cool in a desiccator to room temperature. The cooled petri dishes were then labelled and weighed using a calibrated electronic measuring scale. The fried sweetpotato samples were reduced to smaller particle size and 5g of each of the different genotypes were weighed into the petri dish in triplicate. Thereafter, the samples were placed in a desiccator and transferred into the oven and dried at 105°C for to constant mass. After the drying process, the sample were transferred back into the desiccator and allowed to cool and then weighed (AOAC, 1990).

3.6.2 Determining the fat content of sweetpotato fries

Soxhlet extraction method was used to determine the fat content of the fried sweetpotatoes. A 250 ml round bottom flask was washed, rinsed and dried at 103 ºC ± 2 ºC for an hour. It was cooled to room temperature and weight noted. About 5g of sample was weighed into a filter paper, folded, stapled and put into a thimble. The thimble was then placed in the extracting chamber of the soxhlet extractor. About 240 ml of petroleum ether was poured into the 250 ml round bottom flask and then fixed to the extractor and then the condenser. The burner, on which the extractor was positioned, had a temperature that allowed about 10 – 15 drops of petroleum ether from the condenser to the extractor containing the thimble. Extraction was then done for 15 hours. After the extraction process, the petroleum ether was recovered and poured into a Winchester bottle. The thimble containing defatted sample was then removed from the extraction chamber and the defatted samples taken out and further dried in a hot air oven, cooled in a desiccator and then weighed (AOAC, 1990).

3.7.0 Determining the colour of sweetpotato fries

A hand held Konica chromameter CR-410 (Minolta Co. Ltd., Osaka, Japan) was used to determine the colour of milled sweetpotato fried samples. The chromameter was first calibrated with a white tile. The sample flour was poured to fill a petri dish and then covered. The lens of the chromameter was placed on the petri dish at three different parts. The colour measurements were then taken and recorded as L*= darkness/lightness (0 = black, 100 = white), a* (-a = greenness and +a = redness), and b* (-b = blueness, +b = yellowness). C* is chroma, ranging from 0 (least saturation) to 60 (full saturation); and h° is hue angle, ranging from 0° to 360° where 0° or 360° is red, 90° is yellow, 180° is green, and 270° is blue (Oner and Wall, 2013).

3.8.0 Beta-carotene analysis on fresh and fried sweetpotatoes

The interest of this study was to determine the β-carotene content of only the orange-fleshed sweetpotato genotypes (*Apomuden, Bohye and Nanungungun*) using the method described by Imungi and Wabule (1990). The fresh and fried sweetpotatoes were freeze dried (Vacuum Freezedrier YK-118-50, Taiwan) and milled into flour. 2g of flour sample was weighed into a beaker and then transferred into a mortar. It was then grinded with 50 mL cold acetone. This was filtered with suction through a Buchner funnel. The mortar, pestle, funnel and residue were rinsed with small amounts of acetone, receiving the washings in the suction flask through the funnel. The process was repeated until the residue was devoid of colour. 40 mL of petroleum ether was poured into a 500 mL separation funnel with Teflon stop-cock after which acetone was added. Two hundred millilitres of distilled water was slowly added along the walls of the funnel. The two phases were allowed to separate and the lower aqueous phase discarded. It was washed 4 times, using 200 mL of distilled water each time in order to remove residual acetone. The petroleum ether phase was collected into a volumetric flask by making solution pass through a small funnel

containing anhydrous sodium sulphate to remove residual water. The separation funnel was washed with petroleum 51 ether, collecting each washing in the volumetric flask by passing it through the funnel with sodium sulphate. This was further evaporated to dryness by passing it under a stream of nitrogen gas. It was reconstituted with a known volume of mobile phase. 20 µl of the reconstituted solution was injected into Shimadzu HPLC equipment. The Shimadzu HPLC equipment was made up of an LG6 pump, a UV-Visible detector, a CR6 recorder, ODS-RESERVED PHASE column and a Ryhodyne 1725 injector. Mobile phase was made up of acetonitrile 70%, 20% dichloromethane and 10% methanol. The flow rate was also 1mL/min and wavelength 450nm.

Before sample solution was injected a standard β-carotene was dissolved in petroleum ether and absorbance read at 540 nm. Since the absorption read was 0.432, which was between 0.2 and 0.8, it was injected into the Shimadzu HPLC equipment and the elution time noted. This was to help note the peaks for the sample injections, which was then used to calculate the β-carotene content of the samples.

3.9.0 Statistical analysis

Data obtained was analyzed using one-way analysis of variance (ANOVA) and Tukey's HSD test at 95% confidence interval. Data was expressed as mean and standard deviation. Pearson's correlation was also employed to ascertain any relationship between parameters determined.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1.0 Dry matter and starch of sweetpotato roots

4.1.1 Dry matter of sweetpotato roots

Dry matter refers to materials remaining after removal of water. The dry matter of the different genotypes of sweetpotato ranged from 24.05% to 44.99%. *Apomuden,* an orange-fleshed sweetpotato genotype had the lowest dry matter content (24.05%) whiles *Dadanyuie* had the highest value (44.99%) (Table 4.1). These were similar to values (23.3%-34.45%) reported by Kathabwalika *et al* (2016). The cultivar (BV/009) that recorded the lowest value according to Kathabwalika *et al* (2016) was an orange-fleshed cultivar. Dry matter is a very essential quality attribute in the production of sweetpotatoes as it shows mealiness in boiled or the core of fried sweetpotato and it an attribute that is mostly preferred by consumers (Kathabwalika et al., 2013).

Table 4.1. Dry matter and starch content of sweetpotato genotypes

Genotype	Starch content (%)	Dry matter (%)
Bohye	19.79 ± 0.06^{f}	32.97 ± 0.26^{abc}

CIP442162	17.59 ±0.13^{e}	29.54 ± 0.58^{ab}
Patron	17.46 ± 0.20^{e}	36.31 ± 0.24^{abc}
Obare	16.50 ± 0.08^{d}	31.03± 0.17^{ab}
Nanungungun	15.87± 0.06^{c}	29.97 ± 0.26^{ab}
TU-Purple	14.46 ± 0.01^{b}	33.77 ± 0.25^{bc}
Otoo	14.18 ± 0.15^{b}	36.08 ± 0.09^{bc}
Dadanyuie	14.11± 0.04^{b}	44.99 ± 0.75^{c}
CIP440390	14.09 ± 0.05^{b}	32.13 ± 0.20^{abc}
Apomuden	10.12 ± 0.03^{a}	24.05 ± 0.36^{a}

Values are represented as mean±standard deviation
Values in the same column with same superscripts are not significantly different (p>0.05)

The results presented in this study fell within the general dry matter content of sweetpotato cultivars, which ranges from 13% – 45% (Aina *et al.* 2009; Mensah *et al*. 2016). The dry matter content (24.05%) of the orange-fleshed genotype (*Apomuden)* also fell within 20.4% and 27.8% as presented by Hagenimana *et al*. (1998) of other orange fleshed sweetpotato genotypes.

However, the value of the purple-fleshed (*TU-Purple*) genotype did not fall within the range (20.3% to 30.2%) reported by Hagenimana *et al.* (1998), but was slightly higher (33.77%).

Waramboi et al (2011) had dry matter content values ranging from 14.7% to 28.2%. These values are however lower than the results of this study. The orange-fleshed genotypes recorded the lowest dry matter content values ranging from 18.2% to 22.3% (Waramboi et al 2011). This is however a little lower than the values recorded for the orange-fleshed genotypes (Table.4.1). No significant differences (p>0.05) were observed between the orange-fleshed genotypes, *Apomuden* and *Nanungungun*. Moreover, there were no significant differences (p>0.05) observed amongst some pale yellow, cream genotypes and the orange-fleshed genotypes (Table 4.1).

4.1.2 Starch Content of sweetpotato roots

In relation to the dry matter content, the starch content followed a similar trend. *Apomuden*, an orange-fleshed genotype had the least starch content of 10.12% while *Bohye* recorded the highest (19.79), on fresh weight basis (Table 2). Although *Nanungungun* is an orange-fleshed genotype, it recorded a much higher starch content than *Apomuden*. This may be due to their genetic makeup. *Nanungungun* is a landrace genotype already grown in the Upper East Region of Ghana and has been known to be one of the few orange-fleshed genotypes with relatively higher starch content and dry matter. Due to this farmers are already cultivating this genotype. *Apomuden* on the other hand was made to contain very high beta-carotene content, however it ended up with much higher moisture content and very low dry matter and starch. A significant difference was observed between *Apomuden* and all other genotypes in terms of the starch content. However no significant differences were observed amongst TU-Purple, *Otoo*, *Dadanyuie* and CIP440390. *Nanungungun* was also found to be significantly different from all other genotypes (Table 4.1).

The values obtained were lower than the values recorded by Kathabwalika et al (2016). The starch content of the genotypes in their study were in the range of 22.4% to 27.7%. Their study also revealed that, the average starch content of the genotypes across all the sites were in the range of 20.5% to 29.6%. Utomo and Rahman (2015) reported starch content to be significantly different ($p<0.05$) amongst three cultivars (white, yellow and orange). The starch content values ranged from 12.34 % to 19.30 % (fwb). These values fall within those obtained in this study. Utomo and Rahman (2015) reported that the white cultivar had the highest starch content (19.30 %) which is however higher than the values obtained for the white flesh genotypes in this study (Table.4.1). The pale yellow fleshed was rather found to have the highest starch content value in this study. However, the values recorded by Tuffuor (2013) was found in the range of 14.6% and 31.7% (fwb)

which was comparably higher than what was observed in this study. The combination of high dry matter (>25 %) and starch helps in selection of genotypes for use as fries (Lebot, 2009).

4.2.0 Moisture and fat content of fries

4.2.1 Moisture content of fries

The results revealed high moisture content in the fried sweetpotato genotypes. Moisture content ranged from 20.78% to 51.68%, with *Apomuden* (51.68%) recording the highest moisture content value whiles *CIP440390* had the lowest moisture content amongst the ten genotypes (Table 4.2). However, Yam which was used as a control recorded the least moisture content with a 10.79% value. Genotypes that had low dry matter content had higher moisture content and those with higher dry matter content also had low moisture content after frying. This is true because dry matter increases with decrease in moisture content and vice versa.

Truong et al. (2014) reported that moisture content of Covington SPFF was in a range of 50.1 %67.7 % depending on pre-treatments and frying time. This is similar with the orange-fleshed sweetpotato (*Apomuden*) fries which recorded 51.68% moisture content. The moisture content of restructured sweetpotato sticks made from white and yellow-fleshed sweetpotato cultivars reported by Utomo and Rahman (2015) had higher moisture content than the orange-fleshed sweetpotato. This however contradicts the results obtained from this study with orange-fleshed sweetpotato (*Apomuden*) recording the highest value (51.68%). This could be due to the genetic makeup of their genotypes and restructuring of the sweetpotato sticks. *Apomuden* has very high moisture content, however, the orange-fleshed genotype reported by Utomo and Rahman (2015) may have

had much higher dry matter their white and yellow-fleshed sweetpotato genotypes reported in their study.

Bohye and *Nanungungungu* which are also orange-fleshed genotypes had values lower than that of the orange-fleshed cultivar reported by Utomo and Rahman (2015). Odenigbo *et al*., 2012 also reported moisture content values ranging from 23.50% to 52.67% for French fries from five different cultivars of sweetpotato. Crispiness and increased shelf stability of fried products is mostly due to low moisture content (Fetuga *et al*, 2016). Therefore, it is expected that yam may be more crunchy/crispy and may have a longer shelf life that the sweetpotato genotypes. Amongst the sweetpotato genotypes, the orange-fleshed genotypes (*Apomuden*, *Dadanyuie*, *Nanungungun* and *Bohye*) may be relatively less crunchy and may have a shorter shelf life.

Between genotypes, some of the genotypes were not significantly different ($p>0.05$) from each other (Table.3). Oner and Wall (2012) recorded higher values of moisture content in purple-fleshed sweetpotato (PFSP) fries. The values ranged from 20.13% to 60.04%. The moisture of the purplefleshed sweetpotato genotype of this study was found in this range.

4.2.2 Fat content of fries

Fat content ranged from 14.00% to 23.96% with *Dadanyuie* having the lowest value whiles *CIP442162* had the highest value (Table.3). These values are higher than the fat content values (6.90% -15.54%) reported by Odenigbo *et al*. (2012) in their study. However, fat content in this study was found to be lower than those recorded by Esan *et al.* (2015). These differences could be as a result of the different sweetpotato genotypes used.

Statistically, a number of sweetpotato genotypes were not significantly different from one another ($p>0.05$) (Table 3). Fetuga *et al* (2016) recorded higher values of fat content in fried sweetpotato crisps after pre-treating the samples and frying at 170 °C for 3 mins. Their values ranged from 18.5% to 32.0%, and were found in the range of 22.74% and 35.63%, reported by Rani and Chauhan (1995) but lower than 35.77% to 39.44% (Kita, 2002) for potato crisps. The higher values may be due to the slice size of sweetpotatoes and genotype. Fat uptake during deep fat frying of French fries is usually affected by pretreatment and frying time (Lamberg *et al*. 1990). The values could not have been the same considering the conditions under which the genotypes were produced.

Table 4.2. Moisture and fat content of the sweetpotato and yam fries

Genotypes	Moisture content (%)	Fat content (%)
Yam	10.79 ± 0.02^{a}	20.38 ± 3.45^{abc}
CIP440390	20.78 ± 0.20^{b}	23.54 ± 1.39^{bc}
Obare	21.35 ± 0.73^{b}	14.25 ± 1.21^{a}
Patron	22.24 ± 1.09^{bc}	18.54 ± 0.01^{abc}
TU-Purple	25.25 ± 0.21^{cd}	16.93 ± 2.43^{ab}
CIP442162	25.54 ± 2.04^{d}	23.96 ± 2.56^{c}
Otoo	27.24 ± 0.08^{de}	14.95 ± 1.63^{a}

Bohye	29.68 ± 0.65^{e}	17.96 ± 0.93^{abc}
Nanungungun	33.43 ± 0.42^{f}	17.04 ± 1.48^{abc}
Dadanyuie	34.06 ± 0.94^{f}	14.00 ± 0.23^{a}
Apomuden	51.68 ± 0.13^{g}	17.39 ± 0.76^{abc}

Values are represented as mean±standard deviation
Values in the same column with same letters are not significantly different (p>0.05)

It was suggested that the increased surface moisture content resulted in an increased fat uptake (Lamberg *et al*., 1990). In this study, the moisture on the surface of the strips of sweetpotato were patted dry and this may have influenced the absorption of oil.

Oner and Wall (2012) also reported fat content between 9.5%and 37.9%, dry weight, in purplefleshed sweetpotato French fry. Oil content in white-fleshed sweetpotato French fries normally ranges from 9 to 15% (Miranda and Aguilera 2006; Van Loon et al. 2007). The fat content of the white fleshed sweetpotato in this study fell within this range (Table 4.2).

High moisture and fat content may result in fries becoming soggier; thereby making it less crunchy. This may not be desired by consumers. However, if fat content is high but moisture content is low, as can be seen in the yam in this study, the sample becomes crunchy and is desirable.

4.3.0 Sensory evaluation of sweetpotato fries

4.3.1 Taste score for sweetpotato fries

The taste score for the sweetpotato fries is made up of attributes such as sweetness, caramel, starch/rawness and oily mouthcoat. These were grouped under taste score because they are all attributes perceived by means of taste. Of all the genotypes used in this study, the orange-fleshed genotypes, *Apomuden* and *Nanungungun* were the sweetest; with scores ranging from 7 to 8 (ie. From sweet to very sweet) (Fig 4.1). The least sweet was the control sample, yam, while the less

sweet amongst the sweetpotato genotypes were *Patron*, *CIP440390, Obare*, *TU-Purple*, *CIP442162* and *Bohye*. These genotypes all had similar scores within 4 and 5, which indicates moderate sweetness (Fig 4.1).

Caramel sensation indicated the level at which the strips were burnt due to the frying process. A high detection of caramel sensation on the scale from 7-9 indicates that the sample got burnt while a lower value 1-6 indicates the sample was moderately burnt or did not burn at all. All samples had low scores with a slight detection of caramel sensation in *CIP440390*, *Bohye*, *Dadanyuie*, Otoo and *Apomuden* (Fig 4.1). This indicates the frying conditions chosen were suitable for the strips. This could also be confirmed by the almost zero detection of starch/rawness in the samples (Fig 4.1). This indicated that the starches in the samples were gelatinized. Therefore with the slight detection of caramel sensation and almost no detection of starch/rawness, (which was to determine whether the fries were cooked or not) the frying conditions chosen were right for these strips. The frying conditions were chosen from a series of experiments with varying oil temperatures and time of frying.

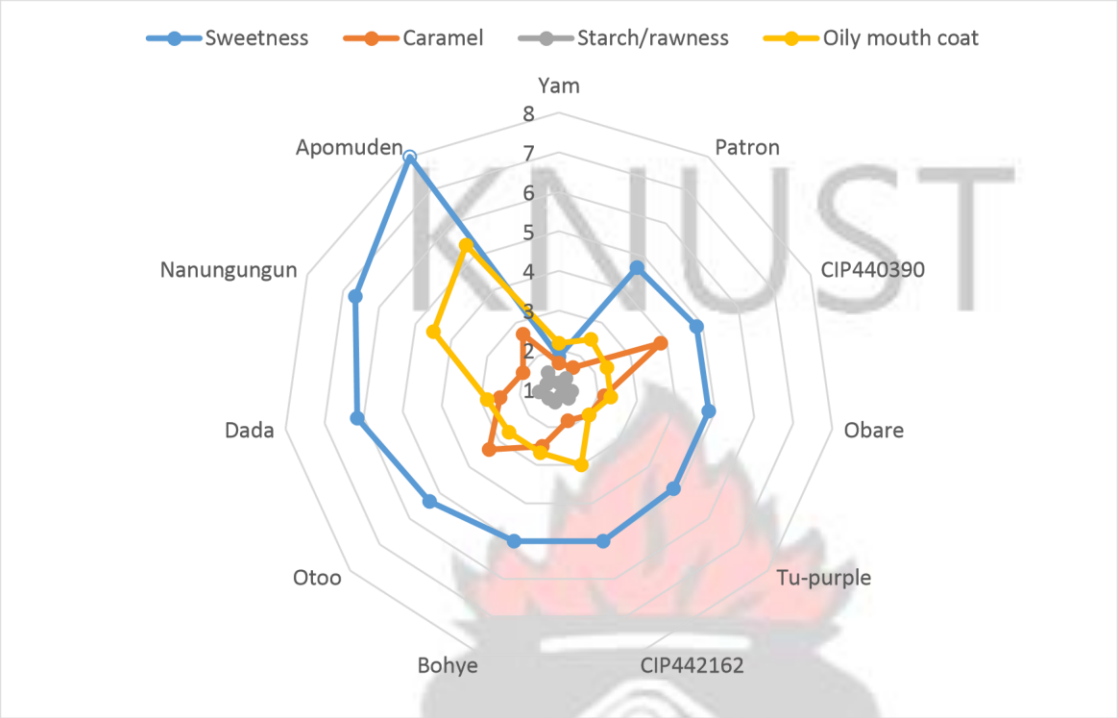

Fig 4.1: Taste score for sweetpotato fries

Oily mouthcoat sensation was detected more in *Apomuden* and *Nanungungun* than all the other genotypes. They had scores between 4 and 5, which indicates either slight detection of oily mouthcoat or no detection (Fig 4.1). These genotypes are the orange-fleshed genotypes among the sweetpotato samples chosen for this study. According to Costa *et al*. (2001), high oily mouth coat may be due to the migration of oil into the cells of the food formed by cell wall shrinkage and water evaporation. Moreover, orange-fleshed sweetpotato genotypes absorbing lots of oil during deep frying may be mainly due to the low starch or dry matter content and beta-carotene content in the samples. Beta-carotene is more non-polar and easily dissolves in non-polar solvents such as oil. Since the orange-fleshed genotypes have more beta-carotene as part of their components, interconnected with other components in the sample, they are more likely to absorb more oils than

the non-orange-fleshed genotypes. *Bohye* is a pale orange fleshed genotype but has more starch or dry matter than *Nanungungun* and *Apomuden*, hence may not have absorbed that much oil.

However these claims are not directly in sync with the fat content of the samples in figure 4.1. For instance, yam, *CIP440390* and *CIP442162* had the highest fat content, however they had low oily mouth coat values when sensory evaluation was conducted. This could be because oily mouthcoat may be enhanced by certain factors such as moisture content of sample or low starch content.

4.3.2 Appearance score of sweetpotato fries

The appearance score is made of colour, sogginess and moistness and is perceived mostly by sight. The moistness and sogginess were perceived by feeling in fingertips and sight as well (These were determined by looking out for dampness of the sweetpotato fries).The colour had to do with the detection of browning, sogginess the detection of oil/moisture and moistness the detection of moisture. *Apomuden* had the highest score for moistness with an average score between 6 and 7, followed by *Dadanyuie* and *Nanungungun*. These had high moisture contents as was seen in figure 4.3. The least moistness score was seen in yam which was the control. Moistness was found to be positively and significantly correlated with the moisture content of the fries ($r = +0.829$, $p = 0.007$).

Regarding sogginess, *Apomuden* and *Nanungungun* were regarded as soggy, which was in line with the "oily mouthcoat" in Fig 4.1. These two genotypes have high moisture content, hence low dry matter, and in addition to the amount of oil absorbed, the fries produced from these genotypes came out soggy. Browning was seen in *Otoo* and *Obare* at a level of 4 and 5, which represented "somewhat brown". The other genotypes, including the orange-fleshed genotypes and purple had less browning in them. Again, this indicates that the frying conditions used were good to not cause

a lot of browning but just enough to cook all starches in the sweetpotato. According to Teruel *et al* (2015) some level of browning occurs during deep frying in oil.

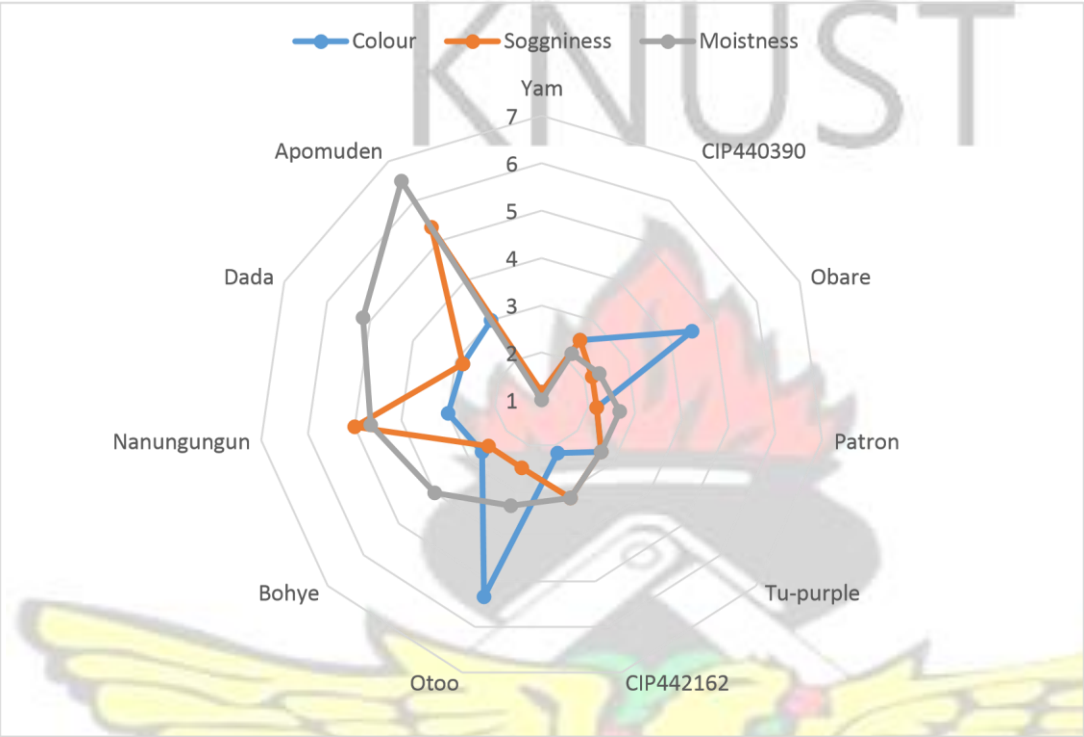

Figure 4.2: Appearance score for sweetpotato fries

4.3.3 Texture score of sweetpotato fries

Texture is a very essential quality attribute for foods since it has a dominant impact on acceptability and the quality of the products (Kayacier and Singh, 2003). Regarding fries, texture is key, because the crunchiness/crispiness and hardness of a fried sample will affect its acceptability by consumers. The texture score for the sweetpotato fries comprised of crunchiness and hardness. Yam was the crunchiest with an average score of 7 while *TU-Purple* and *Bohye* followed with an average score between 4 and 5, which represented "less crunchy" and "moderately crunchy", on a scale of 1-9 (Fig 4.3). The least crunchy samples were *Apomuden* and *Nanungungun* with an average value less than 2, representing "soft" on the 1-9 scale developed (Fig 4.3).

The orange-fleshed genotypes (*Apomuden* and *Nanungungun*) have high moisture content with low dry matter causing them to be flat/soft/stale instead of crunchy after frying, compared to yam which has high dry matter. Oner and Wall (2012) noted that the perceived softness of sweetpotato fries, due to weak crust and moist interior, was related to low dry matter and low oil contents. During frying, water which helps maintain the texture of samples before frying, evaporate to be replaced by the oil being used to fry. However, in samples with very high moisture content, there was still some level of water present and therefore much oil is was not absorbed. The water evaporated, weakens the structure of the samples, thereby causing it to lose its texture. As a result the sample is not able to be crunchy. This may have been the reason why low dry matter genotypes such as the orange-fleshed genotypes used in this study are unable to be crunchy.

Hardness followed a similar trend as that of crunchiness. However lower values were obtained (Fig 4.3). How hard fries may appear, will affect consumer acceptability. If fries are too hard consumers might reject it, while samples that are too soft may not be appealing to consumers. Therefore a moderately hard sample, “a sample that is just right” is what processors should thrive hard to achieve. This is difficult to get as it may vary with regards to the region, country, town and even type of consumers. Therefore a study could be conducted to determine exactly the level of hardness consumers in a particular region may prefer, in order to assist processors of fries. Sensory evaluation and texture analysis could be very important tool to use. In a study by Teruel *et al* (2015) the deep fried fries were found to be less/moderately hard.

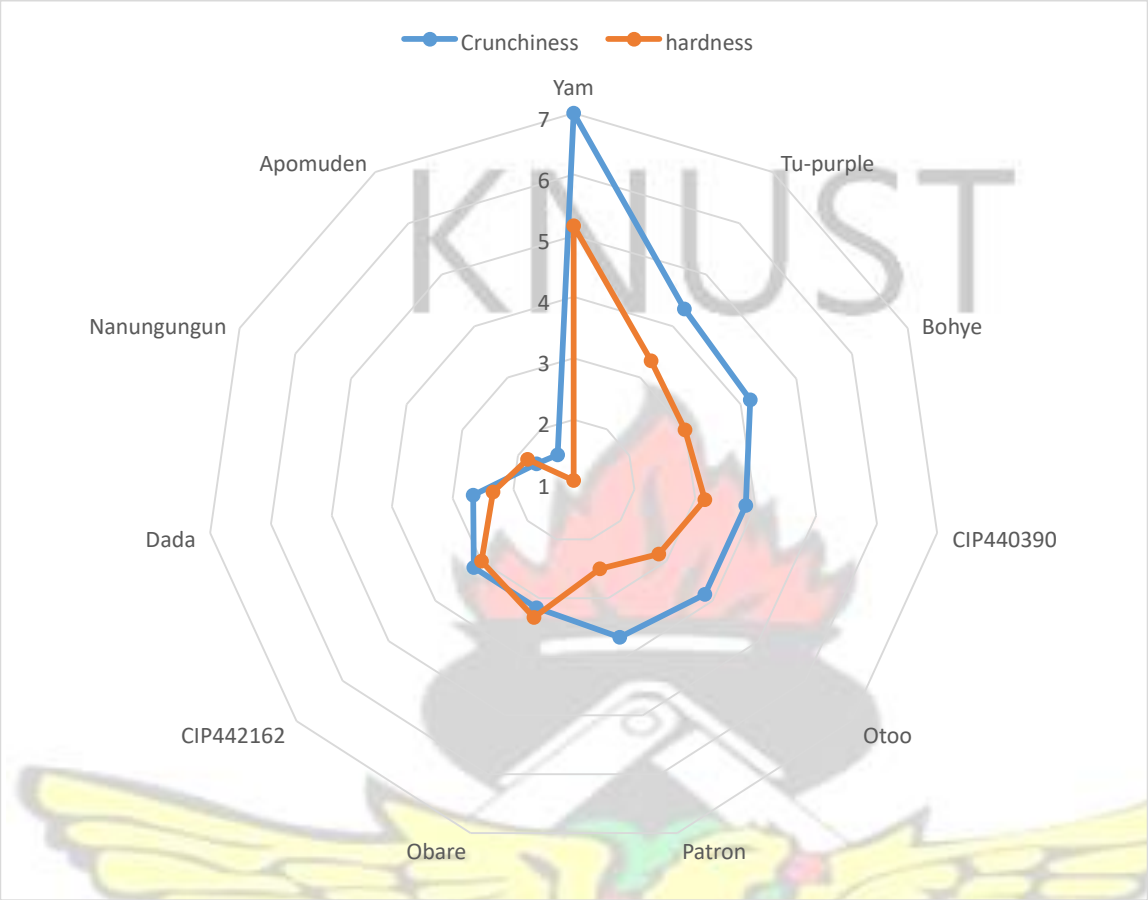

Fig 4.3: Texture score of sweetpotato fries

4.4.0 Colour of fries

Colour is said to be the major acceptability index of most foods by consumers due to its superficiality (Pedreschi *et al* 2005). *L** values beyond 50 indicate relatively lighter or brighter colour while values below 50 represents darker colour (Falade and Olugbuyi, 2010). The *L** values for the sweetpotato fries ranged from 43.96 to 76.02. *Bohye* (pale orange-fleshed) had the highest *L** value (76.02) followed by *Obare* (white-fleshed) (71.51) whiles *TU-Purple* recorded the least value (43.96) which falls within the darker region (Table 4.3). This may be as a result of the deep purple colour of the TU-Purple genotype. *Bohye* was observed to be brighter than the white

genotypes (*Obare* and *Dadanyuie)*. This might be due to the colour of the raw tuber and colour change caused by browning during the frying process (Utomo and Rahman 2005).

All genotypes ended up with bright coloured products ($L^* > 50$) after frying except *TU-Purple* which had L^* value below 50. There was a significant difference ($p<0.05$) observed amongst all 10 genotypes (Table 4.3). Meanwhile, there was no significant difference ($p>0.05$) between *Nanungungun* and *Otoo*. *Bohye* (pale orange) had an L^* value higher than that which was observed by Odenigbo *et al* (2012) in Gingsen Red, a genotype with pale orange flesh colour. The lightness of the white flesh sweetpotato (White Travis) genotype reported by Odenigbo *et al* (2012) had a value lower (64.76) than that of those in present study; that is *Obare* (71.51) and *Dadanyuie* (68.84) (Table 4.3). The variations may be due to browning of the product which is attributed to the frying temperature and time. That is, the products in this study did not brown as much as that of Odenigbo *et al* (2012).

The a^* and b^* values express intensity of redness and yellowness, respectively (Utomo and Rahman, 2005) of the product. The a^* values ranged from 0.03 to 15.55 (Table 4.3). These values were found to be in the range (5.84 – 21.84) reported by Utomo and Rahman (2005).

Table 4.3 Colour of sweetpotato fries

Samples	Colour parameters					
	L*	a*	b*	c*	H	BI
Nanungungun	62.94 (0.03)d	14.24 (0.07)a	37.01 (0.04)a	39.66 (0.06)a	68.95 (0.08)b	21.80 (0.07)h
Obare	71.52 (0.11)h	3.02 (0.03)b	17.63 (0.02)b	17.89 (0.02)b	80.28 (0.08)e	5.47 (0.04)c
Dadanyuie	68.84 (0.05)f	3.71 (0.01)c	19.25 (0.01)c	19.60 (0.01)c	79.10 (0.02)d	6.63 (0.01)e
Apomuden	59.18 (0.01)b	15.55 (0.03)d	33.65 (0.05)d	37.07 (0.06)d	65.20 (0.01)a	24.04 (0.04)i
Bohye	76.02 (0.07)i	0.03 (0.00)e	19.05 (0.04)e	19.05 (0.04)e	89.92 (0.02)g	2.50 (0.00)a
CIP442162	70.58 (0.01)g	1.19 (0.01)f	25.89 (0.01)f	25.92 (0.01)f	87.38 (0.01)f	4.87 (0.00)b
TU-Purple	43.97 (0.04)a	14.58 (0.02)g	-2.87 (0.00)g	14.85 (0.01)g	348.87 (0.04)h	21.85 (0.02)h
CIP440390	67.89 (0.01)e	3.46 (0.01)h	16.45 (0.01)h	16.81 (0.01)h	78.15 (0.02)c	6.05 (0.01)d
Otoo	62.77 (0.01)d	4.91 (0.01)i	28.33 (0.00)i	28.75 (0.00)i	80.17 (0.02)e	10.13 (0.02)f
Patron	62.58 (0.01)c	5.41 (0.01)j	28.13 (0.02)j	28.64 (0.02)i	79.12 (0.04)d	10.69 (0.01)g

BI – Browning Index

Values are represented as mean (standard deviation)

Values in the same column with same letters are not significantly different (p>0.05)

Apomuden (15.55) had the highest *a** value whiles *Bohye* recorded the lowest value (0.02). Orange fleshed genotypes *Nanungungun* (14.24) and *Apomuden* (15.55) recorded high values of a* except for *Bohye*, and this could be due to their flesh colours, which are largely influenced by the high beta-carotene. Though *Bohye* being pale orange, was expected to have some level of redness, it rather recorded the least value in all the genotypes. This could imply that the *Bohye* genotype tends to lose most of its beta-carotene (which provides it with its characteristic colour) during processing and maybe even frying.

All genotypes had positive values for *a**, implying they can be found in the red region. The redness parameter, *a** was also highest in the orange-fleshed sweetpotato genotype studied by Odenigbo *et al*. (2012). According to Odenigbo *et al*. (2012), samples with high *a** values could indicate some level of browning; that is, in cases of long frying time with high temperatures. However, in this study, white, cream, yellow and pale orange genotypes all had very low *a** values, implying they didn't brown that much, based on the frying conditions. Therefore the orange-fleshed genotypes having relatively higher a* values are definitely due to their flesh colour, which is orange. There were significant differences ($p<0.05$) observed amongst all 10 genotypes (Table 4.3).

The yellowness/blueness parameter, *b**, was highest in *Nanungungun* (37.01) followed by *Apomuden* (33.65), which may be due to their orange flesh nature. All genotypes had positive values except TU-Purple which had a negative *b** value (-2.86), indicating that the product is in the blue region (Table 4.3). This is due to its purple colour. Most of the genotypes had positive *b** values (thus, in the yellow region on the b*-scale), which is a desirable trait in fried foods (Krokida *et al*, 2001). Each genotype was again found to be significantly different ($p<0.05$) from the other.

Chroma (C*), which represents the level of saturation ranged from 14.85 to 39.66 (Table 4.3). *Nanungungun* had the highest value and again was followed by *Apomuden,* whiles *TU-Purple* had the least level of saturation. The level of saturation (C*) takes into account the *a** and *b**; hence the trend observed. A significant difference ($p<0.05$) was observed amongst all samples except for *Otoo* and *Patron* (Table 4.3).

Regarding hue angle, *h*, an angle of 90° represented a yellow hue (where b* is yellowness measured). Hue angle, *h*, is expressed in degrees: 0° (red), 90° (yellow), 180° (green) and 270° (blue). The hue angle is another parameter frequently used to characterize colour in food products and has been used extensively in the evaluation of colour parameter in green vegetables, fruits, and meat (Barreiro *et al*., 1997). Hue angle ranged from 65.20 to 348.87 for the fried samples. *TUPurple* recorded the highest hue angle value whiles *Apomuden* recorded the least. Objects with higher hue angles are greener while lower angles are more orange-red. *Tu-Purple* falls within 300° and 360° which represents purple colour indicating the actual flesh colour of this particular genotype. Variations occurring in the samples, in terms of hue angle, were mainly due to their flesh colours. Hue and chroma are the qualities or attributes of any colour.

The browning index ranged from 2.50 to 24.04 with *Apomuden* recording the highest value whiles *Bohye* recorded the lowest value (Table 4.3). *Apomuden*, *Nanungungun* and TU-Purple had the highest values for browning index. This may not be mainly due to the frying conditions used in this study: type of oil used, frying temperature and time, but the colour of the sweetpotato genotypes. Just as was seen in the *L**, *a** and *b** values for the orange and purple fleshed genotypes, the browning index followed in the same trend. Although all samples had browned to an extent, due to the fact that they were fried samples, the browning was not considered unappealing. A positive, strong and significant correlation was observed between the browning

index and colour (r = +0.864, p = 0.01) of fried samples, observed during the sensory evaluation. Same was observed between browning index and caramel (r = +0.929, p = 0.00), also a sensory attribute during the sensory evaluation. The colour followed a scale of 1=no detection of browning to 9=dark brown (burnt) while caramel was 1=no caramel sensation to 9=burnt. As a result, since less caramel sensation was observed (values <3) and colour was less than 4, it could be said that the browning index (BI) of the fried samples were appealing.

Statistically, there was no significant difference ($p>0.05$) between *Nanungungun* and TU-Purple. However, there were significant differences ($p<0.05$) amongst the other genotypes (Table 4.3). Browning of the fried samples may sometimes result from the type of oil being used. This may sometimes depend on the smoke point of the oil which results from the amount of free fatty acids in the oil (Pongsing and Chaoruangrit, 2016).

4.5.0 Beta-carotene content of some selected fries

The β-carotene content was determined on the orange fleshed sweetpotato genotypes; *Bohye, Apomuden* and *Nanungungungu*, for both raw roots and fries. The results for the beta-carotene content is shown in Table 4.4. *Bohye* had the least beta-carotene content (330.76 µg/100g) while *Apomuden* had the highest (6205.07 µg/100g). After frying, the beta-carotene content of all the sweetpotato genotypes decreased. That of *Bohye* almost decreased by half, while *Apomuden* decreased by about 31% (Table 4.4). *Nanungungun* was the only orange-fleshed genotype that was able to retain most of its beta-carotene after frying. Its beta-carotene content only decreased by about 13% (Table 4.4). Therefore, even though *Apomuden* has the highest beta-carotene content amongst all orange-fleshed genotypes of sweetpotato in Ghana, it lost most of it after frying. Fried *Nanungungun* therefore has the highest beta-carotene content amongst all the fries from the orange-fleshed genotypes.

Ukpabi *et al*. (2012) also reported a similar incident when some selected yellow and orange-fleshed sweetpotato genotypes were fried. A loss ranging from approximately 5 – 84% were reported. It is therefore a natural occurrence when beta-carotene is lost after frying. Beta-carotene is known to be non-polar, dissolving in non-polar solvents, such as the oil used in frying. Moreover, they are also heat-labile and as a result could have been decomposed by the heat.

The Institute of Medicine states that the consuming 3mg to 6mg of beta-carotene daily will maintain blood levels of beta-carotene in the range associated with lower risk of chronic disease (Institute of Medicine, 2001). The level of beta-carotene content remaining for *Apomuden* and *Nanungungun* after frying were however found within this range which therefore indicates that the consumption of the sweetpotato fries made from *Apomuden* and *Nanungungun* could maintain the levels of beta-carotene in the blood.

Table 4.4: Beta-carotene content of selected raw and fried sweetpotato

Genotype	Beta-carotene content (µg/100g)		% loss of Beta carotene
	Raw sample	Fried sample	
Bohye	330.76 (12.84)	184.32 (2.19)	44.27
Apomuden	6205.07 (39.84)	4281.11 (30.05)	31.01
Nanungungun	5715.45 (33.18)	4961.23 (51.44)	13.20

Values are represented as mean (standard deviation)

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The starch content of the genotypes used ranged from 10.12% in *Apomuden* to 19.79% in *Bohye*. However, dry matter ranged from 24.05% in *Apomuden* to 38.25% in *Dadanyuie*. The orangefleshed genotypes, *Apomuden* and *Nanungungun*, after frying were considered to be sweeter than the other genotypes. Caramel and starch/rawness sensation detected for all genotypes were very low, indicating the frying conditions were just about right for frying sweetpotatoes. On the average, starch/rawness values were less than 2. Oily mouthcoat, moistness and sogginess were detected in mostly the orange-fleshed genotypes of sweetptoato: *Apomuden* and *Nanungungun*. But this may have been influenced by the level of moisture in these genotypes. Regarding crunchiness, TUPurple, *Bohye* and CIP440390 were considered to be moderately crunchy, compared with other genotypes. Fat content was highest in CIP442162 and least in *Dadanyuie*, while moisture content was highest in *Apomuden* and least in CIP440390. Compared to yam, the fat content absorbed by the sweetpotato genotypes were moderate. Browning index was highest in the orange fleshed and purple genotypes but this was mostly due to their flesh colours and not the frying conditions. Amongst the orange-fleshed genotypes, *Nanungungun* retained more beta-carotene after frying. *TU-Purple, Bohye* and *CIP440390* produced moderately crunchy fries, and had the highest score for desirable attributes compared with the other genotypes. Therefore, *TU-Purple, Bohye* and *CIP440390* could be explored in commercial production of fries for enhanced utilization of developed sweetpotato genotypes.

5.2 Recommendations

1. Studies on the texture of the fried genotypes using instrumental measurement to ascertain its correlation with the sensory analysis on texture.
2. Studies on pre-treatments of the samples to improve on texture.

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APPENDIX A: Formulas

Calculation of dry matter

The dry matter content was calculated as

$$\% \text{ dry matter} = \frac{Wb - Wc}{Wa - Wc} \times 100$$

Wa = Weight of can + sample

Wb = Weight of can + dried sample, Wc = weight of can

Calculation for starch

The starch content was calculated as

$$\%\text{starch content} = \frac{\text{Weight of dried starch}}{\text{Weight of roots}} \times 100$$

Calculation for moisture content

The moisture content was calculated as

$$\% \text{ moisture content} = \frac{Wa - Wb}{Wa - Wc} \times 100$$

Wa = Weight of can + sample

Wb = Weight of can + dried sample Wc = Weight of can

Calculation for fat content

The fat content of the sample was calculated as

$(A + B) - A = B$ $\quad \%$ ether extract $= B/C \times 100$

where A = flask weight, B = ether extract weight, C = sample weight

Formula for calculating β-carotene

β-carotene (mg/100g) $\frac{A\ x\ volume\ of\ extract\ x\ 10000}{A\frac{1\%}{1}\ x\ samle\ weight\ (g)} = _{cm}$

where A = absorbance
volume of extract = total volume of extract
$A^{1\%}{}_{1cm}$ = Absorption coefficient of β-carotene in Petroleum Spirit (2592) **Appendix B: Statistical tables**

ANOVA

dry_matter

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	843.339	9	93.704	4.815	.002
Within Groups	369.777	19	19.462		
Total	1213.116	28			

Homogeneous Subsets

dry_matter Tukey HSD

Factor	N	Subset for alpha = 0.05		
		1	2	3
Apomuden	3	24.0456		
nanungungun	2	29.9719	29.9719	
cip442162	3	30.8983	30.8983	
Obare	3	31.0346	31.0346	
cip440390	3	32.1328	32.1328	32.1328
bohye	3	32.9705	32.9705	32.9705
patron	3	36.3127	36.3127	36.3127
tu-purple	3		37.2765	37.2765
Otoo	3		37.3828	37.3828

Dada	3			44.9997
Sig.		.080	.604	.058

ANOVA

Starch

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	126.710	9	14.079	1469.822	.000
Within Groups	.096	10	.010		
Total	126.805	19			

Homogeneous Subsets

starch Tukey HSD

factor1	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
apomuden	2	10.1174					
cip440390	2		14.0921				
Dada	2		14.1128				
Otoo	2		14.1825				
tu-purple	2		14.4559				
Nan	2			15.8693			
obare	2				16.4951		
patron	2					17.4566	
cip442162	2					17.5911	
bohye	2						19.7887
Sig.		1.000	.071	1.000	1.000	.911	1.000

ANOVA

Fat

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	227.933	10	22.793	7.355	.001
Within Groups	34.088	11	3.099		
Total	262.020	21			

Homogeneous Subsets

Fat

Tukey HSD

factor2	N	Subset for alpha = 0.05		
		1	2	3
Dada	2	14.0030		
Obare	2	14.2540		
Otoo	2	14.9454		
tu-purple	2	16.9324	16.9324	

Nan		2	17.0373	17.0373	17.0373
apomuden		2	17.3936	17.3936	17.3936
Bohye		2	17.9610	17.9610	17.9610
Patron		2	18.5437	18.5437	18.5437
Yam		2	20.3821	20.3821	20.3821
cip440390		2		23.5436	23.5436
cip442162		2			23.9644
Sig.			.083	.068	.052

ANOVA

Moisture content

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2133.335	10	213.334	314.662	.000
Within Groups	7.458	11	.678		
Total	2140.793	21			

Moisture content

Tukey HSD

		Subset for alpha = 0.05						
factor3	N	1	2	3	4	5	6	7
Yam	2	10.7892						
cip440390	2		20.7756					
Obare	2		21.3511					
Patron	2		22.2441	22.2441				
tu-purple	2			25.2498	25.2498			
cip442162	2				25.5439			
Otoo	2				27.2367	27.2367		
Bohye	2					29.6822		
Nan	2						33.4331	
Dada	2						34.0609	
apomuden	2							51.6830
Sig.		1.000	.769	.080	.433	.214	.999	1.000

Colour

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
L	Between Groups	1416.289	9	157.365	74404.452	.000
	Within Groups	.021	10	.002		
	Total	1416.310	19			
A	Between Groups	619.863	9	68.874	90623.234	.000
	Within Groups	.008	10	.001		
	Total	619.871	19			
B	Between Groups	2274.630	9	252.737	385857.565	.000
	Within Groups	.007	10	.001		
	Total	2274.637	19			
C	Between Groups	1347.229	9	149.692	143246.040	.000
	Within Groups	.010	10	.001		
	Total	1347.239	19			
H	Between Groups	132354.159	9	14706.018	7760431.471	.000
	Within Groups	.019	10	.002		
	Total	132354.178	19			
Bi	Between Groups	1175.593	9	130.621	135948.597	.000
	Within Groups	.010	10	.001		
	Total	1175.602	19			

L Tukey HSD

		Subset for alpha = 0.05								
factor4	N	1	2	3	4	5	6	7	8	9

tu-purple	2	43.9650								
apomuden	2		59.1750							
patron	2			62.5750						
otoo	2				62.7650					
nan	2				62.9400					
cip440390	2					67.8900				
dada	2						68.8350			
cip442162	2							70.5750		
obare	2								71.5150	
bohye	2									76.0200
Sig.		1.000	1.000	1.000	.062	1.000	1.000	1.000	1.000	1.000

Tukey HSD

		Subset for alpha = 0.05									
factor4	N	1	2	3	4	5	6	7	8	9	10
bohye	2	.0250									
cip442162	2		1.1900								
obare	2			3.0200							
cip440390	2				3.4550						
dada	2					3.7050					
otoo	2						4.9100				
patron	2							5.4100			
nan	2								14.2400		
tu-purple	2									14.5750	
apomuden	2										15.5500
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

b Tukey HSD

factor4	N	Subset for alpha = 0.05									
		1	2	3	4	5	6	7	8	9	10
tupurple	2	-2.8650									
cip440390	2		16.4500								
obare	2			17.6250							
bohye	2				19.0500						
dada	2					19.2450					
cip442162	2						25.8850				
patron	2							28.1250			
otoo	2								28.3300		
apomuden	2									33.6450	
nan	2										37.0050
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

c

Tukey HSD

factor4	N	Subset for alpha = 0.05								
		1	2	3	4	5	6	7	8	9
tu-purple	2	14.8500								
cip440390	2		16.8050							
obare	2			17.8850						
bohye	2				19.0500					
dada	2					19.6000				
cip442162	2						25.9150			

patron	2							28.6350		
otoo	2							28.7500		
apomuden	2								37.0700	
nan	2									39.6550
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	.089	1.000	1.000

h Tukey HSD

		Subset for alpha = 0.05							
factor4	N	1	2	3	4	5	6	7	8
apomuden	2	65.2000							
nan	2		68.9500						
cip440390	2			78.1450					
dada	2				79.0950				
patron	2				79.1150				
otoo	2					80.1650			
obare	2					80.2800			
cip442162	2						87.3750		
bohye	2							89.9150	
tu-purple	2								348.8650
Sig.		1.000	1.000	1.000	1.000	.308	1.000	1.000	1.000

Browning index Tukey HSD

		Subset for alpha = 0.05								
factor4	N	1	2	3	4	5	6	7	8	9
bohye	2	2.5004								
cip442162	2		4.8669							
obare	2			5.4705						

cip440390	2				6.0456					
dada	2					6.6312				
otoo	2						10.1252			
patron	2							10.6873		
nan	2								21.8033	
tu-purple	2								21.8483	
apomuden	2									24.0416
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	.884	1.000