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IMPROVED YAM-BAOBAB-TAMARIND FLOUR BLENDS: ITS POTENTIAL USE IN EXTRUSION COOKING

BY

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Improved Yam-Baobab-Tamarind Flour Blends and Its Potential Use in Extrusion Cooking

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CERTIFICATION

This is to certify that this thesis is the candidate's own account of her own research

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ABSTRACT

This project was aimed at determining the physicochemical properties of water yambaobab-tamarind flour composites and its potential use in extrusion cooking. Proximate and mineral composition of Baobab (B), Yam (Y), and Tamarind (T) were determined. Six blends of composite flours in the proportions of 0:0:100, 0:40:60, 40:0:60, 30:10:60, 10:30:60 and 20:20:60 (B: T: Y) were formulated and colour, physicochemical, pasting properties were determined. Two of the flour blends were used as trial samples and extruded at 300 rpm feed speed, temperature of 200°C and screw speed of 1200rpm. Sensory evaluation, physicochemical properties, colour, pasting properties and expansion ratio of the extruded products were assessed. Proximate composition of B, Y and T were comparable to literature, however, the mineral compositions were low. Moisture content, pH, water binding capacity, swelling power and bulk density values obtained were in the range of 3.01-5.61%, 3.90-5.39, 87.50-132.50%, 201.43-237.95% and 0.74-0.93g/ml, respectively for flour blends. Peak, minimum, cooling end, final, breakdown and setback viscosities were in the range of 2.50-291.00bu, 2.20-289.50bu, 11.00- 455.00bu, 10-440bu, 0.00-20.50bu and 69.50-148.00bu respectively. The addition of tamarind and baobab flours improved upon the physicochemical and pasting properties. The flours could be used for drinks, puddings, sauces, ice-creams, pastries and yoghurts depending on the desirable characterictsic of the flour blends. The L·valuesof composite flours was in the range of 84.67-85.49 as compared to water yam flour (100Y) which was 85.73. Generally the l, a, b values for extrudates were lower than the flour composites which resulted in a lower value of hue for extrudates. The bulk density and expansion ratio of extruded snacks were low: the values were 0.24g/cm^3 and 0.19g/cm^3; 3.45 and 4.15 for E5 (10B:30T: 100Y) and E6 (20B:20T: 60Y) respectively. Sensory evaluation results revealed that panellists preferred extrudates with higher tamarind kernel powder substitution (E5). Generally pasting analysis showed that the extruded composite flours (E6) had low viscosity values. The values were 14.67bu, 5.33bu, 14.33bu, 7.67bu and 8.33bu for peak, minimum, final, breakdown and setback viscoties respectively. This study has revealed that as tamarind and baobab flours were added to yam flour there was improvement in the physicochemical and pasting properties of flour blends as compared to yam flour only. These composite flours can be used in various food applications. It was demonstrated that incorporation of tamarind and baobab into water yam flour for development of low temperature extruded snacks has great potential as a ready to eat snack.

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DEDICATION

I dedicate this work to my parents, friends, CCI and supervisors for being there for me throughout this successful path.

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LIST OF ABBREVIATIONS

AOAC	Association of Official Analytical Chemists
BFCS	Baobab Fruit Company Senegal
BPP	Baobab Pulp Powder
BSG	Brewers Spent Grains
BV	Breakdown Viscosity
FAO	Food and Agriculture Organisation
FV	Final Viscosity
FW	Fresh Weight
GDP	Gross Domestic Product
HTST	High Temperature Short Time
ICRAF	International Centre for Research in Agroforestry
ICUC	International Centre for Underutilised Crop
IITA	Institute of Tropical Agriculture
LSD	Least Significance Difference

MV	Minimum Viscosity
PRWEB	Press Release on Web
PV	Peak Viscosity
RDA	Recommended Daily Allowance
RDI	Recommended Daily Intake
RTE	Ready-To-Eat
RVA	Rapid Visco- Analyzer
SBV	Setback Viscosity
SCUC	Southampton Centre for Underutilised Crops
SD	Standard Deviation
SPSS	Statistical Package for Social Sciences
TKP	Tamarind Kernel Powder
TSP	Tamarind Seed Polysaccharide
USDA	United States Department of Agriculture
WBC	Water Binding Capacity
WHO	World Health Organization
YF	Yam Flour

CHAPTER ONE

1.0 INTRODUCTION

Yams are vital staple crops in Africa, the Pacific and the Caribbean. West Africa and parts of East, Central and Southern Africa are mainly the three areas of the world where yam is cultivated (FAO, 1999). Nigeria is the leading producer followed by Côte d'Ivoire, Ghana and Benin. It is a high-status root tuber which is a common component of many diets in countries such as Nigeria, Ghana, and Cˆote d'Ivoire (Scott *et al.*, 2000). The per capita average yam consumption per day is greatest in Benin (364 kcal) followed by Côte d'Ivoire (342 kcal), Ghana (296 kcal), and Nigeria (258 kcal) (IITA, 2009).

Aside its role as a major component of the diet of many Ghanaians, yam also serves as a source of foreign exchange and employment in West Africa. In 2013 alone, Yam production contributed to 16% of the total Agricultural GDP (Anaadumba, 2013).

Research activities in Ghana in relation to yam have been mainly on *D. rotundata* and *D. alata* because they are cultivated in Ghana and are produced in highest quantities specifically in the Northern and Brong-Ahafo regions (Aidoo, 2009).

Yam is a good source of vitamins A and C, fibre and minerals (Lebot, 2009). Research done by Wireko-Manu *et al*. (2013) on water yam (*D. alata*) shows their great potential as a functional food and food supplement for fibre and minerals. The mineral contents of the varieties of *Dioscorea alata* (water yam) were from 10.1017.60 mg kg^{-1} for Zn, 10,550-20,100 mg kg^{-1} for K, 83-131 mg kg^{-1} for Na, 260-535 mg kg^{-1} for Ca, and 390-595 mg kg^{-1} for Mg. Total dietary fibre of some varieities were higher than rice whiles two of them were comparable to whole wheat flour. The protein content of yam even though is reported to be in low quantities, is higher than that of cassava and in addition its amino acid profile is superior to that of sweet potato (Bhandari *et al.*, 2003).

The aim of tuber processing is to obtain products that are shelf stable in terms of extended shelf life, nutrition, aesthetic appeal and taste (Oladebeye *et al*., 2008; Alinnor and Alkelezi, 2010).Over the years a lot of technologies such as boiling, roasting, frying and drying have been used to add value to roots and tubers.

Researchers are steadily adding value to yams. Amani *et al.* (2004) and Addy *et al.* (2012) worked on using yam flour and starches as an excellent and alternative source to modified starches, starch based foods and functional components for food products with low pH processed food like sauce and salad dressing. Wireko-Manu *et al*. (2014), Ukpabi (2010) and Oladebeye *et al*., 2008 have also produced bread, pasta, soup thickners, yam extrudates, yam fries, pastries and couscous from yam. Currently yam flours are used widely as food thickners however there is the need to improve the flours composition and characteristics to increase its range of utilization in other food products (Babalola and Oyenuga, 2009). One of the ways is to use tamarind seed kernel and baobab pulp flour due to their individual nutritional and physiochemical benefits (Obizoba an Amaechi, 1993; Shankaracharya, 1998).

Also other researchers have improved upon the technologies used in the production of flours such as amala and poundo yam using fermentation, sulphiting, steaming and oven or drum drying (Abulude and Ojediran, 2006; Adeola *et al.*, 2012; Onayemi and Potter, 2006).Traditionally, the processing of pounded yam using pestle and mortar is highly valued but is gradually being replaced in the market with instant-pounded yam flour.

One of the promising technologies that can be used in adding value to yams is extrusion cooking. Extrusion technology has provided the means to produce novel and innovative snack food and provides varying benefits over conventional methods of food and feed production. Extrusion is simply the process of shaping a plastic or dough-like material by forcing it through a die (Riaz, 2000). Extruders can be used to cook, texturize, form, mix, and shape food products under conditions that favour food quality (nutrient, taste, retention, high productivity and low cost. Extrusion knowledge has led to the diversification of various formulations and ingredients to develop expanded snacks from corn, wheat, rice, potato, tapioca, and oats using single- and twin-screw extruders.Some researchers have also used barley and other cereal sources such as rye, millet, sorghum, amaranth and triticale to develop extruded products (Alonso *et al.*,2001; Baik *et al.*,2004; Castells, 2005).

A recent FAO estimate reveals that tapioca (cassava) and potatoare the two principal tuber crops used for extruded snack foods (Riaz, 2000). Notwithstanding, researchers have used other root and tubers such as yam and cocoyam to develop extruded snacks (Rodríguez-Miranda *et al*., 2011; Oluwole *et al.*, 2013; Jisha *et al.*, 2010; Oke *et al.*, 2013; Sebio and Chang, 2004, Sobukola *et al.* 2013).

The aim of this project was to develop composite flours from under-utilized yam species, tamarind and baobab pulp and to assess its potential use in extrusion cooking.

1.1 PROBLEM STATEMENT

There are several varieties of yams in Ghana however there are some white yam varieties (*asobayere*, *muchumudu , serwaa)* and water yam varieties (*akaaba, akomiya, and matches*) which are less utilized (Addy, 2012; Aseidu-Larbi, 2010) as potential raw materials to supplement/complement the production of convenient and shelf stable food products: existing and novel food products.

Yam is composed mainly of starch (Abulude and Ojediran, 2006) and products made from yam are usually fortified with soybean or fish meal as protein source and leaves or additives for improved mineral and vitamin enrichment (Babalola *et al.*, 2007; Akingbala *et al.*, 1995). However yam products can be nutritionally supplemented with mineral , vitamin and proteins derived from underutilised crops such as baobab and tamarind which are suffering post harvest losses in the northern sector of Ghana (Azam-Ali and Peiler, 2005). In addition there is little knowledge on the diverse uses of these fruits especially in food applications. Little effort has been made to exploit and incorporate their potential as food fortifying agents, stabilisers, thickners and gelling agents into food formulations.

Tropical countries such as Ghana are obviously inappropriate for wheat cultivation and so resort to import wheat to sustain their novel wheat-based diets and this is causing major financial loss to the nation (Asante, 2008; Appiah 2015)

Over the years cereals such as rice and corn have been used as the carbohydrate base for extrusion cooking but little has been done on using the technology on root and tuber product development

1.2 JUSTIFICATION

Value addition to underutilized yam varieties through food product development will gradually reduce postharvest loss of yams, contribute to food security as well as reduce the over dependence on wheat based diets and curb excessive importation of wheat.

Incorporation of Tamarind Kernel Powder (TKP) and Baobab Pulp Powder (BPP) to yam flour will have the potential to improve upon its physiochemical properties of flour composites while finding potential use of the raw materials (Obizoba an Amaechi, 1993; Shankaracharya, 1998).

Lastly, at the end of the project further information will be acquired on a trial work that would give us information on impact of extrusion cooking and consumer acceptability of developed products.

1.3 AIM

This project was aimed at determining the physicochemical properties of water yambaobab-tamarind flour composites and its potential use in extrusion cooking.

1.3.1 Specific objectives

i. To develop six formulations of flour composites and two formulations of extrudates

ii. To determine thephysicochemical,colour (LAB), pasting properties of composite floursand extrudates iii. To evaluate sensory characteristics of preliminary extruded products.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Yam Production and Distribution

2.1.1 Yam Production across the World

Yams are known as to be plants that store up edible material in the root, corm, or tuberand is referred to as a root or tuber (Aidoo, 2009). Roots and tubers can also be described as primary staple foods of the wet tropics (O' Suillivan, 2010). These crops are grown in the tropical regions and consumed as primary, secondary or supplementary staple (Senanyake *et al*., 2011). Yams are ranked as the fourth major crops in the world after cassava, potatoes and sweetpotatoes (Adeleke, 2009; Akinso and Olatoye, 2013) but in West Africa is the second most important tropical root crop after cassava.

Yams are widely grown and consumed as sustenance staple foods in many parts of Africa, Asia, the Pacific Islands and Latin America (FAO, 2010). In the Pacific region, yams are grown throughout the lowlands, but are the dominant staple in relatively few areas (Bourke and Vlassak, 2004). These areas are geographically and culturally distinct from each other, but share a seasonal rainfall pattern O' Sullivan
(2010). FAO (2010) reports a global production of 51,778,000 t of yam cultivated. The yield in that same year was 10.5t/ha. In their report, it was evident that production of yam is more centered in Africa; as production in Africa alone was 96.3 % of the world's production.

In reality, within sub-Saharan Africa 19 nations depend on these crops for at least 20 per cent of their food consumption in terms of calories. (Alexandros, 2006) West

Africa accounts for 90-95 % of world yam production with Nigeria being the largest single producer. Projections into the year 2020 reveal that yam and sweet potato production of Ghana will be greater than that of China. This shows the promising future of yams in Ghana if attention is given to its production. Table 2.1 below shows production of roots and tubers in 1993, projections and growth rates to 2020.

2.1.2 Yam production in Africa and Ghana

In 2004, Ghana was the second highest producer of yam; however, the production was not up to half of what Nigeria was producing in that year. This percentage has been said to decline even though there is an increasing high local demand for the crop.

According to Polycarp *et al*. (2012) out of the varieties of yam produced in Ghana (*D. rotundata, D. praehensalis, D. cayenensis and D. bulbifera*), the most preferred was the *D. rotundata* (White yam).

Ghana happened to be the third largest producer of yam with a percentage of 6.9 of the world's production in 2008; which is only about half of what was produced in Cote d'Ivoire (Table 2.1). However, the yield per hector produced in Ghana was found to be higher than that of Cote d'Ivoire and even that of Nigeria; which implies

Ghana obtains more of the yam after cultivation per hector of land than any of the African countries. Therefore more land will cause Ghana to move ahead of its competitors. Cultivated area in Ghana for yam during 2008 was 299,000 ha, while that of Cote d'Ivoire was almost 3 times that of Ghana (Table 2.1).

Table 2.1 Overview of yam production statistics in 2008

Location	Cultivated land ('000 ha)	Production ('000 tonnes)	Percentage of the world	Yield (t/ha)

World	4,928	51,778	100	10.5
Africa	4,718	49,833	96.3	10.6
West Africa	4,443	48,101	93	10.8
Nigeria	3,045	35,017	67.7	11.5
Cote d'Ivoire	820	6,933	13.4	8.5
Ghana	299	3,550	6.9	11.9
Benin	205	1,803	3.5	8.8
Togo	63	638	1.2	10.2

(FAO, 2010)

A variety of yams are grown in Ghana, but for both the domestic and export market, white yam is most preferred (Addy, 2012). Pona is highly preferred by most Ghanaian consumers and yet during the off seasons (June and August) it is very scarce. Other popular varieties include Dente, Asana and Serwaa (Aidoo, 2009). Yams have a growing cycle range of six to eight months depending on the variety, planting time occurring between February and April, and harvesting time in October (Aidoo, 2009; Ofosu, 2010).

“Ghana yam” is known on the international market because customers desire its sweet taste (Ofosu, 2010). Lack of planting materials is a major constraint in yam production in Ghana. The small scale farmers use traditional methods to grow the yams for seed generation.

2.1.3 Yam storage and Mitigation of postharvest losses

Yam tubers are predisposed to steady physiological damage after harvesting in the absence of good storage facilities (Jimoh and Olatidoye, 2009; Adejumo *et al*., 2013).

Considering the major roots and tubers, yam is noted to be the least delicate or perishable (FAO, 2015a). Generally the tubers are stored fresh whiles the yam chips storage is limited. Processed forms of yam tubers, such as yam flour have been reported to have good shelf life provided the moisture content is within acceptable limits: yam flour can be stored within a period of (12-18 months), therefore yam is commonly processed into flour by drying yam slices and milling (Abioye, 2012).

Effective storage of yams involves the use of healthy tubers, appropriate curing, in combination with fungicide treatment, satisfactory ventilation to eliminate the heat produced by tuber respiration, consistent inspection during storage and removal of tubers with signs of rot and sprouts, and protection from direct sunlight and rain. Proper storage will allow fresh yams to stay for at least 6 months (Baah, 2009).

Postharvest losses have been a problem for fresh commodities such as fruits and vegetables; and roots and tubers are no exception. Yam thrives very well in Africa (Opara, 2003) and though Nigeria continues to be the leading producer in the world, it is unable to meet the consumer demands (Amusa *et al*., 2003). The use of cold storage, in order to reduce respirations, rotting and sprouting was recommended by Onwueme (1997) however this practice of continuous storage seems to be expensive.

2.1.4 Challenges of yam production, consumption and processing

The main limitations in yam production in West Africa are high cost of planting material and labour, poor soil fertility, pests and diseases (on-farm and in storage), low yield potential of local varieties and shortage of quality seed.Availability of raw materials, lack of processing equipment's especially packaging machinery, and inadequate storage facilities are known to be the main constraints with yam processing (FAO, 2015b).

Lack of capital and high labour intensity or cost was ranked topmost of the challenges of the yam production constraints (Aidoo, 2009).

Some constraints in yam consumption are little diversification in its food utilization, high cost of yam tubers, little value addition most especially in the development of ready-to-eat foods(Tetteh and Saakwa, 1991; Degras, 1993).

Some ways to curb this situation is to improve seed yam quality to reduce fungal infections, advancethe links between yam growers and traders in order to progressively improve the quality and increase the quantity of yams cultivated by growers, setting up policies that will aid in the incorporation of yam flour in food products and finally to have development scheme which targets up-scaling of convenience food products.

2.2 Consumption Patterns for Root and Tubers

Yams are a vital source of food and income for farmers, households and also an imperative food source for both local consumption and export (Wongnaa and Awunyo-Vitor, 2013). Trends for the consumption of root and tubers vary with different nations. This is affected by consumption habits and changes in climatic conditions (Domestic Supply and Consumption, 2004) Aside consumption they are also used to fulfil social requirements to chiefs and in-laws in the rural areas (Langyintuo, 1993)

Aidoo (2009) has reported that amongst all the yam varieties over less than 20% of yam consumers consume water yam and yellow yam as compared to white yam. Where as boiled yam (*ampesi*) is the most preferred yam product in Ghanaian urban centres followed by pounded yam (*fufu*).

2.2.1 Groups of Root and Tuber Consumers

Generally there are two sets of consumers of roots and tubers (FAO, 2010).

i. Rural consumers, who are largely self-sufficient. They grow staple crops in a subsistence-oriented traditional production system. Opportunities for modification of agricultural production in their area influence their choice of food.

ii. Urban consumers have high preference for convenient foods which is partly determined by convenience, availability, cash income and improved purchasing power.

The difference between the two is that farmers from rural areas prefer to produce for their own consumption and to gain extra income, exchange any surplus with their neighbours or sell in their local market whiles the urban consumers sometimes considers root and tubers as easily perishable as compared to other stable foods and so would rather resort to other staples consequently influencing the emergence of convenience foods (Aviles, 1987; FAO, 2010).

A report by FAO (2010) reveals that consumption of yam increased from 1988-2003 and fell in 2006. The decline in consumption was attributed to either lack of implementation of interventions or the interventions were not followed through to the end, or the interventions were themselves not sustainable.

2.3 Nutritional composition of yams

Yams are nutritious and considered to be carbohydrate, good fibre and minerals (copper, calcium, potassium, iron, manganese, and phosphorus) source. It is also known to have low antinutrient (phytates) levels (Wanasundera and Ravindran, 1994; Eka 1998; Onwueme and Charles, 1994; Akinoso and Olatoye, 2013). Starch is the vital constituent in the yams (60 -85% dry basis) and forms a significant component in the diet of individuals living in rural areas (Jayakody *et al.*, 2007; Senanayake *et al.*, 2011)

Comparing yam to cassava, it contains approximately four times as much protein. It is considered the most nutritious tropical root crop (Bhandari *et al*., 2003). They are good sources of vitamin B complex and vitamin C and also have highly digestible starch.

D. alata cultivars have a higher vitamin C, protein content and low lipids compared with the other varieties (*D. cayenensis*, *D. escunlenta*, *D. rotundata and D. trifida*) according to Muzac-Tucker *et al*. (1993). It however could contain such anti nutrients as alkaloids and tannins (Lebot, 2009). Sanful *et al*. (2013) has reported that yams are comparable to cereal in terms of contribution to high amount of energy in human diets. Yams provide about 110 calories per 100 grams of products (Babalola and Oyenuga, 2001).

Table 2.2 Compositional characteristics of tropical root and tuber crops

Properties	Composition		
	Yams (*Dioscorea* *spp*.)	Cassava (*Manihot esculenta*)	Sweetpotato (*Ipomoea batatas*)
Dry matter (%FW)	20-40	30-40	20-35
Starch (%FW)	20-25	27-37	18-28
Starch grain (in microns)	1-70	5-50	2-40
Amylose (%Starch)	10-30	15-30	8-32
Gelatinization temperature(°C)	69-88	49-73	58-65
Total sugars (%FW)	0.5-2	0.5-2.5	1.5-5

Proteins (% FW)	2-4	0.5-2	1-3
Fibres (%FW)	0.6	1	1
Vitamin A (µg/100g, FW)	117	17	900
Vitamin C (mg/100g, FW)	25	50	35
Minerals (%FW)	0.5-1	0.5-1.5	1
Energy (kJ/100g, FW)	440	600	500
Antinutrient	Alkaloids, Tannins	Cyanogens	Trypsin inhibitors

*FW=Fresh Weight (Lebot, 2009)

Even though yams have limited essential amino acids such as isoleucine and sulphur, it has a sustainable source of energy, provides superior protection against obesity and diabetes, and has a lower glycaemic index. (Brand-Miller *et al.* 2003; Adejumo *et al.*, 2013). It should be noted that processing methods affects the final nutritional composition of yam-based foods (FAO, 1996; Adejumo *et al.*, 2013).

2.3.1 Anti-nutrient composition of Yams

Roots and tubers contain one or more anti-nutrients. Yam is no exemption as it has been reported to contain alkaloids and tannins. According to Sanni *et al*. (2003), bitter complexes tend to amass in immature tuber tissues of *D. rotundata* and *D. cayenensis*. These he explained to be either polyphenols or tannin-like compounds. However, these bitter principles are present in *D. dumetorum* even when matured; hence its bitter taste and being known as the bitter yam. There has so far not been any report of alkaloids in cultivated varieties of *D. dumetorum*. The bitter principles according to Sanni *et al*.

(2003) have been identified as the alkaloid dihydrodioscorine and dioscorine which is usually found in the Malayan species, *D. hispida*.They are watersoluble alkaloids, which produce severe and distressing symptomsupon ingestion. Fatal cases of alkaloid intoxication have been recorded.

McAnuff *et al*. (2005) reported the presence of Saponins (<600 mg/kg, dry weight) in all tubers analyzed except for bitter yam. According to Polycarp *et al*. (2012), yam varieties which are mostly cultivated and consumed in Ghana have low levels of oxalates, tannins and phytates (<15 mg/100g); hence they safely recommend those varieties (*D. rotundata, D. praehensalis, D. cayenensis and D. bulbifera*, etc.) for food processing applications. *D. cayenensis* was found to contain 181.8 mg/kg on dry weight basis of phytate and 353.6 mg/kg on dry weight basis of tannins (Akin-Idowu *et al*., 2009). Sahore *et al*. (2006) have also reported the presence of antinutritional factors such as cyanide, oxalic acid, tannin, sapogenin and alkaloid in some wild species of yam. They also contain a steroid sapogenin compound called diosgenin, applied as base for drugs such as cortisone and can be used in the production of important steroids for human hormonal drugs (Adejumo *et al.*, 2013; Senanayake *et al.*, 2011).

Udensi *et al*. (2010), have also reported the presence of antinutritional factors in water yam (*Dioscorea alata*); phenol (0.16-0.27%), hydrogen cyanide (9.62-12 mg/kg), alkaloids (0.12-0.55%), tannins (46.5-180.25%), phytate (0.22-0.28%), haemagglutinin (1.22-5.75 Hu/g and trypsin inhibitor (24.02-49.51 TI unit/mg). These results were however regarded too low to cause any hazards when the tubers are consumed.

2.4 Yam Exploitation and Utilization

Root and tuber based products are proceesed to achieve are shelf stable, healthy and delicious products (Oladebeye *et al*., 2008; Alinnor and Alkelezi, 2010).Traditionally, the processing of pounded yam using pestle and mortar is highly valued but is gradually being replaced in the market with instant-pounded yam flour. Instant pounded yam flour requires short processing time and less energy. The aim of the practice was to preserve yam and reduce human drudgery associated with pounded yam production (Komolafe and Akinoso, 2005). The technology includes peeling, washing, slicing/dicing, cooking, drying, milling and packaging. Their processing involves treatment that converts them into finished products with acceptable taste, colour, flavour and texture (Sefa-Dedeh, 1995).

Yam tubers are eaten in several forms (chunks, chips, fufu, flour and slices which are acquired from any of the methods of fermentation, boilng, drying, frying, milling, pounding, roasting, oven baking and steaming (Iwuoha, 2004). Raw yam flour has also found rising use in bakery asdough conditioner in icecream and as thickener in soups (Iwuoha, 2004). Yam based meals are popular in West and Central Africa especially Ghana, Nigeria and Benin. Tubers such as D. Dumetorum, which contain bitter toxic substances (e.g. Dioscorine), are detoxified by soaking it in salt water for several hours before it is boiled, or used in any other way (Otegbayo *et al.*, 2007; Rava *et al.*, 1996; Achi, 1999; Akissoe *et al.*, 2006). Yam Tubers can also be fed to livestock as feed but not often used because of the availability of much inexpensive substitutes. Coloured cultivars of *D. alata* have been used as colouring and flavouring agent for ice cream (Salda *et al.*, 1998).

2.4.1 Supplementation to Root and Tuber Products

In order to maintain a healthy lifestyle, it is essential to have efficient supply of both macro and micro nutrients (Senanayake *et al*., 2011). In many traditional diets, grain legumes, meat, groundnuts and fish are integrated as good sources of protein and are often used to supplement root crops and compensate for their protein deficiencies. Tender leaves of sweetpotato, cassava and cocoyam which are rich sources of vitamins, protein and minerals are also used in some parts of Africa (FAO, 2010).

2.5 Baobab (Adansonia digitata)

2.5.1 Origin and Distribution

The decidious baobab tree (*Adansonia digitata*) is of the *Bombacaceae* family which comprises of about 20 genera and 180 species which was initially located in Africa has been introduced to countries outside of Africa, including Asian countries: India, Sri Lanka, Indonesia and the Philippines northern Australia; many; the Middle East; and the West Indies (Oyeleke *et al.*, 2012). *Adansonia digitata* has a large, round canopied tree with a swollen trunk, about 10-25 m in height with ovoid fruits at least

12 cm in length (embedded in a whitish powdery pulp, have little or no endosperm) (*Orwa et al.,* 2009). The baobab tree has become a symbol of Africa. This iconic thick trunked tree can live up to 3,000 years (Matthias, 2010).

Scientists believe that baobab was originally had an Arabic name "buhibab" meaning "fruit with many seeds" (Diop *et al.,* 2005). The name honors the French botanist Michel Adanson (1727-1806), who lived in Senegal for 6 years and worked on the country's natural history. Linneaus therefore dedicated the genus and species to him; 'digitata' means hand shaped, referring to the shape of the leaf (*Orwa et al.,* 2009).

Plate 1.0 Baobab Fruit (Adansonia

Source: Aluna (2013)

Plate 2.0 Baobab Tree

Source: Beach (2015)

Other names given to it are guinea tamarind, lemonade tree, monkey bread tree, cream-of-tartar tree *(Orwa et al., 2009)*. It is characterized by an unusual, swollen, relatively short, bottle shaped trunk (about 15 m in height) in which spongy fibers store water for the dry season. For this reason, it is also called "bottle tree". It is tolerant to high temperature and long spans of drought (Oyeleke *et al*., 2012)

2.5.2 Utilization and Benefits of Baobab

All plant parts of the baobab tree are uses in pharmaceutical, nutritional, cosmetic and veterinary items which can be explored to meet up with the food demand of the world's increasing population. The seeds, leaves, fruit pulp and are the key ingredient in porridges, sauces and beverages in some West African nations (Chadare *et al*., 2009; De Caluwé *et al*., 2009; Yusha'u *et al*., 2010). It is nutritional good, provides shelter, clothing as well as raw material for many useful substances. In Benin, ropes are made from the bark of the tree (De Caluwé *et al*., 2009).

Baobab leaves are used to cure fever in Nigeria (Wickens, 1982), the young leaves for treating painful swellings, disease of the urinary tract, insect bites guinea worms (Sidibe and Williams, 2002), used against excessive sweating, insect repelling

(Denloye *et al*., 2006) and cooked as vegetables (Van Wyk *et al.,* 1997). Sidibe and Williams (2002) have also proposed that the leaves of baobab retain their high vitamin content when stored whole rather than in the powdered state. Pollen grains from its flowers are used as raw material for the manufacture of glue (Wickens, 1982; Nhukarume *et al*., 2008).

The dried bark of the baobab tree has been used to relieve fever associated with febrifuge, swollen joints (Shukla *et al.,* 2001;Wickens and Lowe, 2008) in Ghana, Mali other African countries. The bark has been used for making ropes, cordage and cloth in Benin (De Caluwé *et al*., 2009).

Baobab seeds have been used for the making of vegetable oil in Madagascar, (Bianchini *et al.,* 1982 cited in *Orwa et al., 2009*) and used in gala occasions in Senegal and as a substitute for cooking oil in Tanzania.The seeds contain substantial quantities of tartaric acid and potassium bitar; they are refreshing to taste, and when soaked in water make an appetizing drink. *(Orwa et al.,* 2009). As compared to groundnuts the seed kernels contain edible oils and more protein and are rich in the amino acid lysine, vitamin B1 (thiamine), calcium and iron (Obizoba and Amaechi, 1993; SCUC, 2006). Baoab seed oil is used in the treatment of diarrhoea and hiccough
(De Caluwé *et al.,* 2009). Seeds are used to cure gastric, kidney and joint diseases; they are roasted then ground and the powder smeared on the affected part or drunk in water (Orwa *et al.,* 2009).

Chimvuramahwe *et al.* (2011) reported on the effect of feeding graded levels of *Adansonia digitata* seed cake on the performance of broilers. He discovered that incorporation of baobab seed cake in broiler chick diets at 10% level of addition economically reduced the total feed cost.

2.5.2.1 Food Applications of Baobab Pulp Powder

Fruit pulp is vital in indigenous foods as a seasoning ingredient and appetizer (Burkill (1985) cited in Ajayi *et al.*, 2003). The pulp of the baobab is considered as novel food ingredient (Commission Decision 2008), health enhancing and a "superfruit" (Gruenwald, 2009). The ripe fruit pulp is ivory colouredand naturally dry (Kurebgaseka, 2005). Sidibe & Williams (2002) considers the pulp as the most significant foodstuff which is soluble in both milk and water.

The pulp has been used in different kinds of juices and jams, as a fermenting agent in local brewing, an additionalmix with staple food such as cassava andcorn meal, as a substitute for cream of tartar in baking, a popular ingredient in ice products in urban areas and can be taken as a milk substitute (Kurebgaseka, 2005, Sidibe*et al.* (1998b) cited in Gebauer *et al.*, 2002). The pulp is acidic, due to the presence of the organic acids citric, succinic, tartaric, ascorbic and malic, with pH 3.3 (Nour *et al.*, 1980).

In India, it is described that baobab pulp is consumed with butter milk for the relief of diarrhoea and dysentery (Sidibe and Williams, 2002). It serves as a great repellent for cattle flies when burned (Kurebgaseka, 2005).

2.5.3 Nutritional Composition of Baobab Pulp Powder

The nutritious pulp is known for its high dietary fibre and contentascorbic acid. Baobab fruit pulp contains high amount of 76.2% carbohydrate, 8.2%low protein,0.3% extremely low fat and320 Kcal/100 g metabolizable energy and 5.4%crude fiber content (Magdi , 2004; Osman, 2004). The pulp has high sugar content however the sweetness may vary for diverse varieties of pulp (Cisse *et al.*, 2009; Chadare *et al.*, 2009).

Drinks prepared from baobab (baobab milk) has more protein (1.5%) and minerals (Fe: 17.8 mg; Ca: 134.2 mg) than human milk (protein: 1.3%; Fe: 0.2 mg; Ca: 30 mg) or cow milk (Fe: 0.1 mg; Ca: 1.20 mg) and most principal national commercial infant milk powder formulas e.g. Cerelac (Fe: 10.0 mg) (Oyeleke *et al.*, 2012).

It is also considered to have high vitamin C, calcium, potassium and phosphorus content. The acidulous taste is accredited to the existence of organic acids, such as citric acid, tartaric acid, malic acid and succinic acid (Murray *et al.*, 2001; Shukla *et al.*, 2001; Osman, 2004). The level of vitamin C contained can range from (150499mg/100 g) and can kill a range of cancer cells (PRWEB.UK, 2012; Vertuani *et al.*, 2002; Besco *et al.*, (2007); Eromosele *et al.*, 1991; Gebauer *et al.*, 2002). However, to preserve vitamin C in soft drinks it is imperative to add the powder to the boiled water and not to boil the pulp (Sidibe *et al.*, 1996).The vitatmin C content of the pulp is dependent on the source of the tree (Sidibe *et al.*, 1996; Manfredini *et al.*, 2002; Täufel *et al.*, 1993).

Boabab contains higher levels of calcium than milk. When compared to other fruits such as apples, apricots, bananas and peaches, baobab shows a higher calcium levels than other superfruits such as blueberries, cranberries and pomegranate (phytotrade, 2009). Baobab fruit pulp exhibits higher antioxidant properties than the leaves and its activity is comparable to 6 oranges per 100 g (Chadare *et al.*, 2009) hence have the higher ability of combating the formation of free radicals (BFCS, 2011). Baobab fruit pulp antioxidant is quite stable for at least a year (Sidibe *et al.*, 1996).

Chadare *et al.* (2009) reported that when 60 g of baobab pulp powder is consumed by a child it can provide coverage of 21.5% to 40.6% of carbohydrate RDI and when 100g is taken by a pregnant woman, it will cover 26 to 50% of the carbohydrate RDI. On the other hand, the energy contentof the pulp is rather low when compared with the RDI for children and pregnant women. About 23 g of baobab fruit powder provides the daily recommended amount of vitamin C for an average adult (Odetokun, 1996).

The baobab fruit pulp is an excellent source of potassium (240 mg/100 g), calcium (295 mg/100 g) and magnesium (190 mg/100 g) (Prentice *et al*., 1993; PRWEB, 2012) and is beneficial to good health and lowering of blood pressure. This was confirmed by a research work done by Magaia *et al*. (2013).

Dietary fiber is essential aspect of good nutrition because of its ability to alter the water content, viscosity and microbial mass of the intestinal contents, allow ease of passage through the intestine glucose tolerance, delay the transport of carbohydrates into the small intestine and reduce the risk of cardiovascular disease (Anderson et al. 2004; Elleuch *et al*. 2011; Van Duyn and Pivonka 2000).

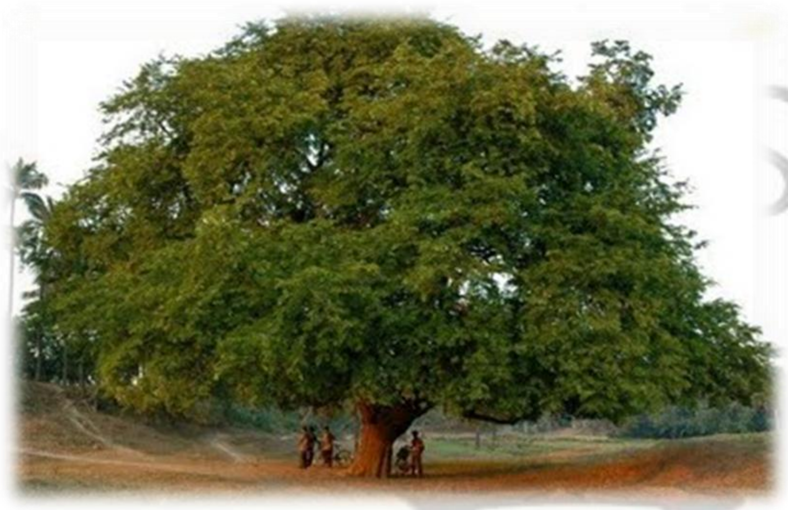
Baobab has been considered as a good source of fibre with prebiotic-like activity. Research has shown that, the water-soluble section of the fruit pulp has impact on the growth of lactobacilli and bifidobacteria (Manfredini, 2002).
The total dietary fibre is split into 77% soluble fibre and 23% insoluble fibre. It also has the role of acting as a gelling, thickening agent or stabilizer in food formulations due to the presence of pectin n the pulp (average 56.2%) (Phytotrade, 2009). Its water soluble pectin has a low degree of esterification and a low intrinsic viscosity for which reason the pulp is usually used as a base for jam making. However the quality of the pectin is of lesser quality as compared to commercial citrus waste and apple pectins. Researchers have reported the absence of starch in the pulp (Nour *et al.* (1980) cited in Abdalla *et al.* (2010).

2.6 Tamarind (Tamarindus indica)

2.6.1 Vegetative Morphology, Origin and Distribution

The evergreen or semi-evergreen large tamarind tree is about 20-30 m tall, with a thick trunk up to 1.5-2 m across and up to 8 m in circumference. It has spreading rounded crown and brownish-grey, rough and scaly bark which releases dark red gum from the trunk and branches when they are broken or damaged (El-Siddig, *et al*, 2006).

Plate 3.0 Tamarindus indica tree



Source: Shubhang (2013)

Asian nations like Bangladesh, India, Sri Lanka, and Thailand are known to be the main production sites for tamarind. Even though it is native to tropical Africa, it has been presented and established in more than 50 countries. The largest producers are in America, Mexico and Costa Rica. Tamarind is not produced on a commercial scale, in the whole of Africa however it is widely utilized by the indigenous people. Countries in Africa such as Zambia, Senegal, Tanzania, Gambia, Kenya, and Ghana produce tamarind in low quantities (Gunasena and Hughes, 2000; El-Siddig *et al*., 2006).

2.6.2 Utilization and Benefits of Tamarind

2.6.2.1 Fruit Pulp

The exclusive sweet/sour taste of the pulp is common in cooking and flavouring. Tamarind juice concentrate made from the pulp easily dissolves and reconstitutes in warm water. The product has long shelf life and low water activity (Ahmed *et al.,* 2007).

The pulp is used in many countries (Africa, Asia, and America) due to its medicinal properties (Gunasena and Hughes, 2000). The pulp has been used in the treatment of wounds, repair of responsiveness in cases of paralysis and to improve loss of appetite (Ahmed, 2007) and is said to aid the.Tamarind kernel powder, gum arabic and maltodextrins have also been combined in a novel way for the development of agents for the encapsulation of phenolic antioxidants (Pitchaon *et al.*, 2013).

Plate 4.0 Tamarind Fruit

Source: Barua (2014)

Plate 5.0 Tamarind Kernel Seeds

Source: Patel (2013)

2.6.2.2 Seeds

The seed contains the seed coat or testa (20-30%) and a kernel or endosperm (7075%) (Shankaracharya, 1998; Coronel, 1991). The seed is a by-product of the tamarind pulp industry. Tannins and other dyeing matter in the seed makes the whole seed unsuitable as a food source (Kumar & Bhattacharya, 2008). However, after soaking, boiling in water and/or roasting (for easy seed coat removal) the seeds become eatable (El- Siddig *et al.*, 2006).In relation to its food applications, scientists have discovered that the whole seed of tamarind is unsuitable for consumption unless it is boiled and soaked in water. It has been used in the production of tomato ketchup (De Cawule *et al.*, 2010)

Cakes and bread can be made from the seed kernel powder. It is also used as a stabilizing, thickening, and gelling ingredient in the food industry, particularly in Japan where it is a allowed food additive (Glicksman, 1986; Gidley *et al*., 1991). A report has shown that the roasted tamarind kernel seeds have a better flavour appeal than groundnuts (ICRAF, 2007). The seeds are currently gaining significance as an substitute source of protein, rich in some essential amino acids.

The powdered seed paste is used for the treatment of boils with or without cumin seeds and palm sugar. The seed coat, astringent in nature, is specifically used for treating chronic diarrhoea and dysentery. A mixture made from the roots alleged to have therapeutic significance in chest diseases and is a component in remedies for leprosy (Morton, 1987).

Kumar and Bhattacharya (2008) have reported its use as an essential sizing material used in the paper, textile and jute industries. Tamarind seed is the raw material used in the production of polysaccharide (jellose), tannin and adhesive.

2.6.2.2.1 Tamarind seed polysaccharide (Jellose)

In 1942, two Indian scientists asserted that decorticated kernels had 46-48% of a gelforming substance. This polysaccharide (pectin) with carbohydrate character and gelly forming properties, named “jellose” has been suggested for use as a stabiliser in ice cream, mayonnaise and cheese as a constituent in many pharmaceutical products (Morton, 1987; El-Siddig *et al.*, 2006). Tamarind seed kernel polysaccharides form and forms gels with sugar concentrates like fruit pectins in combination with waterin mucilaginous dispersions. Its ability to form gels over a wide pH range which includes neutral and basic conditions, is an advantage over other fruit pectins. Another advantage is that it gelling polysaccharides have high gel stability even under boiling temperature (neutral aqueous solutions). Consequently, it can be convenient as a gel formation agent and replacer for fruit pectins (El-Siddig *et al*., 2006).

Manchanda *et al.* (2014) studied the use of tamarind seed polysaccharide (TSP) extracted from the seed kernel, for drug delivery system design. It was revealed from the study that tamarind seed polysaccharide was a very feasible source of material in the design of drug delivery systems if issues of purity, source and microbial contamination can be properly controlled. Another researcher revealed that tamarind seed gum could be used to develop and evaluate of mucoadhesive buccal patches of miconazole nitrate (Jana *et al*., 2010).

2.7 Snack industry

One of the fastest growing sectors of the food industry is the snack industry. During World War II, corn snacks were commercially produced using high-shear extruders. Snacking has become more common in our diets consciously or unconsciously as consumer preferences keep evolving for several reasons (Ilo *et al.*, 2000). Consumers want food that is effortlessly consumed on the go for example ready-made sandwiches, ice-cream and biscuits instead of sitting down and having a complete meal.

Snacks can be defined as light meals eaten between regular meals and include a extensive range of products with varying forms. Snacks supply an imperative part of day-to-day nutrient and calorie consumption for many consumers (Deshpande and Poshadri 2011).Ready-to-eat (RTE) snacks are savoury products that are capable of being held at ambient temperature for a reasonable length of time (Okaka, 1997). In recent times, RTE snack products are increasingly gaining global acceptance, due to job demands, convenience driven lifestyles and dietary habits. Also they add variety to diet, which partially explain their popularity (Lasekan *et. al.*, 1996).

Snacks commonly consumed in Ghana are in the categories of fruits, beverages and pastries. The pastries are usually prepared by baking or frying. Cereals are the popular raw materials used for extruded snacks primarily because of low cost, functional properties and ready availability (Deshpande and Poshadri, 2011).

Scientists have also made efforts to incorporate oil seeds and pulses to improve the nutritional content of cereal based extruded snacks owing to their high protein content.Similarly a relatively new concept motivated largely by health concerns has surfaced and researchers have tried to improve upon nutrition via incorporation of fruits and vegetables in ready-to-eat expanded snacks (Trater and Alavi, 2005; Deshpande and Poshadri, 2011).

2.7.1 Technology for Extruded Snack Production

Extrusion processing, an important continuous cooking and puffing technology, is used for producing a diversity of breakfast cereals and expanded snacks (Trater and Alavi, 2005; Agbisit *et al.*, 2007).

Sausages were the first products that were developed through extrusion cooking in the 1870s. In the 1930s the single screw extruder was used in the making of ready-to-eat (RTE) cereals to shape precooked, hot dough. The use of the twin screw extruder was used in 1950s (Hunter and Frisken, 2009). It has become a very vital process in theproduction of food products and is broadly used in the food industry due to its versatility, high productivity, low cost, and energy efficiency (Akdogan, 1999).

Food extrusion is defined as the process of pushing a material through an orifice or a die of given shape, the pushing force is applied using a piston or a screw” (Rao and Thejaswini, 2015).

Food extruders are used usually for cereal and protein processing, this includes cereals, pasta and other cold formed products, baby foods, pet foods, feed, confectionery products, snacks, modified starches for sauces/soup, infant foods, and instant foods, texturized vegetable proteins and beverage bases.

In recent times, food extrusion has developed into a complicated cooking process from an easy pressing and forming technology, and has substituted many conservative foods processing technologies. In addition, the use of extruders has progressed to yield refined products, new flavour generation, encapsulation and sterilization (Steel, 2012).

2.7.2 Benefits of Extrusion in Food Processing

Extrusion technology, also considered one of the most resourceful and energy efficient processes presently providing solution to world hunger and nutritional problems. It has become one of the main processes of creating new food products and improving existing ones (Bailey, *et al.*, 1991; Rizvi *et al.*, 1995; Okafor, 2014).

Extrusion cooking is a high-temperature short-time (HTST) process which incapacitates enzymes and reduces microbial contamination which is advantageous in foods (Aruna, 2012). Extrusion is a highly efficient process, which is versatile, minimizes cost, environmentally-friendly and provides high quality products. Singh *et al*. (2007) has reported that extrusion also aids in the destruction of antinutritional factors, gelatinisation of starch, increased soluble dietary fibre and reduction of lipid oxidation. The extrusion process also offers the opportunity of modifying the functional properties of food ingredients and/or of texturizing them.

2.7.3 Types of Extruders

Extruders are classified generally as single screw and twin screw extruders. Most researchers now prefer the twin screw extruders to the single screw because it is more efficient. Single-screw extruders have deprived mixing ability and therefore materials should be pre-mixed or pre-conditioned. A single-screw extruder's processing conditions can be organised to attain a range of effects on temperature and residence time. Twin-screw extruders (Counter-rotating /co-rotating) are also used for more challenging applications (Steel, 2012).

Extruders with counter-rotating twin-screws are normally used for the production of relatively non-viscous materials which requires long residence times and low speeds. Co-rotating twin-screw extruders have extended the variability of products that can be produced with extrusion technology and are frequently used in the snack food industry (Aruna, 2012).

Extruders can also be categorized as low, medium, and high shear stress (Camire, 2000). "Shearing" is a term used to describe the working, mixing action that standardizes the conveyed material. Low shear stress extruders (forming extruders) are used to increase the density of a material that is commonly high in moisture, such as pasta. They function with low levels of mechanical energy per unit of throughput, gentle speed and feature long length-to-diameter ratio. When the moisture content is lower and mechanical inputs are higher, medium shear stress extruders are used. Aquatic feeds, pet food and textured vegetable proteins are characteristic medium shear processed products. Greatly expanded products with low moisture and bulk density levels are processed with high shear stress extruders (Steel, 2012).

Several factors (specific mechanical energy, screw configuration, screw speed, residence time, temperature, pressure) but the output of extrusion cooking is mainly influenced by raw material properties and operational parameters of the extruder (Fellows, 2000).

2.7.4 Types of Extruded Snack Foods

Specific unit operations, varying technologies and processing technologies produce exceptional snacks. There are many ways to categorise snacks. Some researchers have classified them in three categories. First, second and third generation snacks.

First generation snacks have great potential. They are known as “simply extruded snacks”. Majority of snacks fall in the category of second generation snacks. Simple shaped (single ingredient) products (puffed corn curls) and all directly expanded snacks are included in this category.

Snacks described as pellets or half- products are third generation snacks. Thirdgeneration snacks have been very trendy in several sections of the world and are known the snack-food industry. The making of third-generation snacks are proficient, economical to run and result in a product with good marketing tractability due to extended shelf-life and increased bulk density prior to frying or puffing (Riaz, 2000). Snack manufacturers largely employ extrusion of multi ingredients to form this category of snacks as well as pellets (Kuntz, 1996). Snacks in this category do not expand during extrusion. Expansion occurs after extrusion or in the future after these products are dried by a puffing gun, microwave, fryer or oven.

Apart from pellets (third generation snacks), other categorizations of extruded snacks are known as collets. Fried and baked collects have been identified. Collets are considered as second generation snacks (Riaz, 2000).

Fried colletsexpanded snacks made on collet extruders, fried in vegetable oil and additional cheese and flavour coating. The product is usually twisted and puffed with low moisture content (1-2%). Corn as well as cereal grains can also be used for this kind of product (Rmoreira, 2001).

Cereal grains and tuber flours in varying formulations can be used in the manufacture of baked collects. Cellulose, protein, fibers and bran can be mixed with cereal grains(<20%) to make healthy snacks (Huber and Rockey, 1990).A combination of potato flour and corn flour are used in the production on potato sticks.

2.7.2.1 Co-extruded products

Co-extruded snacks are becoming increasingly popular on the market (Rmoreira, 2001). The technology of making these kinds of extrudates where two different materials are extruded from one die is relatively new (de Cindio *et al*., 2003). These co-extruded products are filled in the die with creams, jellies, or other substances with varying flavours and colours.

They come in different varieties; cereal-based tubes with either cereal-based fillings, fat-based fillings, or water-based fillings. However the migration of oil/moisturelimits the shelf life of filled extruded snacks (Peressini *et al.*, 2002). The filling process is the important step in filled snacks production because of its great influence on the sensory properties of the final product (de Cindio *et al*., 2003).

2.7.5 Common Ingredients used for extruded snacks

Over the years there has been various the diversification of various formulations and ingredients to develop expanded extruded snacks with most widespread source of ingredients is corn, tapioca, wheat, potato, rice, and oats. Some researchers have also used barley and other cereal sources such as rye, sorghum, millet, amaranth, and triticale (Alonso *et al*., 2001; Baik *et al.*, 2004; Castels, 2005).

A recent FAO estimate reveals that potato and tapioca (cassava) are the two main tuber crops used for extruded snack foods (Riaz, 2002). Notwithstanding, researchers have used other root and tubers such as yam and cocoyam to develop extruded snacks (Peluola-Adeyemi *et al*., 2013; Sebio and Chang, 2004; Oke *et al*., 2013; Oluwe *et al.*, 2013).

2.7.6 Current trends of extruded snacks

The current trend on ascendency in the use of extrusion processing is the incorporation of vegetables andfruit based ingredients in expanded snacks. Several recent works focused. According to Bressani and Elias (1974) as cited in Okafor and Ugwu (2014) high protein snacks could be produced by mixing cereals with available plant source proteins, animal food sources or with less expensivesources such as legumes and oil seeds. Over the years traditional processing methods have not fully tackled the issue of short shelf life of foods developed even though some of them are highly nutritious. Extrusion cooking has therefore been recommended by many researchers to yield shelf stable, hygienically processed and acceptable products (Bailey, *et al.*, 1991; Rizvi *et. al.* 1995).

2.7.7 Food Applications of Extrusion Cooking

Oluwe *et al.* (2013) conducted a study to investigate impact of extrusion parameters on physicochemical properties of bambara nut and yam flour blends in a ratio of 4:1. Theresults revealed that all the extrusion variables (barrel temperature, screw speed, and feed moisture content) had significant effects ($p<0.05$) on the product properties considered in this study.

Jisha *et al.* (2010) developed potential low calorie snacks for obese and diabetic people from malted flour based extrudates and gram malted cassava based blends. These products were developed from native, malted and modified flour blends made from cereal (finger millet and whole wheat flours) and/or legume flours (chick pea flour). It was discovered that native flour had higher starch content than malted flour based extrudates whiles gram malted cassava based blends gave products with the highest protein.

Oke *et al*. (2013) revealed that extruded water yam (*D. alata*) starch product characteristics were related to feed moisture content, barrel temperature and screw speed using response surface analysis and contour graphs. At lower feed moisture contents and high screw speed, physical properties of the extruded products like expansion index was higher. The study showed that water yam starch has a great potential as a food ingredient in extruded products and can be effectively used in the production of snacks, pre-gelatinized flours and breakfast cereals due to its high starch content.

Sebio and Chang (2004) also extruded white yam flour and stated that it had high paste stability during heating. High values of the expansion index were obtained at low moisture contents, independently of barrel temperature whiles the bulk density was influenced directly by feed moisture content and the barrel temperature. Among all the parameters, the colour change was greatly affected by barrel temperature.

Sobukola *et al.* (2013) studied the effect of the addition of brewers spent grain (BSG) addition (5–15% level) on proximate composition and functional properties of extruded yam starch-based pasta. The extrusion process was successful. BSG served as a potential source of fibre. Practically this study was an attempt to handle brewers spent grain (BSG) which was regarded as a problematic waste in the brewing industry.

Méndez-García*et al*. (2011) used extruded lemon residues in order to modify and increase the soluble fiber fraction to serve as a potential source of high fiber ingredient. It was discovered that extrusion cooking transformed some insoluble fiber to soluble fiber in lemon residues.

Camire *et al*. (2007) examined the effects of dehydrated fruit powders as colorants and antioxidants in extruded white cornmeal breakfast cereals. The anthocyanins enduredextrusion. However the levels of antioxidant activity were too low (1% w/w).

Lee (2001) conducted a study of physicochemical properties of snacks extruded from sweetpotato and tapioca raw materials under optimum extrusion parameters. From the study the snack with a formulation of 50% sweetpotato flour had acceptable qualities with relatively good aroma, sweetness and crispiness.

Martha *et al*. (2015) evaluated the effect of barrel temperature and screw speed during the extrusion cooking process on bioactive compounds of encapsulated red cactus pear powder.The extrusion process affected the preservation of encapsulated red cactus pear pigments however, the values obtained were higher than those reported in other extrusion studies. The study revealed that cactus pear powder is a promising natural pigment that can be used in extruded products.

In 2007, a study done by El- Samahy *et al*. (2007) showed a high potential of producing a new appetizing product of rice-based extrudates using both red and orange-yellow concentrated cactus pear pulps (40ºBrix). Substitution levels of 5% and 10% concentrated cactus pulps gave the best extruded products with good functional, nutritional, and sensory characteristics.

Table 2.3 Other Recent Extrusion Works on Value Addition to Crops

DATE	RESEARCHER (S)	FINDINGS/SUMMARY
2014	Wioletta Drożdż, Ewa Tomaszewska-Ciosk, Ewa Zdybel, Hanna Boruczkowska, Tomasz Boruczkowski, Piotr Regiec	Effect Of Apple And Rosehip Pomaces On Colour, Total Phenolics And Antioxidant Activity Of Corn Extruded Snacks
2013	Sawant A. A, N. J. Thakor, S. B. Swami, A. D. Divate Balasaheb Sawant Konkan Krishi Vidyapeeth	Physical and sensory characteristics of Ready-ToEat food prepared from finger millet based composite mixer by extrusion
2012	Noorakmar, A. W., Cheow, C. S., Norizzah, A. R., Mohd Zahid, A.and Ruzaina, I.	Effect of orange sweet potato *(Ipomoea batatas)* flour on the physicalproperties of fried extruded fish crackers
2012	Parisa Fallahi	Twin-Screw Extrusion Processing Of VegetableBased Rainbow Trout (Oncorhynchus Mykiss) Feeds Using Graded Levels Of High Protein Fermented Soybean Meal (FSBM)
2012	Navneet Kumar, B.C. Sarkar, H.K. Sharma, Sunil Kumar Jha,	Colour Kinetics And Storage Characteristics Of Carrot, Pulse And Rice By- Product Based Extrudates
2011	Balunkeswar Nayak	Effect Of Thermal Processing On The Phenolic Antioxidants Of Colored Potatoes

2.7.8 Chemical and Nutritional Modifications in Extrusion Cooking

Extrusion cooking has both beneficial and negative effect on the macro and micro molecules of extrudates (Davis and Arnold, 1995). Extrusion cooking may or may not impact on the bioavailability and digestibility (Ljokjel *et al.*, 2000; Mahasukhonthachat *et al.*, 2010; Saalia and Phillips, 2011). The impact is dependent on ingredient composition, the extrusion parameters and the kind of extrusion equipment used (Aziz

Ur Rahman *et al.*, 2012; Nalle *et al.*, 2013). Singh *et al.* (2007) has reported that mild extrusion conditions (low residence time, high moisture content, low temperature) are more beneficial in improving the nutritional quality of extruded products whiles Nikmaram *et al*. (2015) stated that HTST processes are preferable in the retention of nutrients in products.

2.7.8.1 Carbohydrates and Fibre

Extrusion cooking may pre- digest starch molecules and produces digestion resistant starches by starch gelatinization, disintegration, melting or transglycosidation. It may also cause starches to be easily accessible to digestive enzymes when anti nutritional factors are destructed (Aziz Ur Rahman *et al.*, 2015; Nayak *et al.*, 2014; Parker and Ring, 2001; Lankhorst *et al.*, 2007).

It has been documented that during extrusion the molecular weight of both amylopectin and amylose decreases. In addition, amylopectin molecule branches are readily cut off in the barrel. As branches are detached from amylopectin molecules, new linkages are formed within carbohydrate molecules that cannot be broken down by enzymes (Ur Rahman *et al.*, 2015). Work done by (Kelkar *et al.*, 2011; Borejszo and Khan, 1992) also revealed that extrusion cooking could decrease the levelsof flatulence oligosaccharides such as sucrose, stachyoseand raffinose. This was observed in pinto beans.

Colonna and Mercier (1985) have stated that high amylose containing cereals are more resistant to swelling or gelatinization as compared to high amylopectin content. Their levels in starch also influence the expansion characteristics of extrudates. The lower the amylose content (waxy starches), the higher the expansion ratio (Chinnaswamy Hanna, 1998; Chinnaswamy, 1993; Mercier and Feillet, 1975).

The breakdown of starches produces sugars which are responsible for sweetness and also several mechanisms and reactions such as maillard reactions between protein and sugars which reduces the nutritional value of the protein (Singh *et al.* (2007).

Studies have shown that extrusion has an impact on fibres by increasing the levels of soluble fibre after extrusion (Méndez-Garcia *et al.*, 2011).

2.7.8.2 Protein

Protein loss is evident under extrusion conditions of high temperature, low moisture and high shear. Extrusion cooking causes protein modification and influences protein digestibility by denaturation of protein, denaturing of antinutritional factors and modifies amino acids side chains (Aziz Ur Rahman *et al*., 2015).

The impact of heat and pH on proteins improves its digestibility by inactivating enzyme inhibitions and denaturing the protein. This may expose new sites for enzyme attack. Protein value could also be reduced by maillard reactions where lysine may react with the reducing sugars (Cheftel *et al.*, 1985). This is a challenge with cereal based extrusion since lysine is a limiting essential amino acid. However denaturation is a change in conformation of proteins which does not engage the breaking of peptide bonds but their hydrophobic groups are uncovered with consequential decrease in protein solubility. Low temperature and residence time has less negative impact protein solubility (Camire *et al.*, 1990).One application of extruders is for texturization of defatted vegetable proteins where new hydrogen and disulphide bonds formed.

2.7.8.3 Lipids and Water

Most foods extruded have low fat content as a result of the processing methods applied and the initial food composition. The most common type of lipids in foods are triglycerides. Generally crops such as cereals are characteristically low in oils, even though oats may contain up to 10% oil. Oilseeds such as peanut, soybeans and cottonseed may have over 40% lipid level. If increased fat level is required the extruded product could be fried after extrusion. Another reason for frying after extrusion is to impact flavor and improve upon the texture (Camire *et al.*, 1990). High levels of fat and moisture in extruded products also promotes rancidity due to hydrolysis. However extrusion cooking under high temperatures is known to inactivate hydrolytic enzymes, reduce lipase activity and moisture levels. When lipases and lipoxidases are inactivated during extrusion the extrudates are better protected from oxidation during storage (Cheftel et al., 1985). Maga (1978) also discovered that unsaturated fatty acids that were converted from the cis to the transform during the extrusion of cornmeal were less than 2%.

Water or moisture content is constantly considered principal part of the extrusion process. High moisture extrusion is known as wet extrusion (Aziz Ur Rahman, 2015). In the early years of introducing extrusion cooking, wet extrusion was a challenge (Noguchi, 1989) but recently twin screw extruders with sophisticated barrel designs, screws and dies enable wet extrusion. High moisture extrusion favours starch gelatinization whereas low moisture gelatinization favours caramelization and maillard browning (Akdogan, 1999). Camire *et al.* (2007) discovered that extruding fruit products with high sugar and moisture content can cause strain on extruder motors.

Some studies have reported that there is improved digestibility and gelatinization of raw starches during dry extrusion cooking. The reasons were attributed to granular disorganization and changes in crystallinity of starches (Al-Marzooqi and Wiseman, 2009; Liu *et al.*, 2013).

2.7.8.4 Vitamins minerals and antinutrients

Some vitamins and minerals are heat liable and so they are easily destroyed under high temperatures (Singh, 2007). The bioavailability of minerals is dependent on the interractions they have with fibres and antinutrients. Research has shown that extrusion could increase the bioavailability of minerals locked up by fibres and antinutrients such as tannins and phytates (Aziz Ur Rahman *et al.*, 2015; Nayak *et al.*, 2014; Parker and Lankhorst *et al.*, 2007).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Source of materials

The baobab and tamarind fruits were obtained from the Upper East (Bolgatanga) and Upper West Regions (Wa) of Ghana respectively. Matches, a variety of water Yam (*D. alata*), was obtained from the Kejetia market, Kumasi.

3.2 Sample preparation

3.2.1 Yam flour production

Yam flour (15kg) was prepared by a method described by Adeola *et al.*, (2012) with little modification to the drying temperature, drying time, sodium metabisulphite solution concentration and inclusion of blanching to reduce browning. The yam tubers (46kg) were washed with clean water to remove dirt, sand and unwanted particles. The yam tubers after peeling and slicing (0.05 mm thickness) were flushed with sodium metabisulphite solution (0.2%) to prevent browning reaction and placed in a sieve to remove excess water. The samples were blanched for 10 min at 100 ºC oven dried at 65 ºC for 12 h followed by milling using a hammer mill and the yam flour was sieved (500µm) , packaged in low density polythene bag and stored in the freezer prior to analysis.

3.2.2 Tamarind kernel powder (TKP) preparation

The seeds were boiled for 10 min to remove the hard testa. The kernel was separated from the hard testa. The kernel obtained was grounded into fine powder. The mixture was sieved through a 0.09 micron sieve to obtain a fine powder. The powder was packed in polyethylene bags sealed and stored in a dark cool place.

3.2.3 Baobab pulp powder (BPP) preparation

The fruits of baobab was cleaned, shells of the fruits were opened to obtain seeds, and then seeds were removed from the pods. The seeds were grounded using mortar and pestle to separate the pulp from the seeds. The mixture was sieved through a 0.09 micron sieve to obtain a fine powder. The powder was immediately packed in polyethylene bags sealed and stored in a dark cool place (Ndabikunze *et al.*, 2011).

3.2.4 Flour Formulations

Six blends of composite flours in the proportions as shown in Table 3.1 was prepared for physicochemical, colour and pasting analysis

Table 3.1 Flour blends

	Baobab Pulp Powder (BPP)	Tamarind Kernel Powder (TKP)	Yam Flour (YF)
F1(100Y)	0	0	100
F2(40T:60Y)	0	40	60
F3(40B:60Y)	40	0	60
F4(30B:10T:60Y)	30	10	60
F5(10B:30T:60Y)	10	30	60
F6(20B:20T:60Y)	20	20	60

3.3.0 Proximate and mineral analysis on samples

3.3.1 Determination of Moisture

The moisture content was determined using the Official Methods of Analysis (AOAC, 1990). Five grams of samples was weighed and transferred into previously dried and weighed glass dishes. The dishes with samples were placed in a thermostatically controlled oven and heated at 105 ºC for 5 h to a constant weight. The dishes were removed and cooled in a desiccator and re-weighed. The dishes were dried again for 30 min, cooled down and weighed. This procedure was repeated until constant weight was reached. The moisture content was determined by difference and expressed as a percentage.

$$\% \text{ Moisture} = \frac{\text{Weight of can + fresh sample} - (\text{Weight of can + dry sample})}{\text{Weight of sample}} \times 100$$

3.3.2 Determination of ash

The ash content was determined using the Official Methods of Analysis (AOAC, 1990). A porcelain crucible was ignited, cooled and weighed and then 2 g of flour sample was transferred into the porcelain crucible. The crucible and its content were then placed in a muffle furnace preheated to 600 ºC for 2h, removed, cooled in desiccators and finally weighed. The total ash content was calculated and expressed as a percentage.

$$\% \text{ Ash} = \frac{\text{Weight of crucible + ash - Weight of empty crucible}}{\text{Weight of sample} \times 100}$$

3.3.3 Determination of crude fat

The crude fat content was determined using the Official Methods of Analysis (AOAC, 1990). A previously dried (air oven at 100ºC) and cooled 250 ml round bottom flask was weighed. Two grams of the flour sample was transferred to a 22x80 mm filter paper (thimble) and glass wool was placed into the thimble to prevent loss of flour. One fifty millilitres of petroleum ether were added to the round bottom flask and the apparatus was assembled. The Quick fit condenser was connected to the Soxhlet extractor and refluxed for 16 h using a heating mantle. The flask was removed and evaporated on a steam bath. The flask and its content was heated in an oven for 30 min at 105 ºC, cooled to room temperature in a desiccator and weighed.

Crude fat was calculated as follows:

% Crude fat = Weight of extracted matter× 100

Weight of sample

3.3.4 Determination of crude fibre

The official Methods of Analysis (AOAC, 1990) was used to determine the fat content. The defatted flour was transferred into a 750 ml Erlenmeyer flask and approximately 0.5 g of asbestos was added for the crude fat determination. Two hundred millilitres of boiling 1.25% H_2SO_4 was added and the flask was immediately set on a hot plate and condenser connected to the Erlenmeyer flask (cold finger type) and then heated for 30 min. The Erlenmeyer flask was removed and the contents immediately filtered through linen cloth in funnel and washed with a large volume of boiling water until washings was no longer acidic. This was done using a pH meter.

The filtrate and asbestos was washed back into a Erlenmeyer flask with 200 ml boiling 1.25% NaOH solution. The Erlenmeyer flask was connected to the condenser and boiled for exactly 30 min. At the end of 30 min the contents of the flask were filtered through linen cloth in a funnel and washed with large volumes of boiling water.

The residue was transferred into a Gooch crucible with clean water and washed with 15 ml alcohol. The crucible and its contents was dried for 1 h at 100 ºC, cooled in a desiccator and weighed. The crucible with its content was ignited in a muffle furnace preheated to 600 ºC for 30 min cooled in a desiccator and reweighed.

% Crude fibre = Weight of dried sample - Weight of ash

Weight of sample × 100

3.3.5 Determination of protein

Standard methods of the Association of Official Analytical Chemists (AOAC, 1990) were used to determine the crude protein content. Two grams of sample flour, half of selenium based catalyst tablet and a few anti-bumping agents (broken porcelain crucibles) were transferred into a digestion flask and then twenty five millilitres of concentrated sulphuric acid (H_2SO_4) was added. To make sure that the sample is thoroughly wet, the flask was shaken. The flask was put on a digestion burner and heated gradually until boiling stops and the resultant mixture clarifies. The flask and its content were cooled to room temperature. The digested flour solution was transferred into a 100 ml volumetric flask and distilled water was added to the mark.

The distillation apparatus was flushed out before use by boiling distilled water in a steam generator for a minimum of 10 min. Twenty five millilitres of 2% boric acid was pipetted into a 250 ml conical flask and 2 drops of mixed indicator (bromocresol green and methyl red) added. Liquid from the steam trap was drained. The conical flask and its contents were placed under the condenser in such a position that the tip of the condenser was totally immersed in solution formed in the conical flask. Ten millilitres of the digested solution sample was measured. The stopcock of the funnel on the steam jacket was opened and the 10 ml of the digested solution poured. Excess of 40% NaOH was added to the decomposition flask and the funnel stopcock closed. The stopcock on the steam trap outlet was shut to force steam through the decomposition chamber in order to drive the liberated ammonia into the collection flask. The distillate was titrated with 0.1 N HCl solution. The acid was added until the solution was colourless. Additional acid caused the solution to become pink. The same procedure was followed for the blank.

3.3.6 Determination of Carbohydrate

The contents of carbohydrate of the samples were estimated by difference (% carbohydrate = 100% - sum of percentage of moisture, ash, fat, crude fibre and crude protein contents) (Kirk and Sawyer, 1981).

3.3.7 Mineral Analysis

Mineral analysis was done using the method of Jones*et al.* (1990).The flour sample was weighed into a porcelain crucible. An empty crucible was included as a blank. The crucibles was placed in a muffle furnace and heated to 600 ºC over a period of 2 h and cooled in a desiccator. The ashed samples was transferred into 50 ml centrifuge tube and the crucibles was rinsed with 5 ml distilled water and 5 ml (3 times) of *aqua regia* (1200 ml of distilled water was poured into a 2 L volumetric flask. 400 ml concentrated hydrochloric acid and 133 ml of 70% nitric acid was cautiously added and the volume was made to 2 L.) to a total volume of 20 ml. The tubes was corked and vortexed to mix the contents carefully and centrifuged at 3000 rpm for 10 min. The supernatant was decanted into micro-vials.

The flame atomic absorption spectrophotometer was used in the determination of calcium (Ca), phosphorus (P) and iron (Fe) contents.

3.3.7.1 Calcium Determination

Twenty milliters of ash solution was pipetted into a 150 ml beaker and 10 ml of hydrochloric acid solution added. Forty milliters of distilled water is then added. Two to three drops of methyl red indicator is added to solution and boiled. Fifteen milliters of saturated ammonium and 5g of urea were then added to the hot to boil for about 10 minutes. To the hot solution (70-80ºC) dilute ammonia solution was added drop wise and with stirring, until the liquid is neutral or faintly alkaline (colour change from red to yellow). The solution was allowed to stand at least 4 hours (preferably overnight), and cover the beaker with a water glass. The solution was filtered quantitatively through a coarse filter paper (Whatman no. 1) taking care not to disturb the precipitate. The precipitate was washed with small volumes of cold water, until free from chloride (2 to 3 ml of filtrate should not give any turbidity when added to 2 ml of 5 per cent silver nitrate solution in dilute nitric acid. The filter paper and precipitate were transferred to the original beaker and then the precipitate was dissolved with hot dilute sulphuric acid (about 30-50ml of 2N H_2SO_4) and finally titrated with standard N/50 potassium permanganate maintaining the liquid of 60ºC. The blank was carried out at the same time. The Calcium content was calculated as follows:

$$\frac{(\text{Tit} - \text{Blank}) \text{ x } 0.4 \text{ x } 100}{\text{wt of sample x } \left(\frac{\text{mass}}{\text{volume}}\right)}$$

3.3.7.2 Phosphorus Determination

Ten milliters of digested flour solution was pipetted in a 50 ml volumetric flask and distilled water was added to make the volume to about 40 ml. Five milliters of the ammonium molybdate-sulphuric acid was added and one gram of crystalline ascorbic acid is added with a small spatula, and the neck of the flask is rinsed with a small volume of water. The solution was heated to about boiling point and boiled for 1 minute, and blue colour developed rapidly. The solution was cooled and the volume was topped up to 50ml. The optical density of the solution was measured at 655 mmu. For the setting of the colorimeter a blank solution was used, which contains all the reagents, including the acid used for dissolving of ash, except the food sample. In exactly the same way: 0.5 – 1.0 -2.0 – 5- - 10.0 – 15.0 – 20.0 ml of phosphate standard solution was treated and measured and the resulting calibration curve was used for the determination of the phosphorus in the sample solution. A graph was plotted and the optical density against concentration

$$\text{Calculation : } \frac{\text{Con} = \frac{\text{mg}}{\text{ml}} \text{x} 250}{\text{wt of sample x V}}$$

3.3.7 3 Iron Determination

Ten milliters of the digested food sample solution was pipetted in a 50 ml volumetric flask and 30 mg of crystalline ascorbic acid was added, the neck of the flask rinsed with small volume of water, and 10 minutes was allowed for complete reduction of the iron to the ferrous state. Ten milliters of ammonium acetate solution was added and the pH value of the solution was tested with the indicator of paper. It was in the pH range of 4-5. If necessary some drops of ammonia or hydrochloric acid are added for the correction of the pH. 2 ml of dipyridyl solution is added, and the volume is made up to 50ml. For full development of colour 60 minutes was allowed at room temperature. The optical density of the solution was measured at or near 500 mput. For the setting of the colorimeter a bland solution was used, which contains all the reagents, including the acid used for dissolving of ash, except the food sample. In exactly the same way: 0.5, 1.0, 2.0, 5.0, 10.0, 15.0, 20.0 ml of iron standard solution was treated and measured and the resulting calibration curve was used for the determination of the iron in the sample solution.

3.4 Extrusion of Products (Preliminary Study)

3.4.1 Composite formulation/preparation

The flour composites were prepared using the formulation as described in the table

3.2. The samples were mixed on dry basis using a laboratory blender (E8150 - Waring @ Variable Speed Blender) for 10 min at 10000 rpm. The flour composites were stored at 5 ºC until use. The composites were extruded using a twin screw extruder (Clextral Extruder BC21, Germany) to determine the desired sensorial and textural characteristics of the extrudates using moisture feed rate (70 l/hr), screw speed (1200 rpm) and temperature (200 ºC).

Several researchers have worked on substituting or improving cereal based snacks with some legumes, pulses and leaves. The main ingredient, usually cereal based has a percentage range of 50-80% depending on the objective of the investigation (Pelembe, 2002; Deshpande and Poshadri, 2011); Shadan *et al.*, 2014). Research has also shown that high percentages of baobab in "heat subjected" food products are not desirable sensorially (Chadare 2009). Based on this this background 2 formulations out of the six were selected, F5(10B:30T:60Y)and F6(20B:20T:60Y), for extrusion cooking trial. Table 3.2shows the extrusion parameters selected for the trial work.

Table 3.2 Flour Composite Formulation and Extrusion Parameters

Formulations	Temp (ºC)	Feed rate (g/min)	Screw speed (rpm)
F5(10B:30T:60Y)	200	300	1200
F6(20B:20T:60Y)	200	300	1200

*F= Formulation Y= Yam T=Tamarind B= Baobab

3.5 Physicochemical Analysis

3.5.1 Determination of pasting properties

Fourty grams of flour sample and 420 ml distilled water was mixed to form a slurry (8.8% Sslurry) for pasting properties of flour samples using Brabender Visco amylograph (Viskograph-E, Brabender Instrument Inc. Duisburg, Germany) equipped with a 1000 cmg sensitivity cartridge. Pasting properties of flour after extrusion was characterized using rapid visco analyzer (RVA) as described by Declour *et al.*, (2000) for peak viscosity, holding strength set back, breakdown viscosity and final viscosity was also measured on flour samples after extrusion. Total running time was about 13 min and the viscosity values were recorded every 4 seconds by Thermocline Software as the temperature increases from 50 °C to 95 °C before cooling to 50 °C again.

3.5.2 Water Binding Capacity (WBC)

This was determined using methods described by Beuchat (1977) as cited in Amza *et al*. (2011) with little modification to centrifuge speed and time. One gram sample was weighed into 25 ml graduated conical centrifuge tube and about 10 ml of water added. The suspensions were allowed to stand at room temperature (30 ± 2 °C) for 30mins and centrifuged at 2000 x g for 30 minutes. The volume of water on the sediment was measured and the water absorbed expressed as per cent water absorption based on the original sample weight.

Water binding capacity (grams of water per gram of flour) was calculated as

$$\% \text{ Water Binding Capacity} = \frac{(W_2 - W_1)}{W_0} \times 100$$

where W_0 is the weight of the dry sample (g), W_1 is the weight of the tube plus the dry sample (g), and W_2 is the weight of the tube plus the sediment (g).

3.5.3 Determination of swelling power

This was determined with the method described by Leach *et al.* (1959) with modification. Modification was made with water and flour quantities. One gram of the sample was mixed with 10 ml distilled water in a centrifuge tube and heated at 80 °C for 30 min. The mixture was continually shaken during the heating period. After heating, the suspension was centrifuged at 1500 x g for 15 min. The supernatant was decanted and the weight of the paste taken. The swelling power was calculated as:

$$\text{Swelling power} = \frac{\text{Weight of the paste x 100}}{\text{Weight of dry sample}}$$

3.5.4 Determination of Bulk Density

The bulk density was determined by the method of Makinde and Ladipo (2012) with little modification to flour quantities. Ten grams sample was weighed into 100 ml graduated measuring cylinder. The samples were packed by gently tapping the cylinder on the bench top 10 times from height of 5 cm. The volume of the sample was recorded.

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of the sample}}{\text{Volume of the sample after tapping}}$$

3.5.5 Determination of pH

Five grams of yam flour was weighed and mixed with 50 ml of distilled water to obtain slurry. The pH was then determined using a Fisher Science Education pH (Model S90526, Singapore) meter by inserting the pH probe into the slurry and the reading is taken.

3.5.6 Determination of Expansion Ratio

Expansion ratio was determined using the method described by Kannadhason *et al.,* (2009). The diameter of the extrudates was measured with vernier caliper and then divided by the diameter of the die nozzle (5.0 mm) to determine its expansion ratio.

3.5.4 Colour Determination

The colour of the flour samples was measured with a Minolta CR-310 (Minolta camera Co. Ltd, Osaka, Japan) tristimulus colorimeter, recording L, “a” and “b” values. L represented lightness (with 0= darkness/ blackness to 100=

perfect/brightness); a corresponds to the extent of green colour (in the range from negative= green to positive = redness); b represents blue in the range from negative=blue to positive=yellow. Chroma (C) is the saturation or vividness of color. As chromaticity increases, a color becomes more intense; as it decreases, a color becomes duller. Hue angle (h) is the basic unit of color and can be interpreted, for example, as 0 = red and 90 = yellow. Both chroma and hue are derived from a and b using the following equations: metric chroma: C = O (a) ^{2} + (b) ^{2}, metric hue angle:

h = tan–1 (b/a) (degrees) and colour intensity is measured as: $\sqrt{\;^{2}\quad^{2}\quad^{2}}$. The colorimeter was calibrated against a standard white reference tile. Samples were placed in a clear glass Petri dish (10 replicates), and colour measurements were done
in triplicate.

3.6. Sensory Evaluation of Extrudates

A method used by Meilgaard *et al.*, 1999 was used for the consumer acceptance tests to evaluate the overall acceptance of the two blends of trial extruded snacks. The sensory assessments were conducted in Food Science and Technology laboratory. The panel of 30 members consisted of students from the department of Food Science and Technology. The panellists were naive to project objectives. Samples were coded using random three-digit numbers and served with the order of presentation counterbalanced. Panellists were provided with a glass of water and, instructed to rinse and swallow water between samples. They were given written instructions and asked to evaluate their liking for aroma, texture, shape, crunchiness, puffiness and taste of the extruded products using nine-point hedonic scale, wherein 1 = Dislike extremely, 2 = Dislike very much, 3 = Dislike moderately, 4= Dislike slightly, 5 = neither like nor like, 6 = Like slightly, 7 = Like moderately, 8 = Like very much, and 9= Like extremely.

Panellists were then asked to assess their overall preference for the two extrudates using the scale, 1= most preferred and 2= least preferred. The extrudate that had the highest perentage for preference was considered the most preferred extrudate in terms of overall acceptability.

3.7 Statistical Analysis

Quantitative data were expressed as means and standard deviation (SD) of at least 2 measurements. Each experimental set was analyzed using Statistical Package for Social Sciences (SPSS) version 11.5 (SPSS Inc., Chcago, IL, USA). Least Significant Difference (LSD) test was used to determine the differences of means. P values <0.05 were regarded as significant.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Proximate Compositionof Flour Samples (yam, tamarind, baobab)

4.1.1 Moisture

Yam flour (YF),baobab pulp powder (BPP) and tamarind kernel powder (TKP) had average moisture values of 5.5%, 9.45% and 2.68% respectively as shown in Table 4.1.The moisture value of YP was within the range (5.26-7.57%) reported by Udensi *et al*. (2008) for six varieties of *D. alata* flour understudied. There were significant differences ($p<0.05$) within flour composites.It was also within the range (4.11- 6.79%) reported by Ezeocha and Ojimelukwe (2012) for water yam flours that were subjected to varying processing methods whereas the value (8.8%) reported by

Adeola *et al.* (2012) for instant "poundo yam" flour was higher than what was observed in this study. Moisture content which is related to water activity gives an indication of the solid matter in a sample as well as the rate of spoilage or stability (Baah *et al.*, 2009). The moisture levels were however within the suitable limit of not more than 10% for extended flour storage period (Polycarp *et al.*, 2012).

The baobab pulp powder (BPP) is a naturally dried nutritious product. Many researchers have reported various results on its moisture content.Arnold *et al*. (1985) (cited in Gruenwald and Galizia, 2005) reported average moisture of 8.7%. Abdalla (2010) accessed baobab pulp powders from four towns in Sudan and obtained moisture values within a range of 7.78- 8.59%. Results from Table 4.1a indicates that the moisture value of BPP (9.54%) in this study was higher than what these researchers have reported. However Oyeleke *et al*. (2012) obtained moisture value of

11.2% for baobab pulp in Nigeria and this was higher than what was observed in this study.

These differences could be attributed to sampling sources/locations, variety or processing methods used. Furthermore, an observation made during the study showed that baobab pulp powder absorbed more moisture faster when exposed to the atmosphere than other flour samples even though sorption isotherm was not determined. This could be linked to the presence of simple sugars which account for about 35.6% of the total carbohydrate content in the baobab pulp (Murray *et al*, 2001).

Tamarind had a moisture value of 2.68%, as shown in Table 4.1. Klahali *et al*. (2012) and Pugalenthi *et al*. (2004) have reported higher moisture values of 9.09- 10.78% and 11-4-22.7% respectively for tamarind kernel powder. A review of works done by Anon (1976) (cited in El-Siddig *et al*., 2006), Ishola *et al.* (1990) and Parvez *et al*. (2003) also demonstrated that tamarind pulp powder had higher moisture content in the range of 15-30% (El- Siddig, 2006). The moisture value obtained in this study was quite lower than what has been reported in other studies. This could be attributed to the fact that the researchers subjected the tamarind seed kernel to different processing methods. The seed could have also been processed when it was still fresh as the fresh seeds are consumed in some parts of the world. Also in this study the seeds were roasted after removal of testa and so the moisture content was reduced consequently.

4.1.2 Ash Content

Ash content of YF, BPP and TKP were 3.28%, 6.04% and 0.67%respectively (Table 4.1a). BPP had the highest ash content whiles TKP had the lowest. The ash content gives an idea in identifying the authenticity or grade of food (USDA, 2011). Also ash content gives an idea of the mineral content.

Ash content of *D. alata* as reported by Ezeocha and Ojimelukwe (2012) was 2.93% whiles Senanayake *et al*. (2012) also reported 1.66%. Udensi *et al*. (2008) reported ash content of 2.25- 3.15%. There were significant differences ($p<0.05$) within flour composites.The ash content values reported by these researchers were lower than what was observed in this study (3.28%). This could be attributed to varietal differences.

Ash value for BPP as reported by Manfredini *et al*. (2002), 6%, Magaia *et al*. (2005) 4.9-5.3% and (Oyeleke *et al*., 2012), 4.5% were lower than the value obtained in this study (6.4%).

The ash content of tamarind as revealed by Klahali (2012), Adekunle and Adenike (2012), Pugalenthi (2004) were0.05-0.39%, 1.69% and 2.4-4.2% respectively. The results from Table 4.1a (0.67%) shows that the ash content differed from the values reported by certain researchers. The varying results of ash content in samples could be attributed to variety differences and source of samples.

4.1.3 Protein Content

Results from Table 4.1a shows that yam flour (*D. alata*) had a protein content of 4.9%. The values from this study were lower than what has been reported by Polycarp (2012), Senanayeyake *et al.* (2012), Ezeocha and Ojimelukwe (2012), Udensi *et al.* (2008) Harijono *et al*. (2013) and Baah *et al*.(2009) who obtained protein values of 6.08, (6.24 – 10.16), (7.10 – 10.27), (5.69-8.31), (5.62-8.33), (5.23-8.24) in percentages respectively. However, these disparities could be attributed to the differences in pre-treatment methods, varietal and geographical locations.

Tamarind kernel powder in this study had a protein content of 15.43%. A study done by Iqbal *et al*. (2006) showed protein range of 12.53-13.46% for tamarind sourced from three different locations in India. Work done by Panigrahi *et al.* (1989), Anon (1976) cited in El-Siddig *et al*. (2006) and Marangoni *et al*. (1988) have also shown that tamarind protein levels are in the range of 13-20%. Apart from Marangoni *et al*. (1988), all other reports on tamarind protein levels were lower than obtained in this study. These values indicate that the seed is a good source of proteins (Shankaracharya, 1998). Tamarind has a very good balance of essential amino acids: high methionine and cystine contents as compared to other legumes hence it could be used to complement cerealsand also supplement other legumes (El-Siddig *et al*., 2006).

The protein content of baobab pulp was 3.35% as shown in Table 4.1. Studies by Nour *et al.* (1980), Mafredini (2002) Oyeleke *et al.* (2012) and Eke*et al*. (2013) have all reported protein values of 3%, 8.2%, 3.5% and 2.3% respectively. The result from this study is comparable to those reported in literature which confirms report by Osman (2004) that the protein content of baobab pulp is quite low.

Table 4.1 Proximate Composition of Flour Samples

	Moisture %	Ash %	Crude Protein %	Crude Fat %	Crude Fibre %	Carbohydrate %	Energy (kcal)
Yam flour	**5.50±0.18[a]**	**3.28±0.15 [a]**	**4.9 ± 0.02 [a]**	**0.46± 0.04 [a]**	**1.89± 0.11 [a]**	**83.98 ± 0.45 [a]**	**359.66 ± 1.54 [a]**
Baobab pulp Powder	**9.54±0.23[b]**	**6.04±0.01 [b]**	**3.35 ±0.01 [b]**	**0.33± 0.01 [b]**	**7.94 ±0.35 [b]**	**70.61 ± 0.84 [b]**	**323.07± 3.46 [b]**
Tamarind Kernel Powder	**2.68±0.03 [c]**	**0.67±0.02 [c]**	**15.43±0.03[c]**	**6.24±0.01 [c]**	**3.99±0.16 [c]**	**71.59 ± 0.17 [c]**	**404.23±0.48 [c]**

* Analysis was done in duplicates
*Means with the same superscripts within the column are not significantly different (p>0.05)

4.1.4 Crude Fat Content

The crude fat value of *D. Alata* obtained in this study was 0.46%. However, 1.8-2.0% was reported by Senenayake *et al.* (2012), 0.09- 1.15% by Ezeocha and Ojimelukwe (2012), 0.82% by Polycarp (2012), 0.75-1.10% by Udensi *et al*. (2008) and 0.40-0.5%

by Harijono *et al*. (2013). These values are comparable to the results in this study. There were significant differences ($p<0.05$) within flour composites.Generally the crude fat content values reported by most scientists were however higher than that obtained in this study.

Crude fat content of tamarind was 6.24% as shown in Table 4.1. This value is comparable to results revealed by Anon (1976) (cited in El-Siddig *et al*., 2006)**,** Chandramouli *et al*. (2012) and Pugalenthi *et al*. (2004). According to them the fat content of tamarind seed kernel was 5.64-7.71%, 3.9-16.2% 3-7.5% and 7.0% respectively. The fat content of tamarind was higher than what was reported for other legumes such as cowpea (4.8%), chickpea (5.2%), lentil (3.2%) and green pea (1.5%) (Iqbal *et al.*, 2006). Oil legume seeds such as peanut and soya beans have been reported to have more oils than tamarind (McKevith, 2005). ICUC (2001) and ICRAF (2007) have reported that the high lipids content (value of your study) of tamarindmakes it suitable for use in cooking. Its oil resembles that of groundnut in terms of flavour and has a good culinary appeal.

Baobab fat content was discovered to be 0.33% from the results shown in Table 4.1. Several scientists have reported that the fat content of baobab pulp is very low and the result in this study falls within the range reported by Nour *et al*. (1980), Eke*et al*. (2013), Oyekele *et al*. (2012) and Phytotrade (2005). Their reports indicate that the range of fat content of baobab pulp is in the range of 0.3-0.7%.

4.1.5 Crude Fibre Content

The results from this work indicate that yam crude fibrecontent was 1.89%. Other works done on *D. Alata* showed that water yam had fibre contents of 1.37- 2.31%, 4.07-5.73%, 0.75- 1.13% and 1.1 -1.2% (Ezeocha and Ojimelukwe, 2012 ; Harijono *et al*., 2013 ;

Udensi *et al*., 2008; Adeola *et al*., 2012) which are comparable to what was discovered in this study.

Tamarind seed kernel crude fibre content was 3.99% in this study. Works done by Anon (1976) cited in El-Siddig *et al.* (2006), Pugalenthi *et al*. (2004); Ishola *et al*. (1990) and Bhattacharyya *et al*. (1994) showed a range of 2.5-8.2%. The fibre contents in this study were comparable to what other scientists reported.

Results from Table 4.1a again reveal that the fibre content of baobab pulp powder was 7.94%. This value is higher than what was discovered by Eke *et al.* (2013), (5.4 %) and comparatively lower than the results of Nour *et al.* (1980) (8.19- 13.06%) Baobab fruit pulp is known to have both soluble and insoluble fibres and its water-soluble fraction has stimulating effects on the growth of lactobacilli and bifidobacteria (Manfredini, 2002). Baobab fibre content (7.94%) is relatively higher as compared to fruits including apples (4g), peaches (3g), apricots (6g) and bananas (3g) (phytotrade, 2010; USDA, 2011). Its fibre content also plays a role as a gelling, thickening agent or stabiliser in food formulations.

Generally sufficient levels of dietary fibre in a diet help sustain a healthy digestive tract, improve glucose tolerance by delaying the transport of carbohydrates into the small intestine, decreases blood cholesterol levels, aiding weight loss and normalizing bowel movement (Adekunle and Adenike, 2012; Anderson *et al*. 1994; Rodríguez-Miranda *et al*., 2011).

4.1.6 Carbohydrate Content

The carbohydrate content of *D. alata* was 83.98%. Several works have been done in determining the carbohydrate content of water yams. Senenayake *et al*., 2012, Ezeocha and Ojimelukwe (2012), Udensi *et al*. (2008), Adeola *et al*. (2012) have reported carbohydrate values of 75.86-78.32%, 76.57-85.20%, 81.53-87.64% and 83.5-83.8% respectively. These high values are all evidences that yams are known to be starchy foods with high carbohydrate content (Baah, 2009).There were significant differences ($p<0.05$) within flour composites.

Tamarind carbohydrate value as shown in Table 4.1a is 71.59%. This value is comparable to results revealed by Iqbal *et al*. (2006) and Anon (1976) cited in ElSiddig *et al.* (2006). They had carbohydrate values of 78.52-81.62% and 65.1-72.2% respectively. This difference in carbohydrate values is influenced by the location of samples (El-Siddig *et al.*, 2006). The polyssacharides in tamarind kernel powder are known to have gelly forming properties, named 'jellose'. It is the major polysaccharide present in the kernel powder (60%). This is composed of D-glucose, D-xylose, D-galactose and L-arabinose in the ratio 8:4:2:1 (Rasala *et al.*, 2011). It has been recommended for use as a stabiliser in ice cream, mayonnaise and cheese and as an ingredient or agent in a number of pharmaceutical products (Sukhawanli and Thamakorn, 2014; El-Siddig *et al.*, 2006).

Baobab also had carbohydrate content of 70.91% as shown in Table 4.1. However Nour *et al.* (1980), Eke*et al*., (2013) and Oyeleke *et al.* (2012) have reported values of 74%, 76.2% and 74.3%. These values are quite higher than what was observed in this study. These could be attributed to varietal and location differences. Researchers such as Odetokun, (1996); Lockett *et al.* (2000); Murray *et al.* (2001); Shukla *et al.*, (2001) and Osman (2004) have reported the absence of starch in the pulp of baobab. Simple sugars account for about 35.6% of the baobab pulp and they are also responsible for the sweetness of baobab pulp (Murray *et al.* (2001); Chadare *et al.* (2009). The pulp also has high pectin and fibre content (Kamatou *et al.*, 2011).

4.1.7 Energy Content

The calculated metabolizable energy of yam flour, tamarind seed kernel and baobab in this study was 359.66k cal, 404.23kcal and 323kcal respectively as shown in Table 4.1. The high energy value of tamarind may be attributed to the high protein and fat contents.

Ezeocha and Ojimelukwe (2012) and Udensi *et al*. (2008) have reported energy values of 357.65-370.01kcal and361.27-385.33kcal for *D. alata* respectively. These are comparable to what was obtained in this study.The energy values calculated for tamarind in this work was quite higher than what was reported by Anon (1976) cited in El-Siddig *et al*. (2006) which showed energy value of 340.3kcal. Energy calculated for baobab (Table 4.1a) was quite higher than that reported by Eke *et al*. (2013). The energy content of these flour samples can meet up with RDI for carbohydrates (9001300kcal) per every 100g consumed.

4.2 Mineral Composition of Flour Samples

4.2.1 Iron content

Iron content of YF, BPP and TKP in this study was 2.11 mg/100g, 5.54mg/100g and 2.37 mg/100g respectively as shown in Table 4.2. BPP had the highest whiles YF had the least iron content. A range of 6.22-7.17mg/100g has been reported by Senanayake *et al.* (2012) for *D. alata* flour. This value is higher than what was obtained in this study. Marangoni *et al.* (1988) and Pugalenti *et al.* (2004) have reported iron content values of 6.5mg/100mg and 7.14mg/100mg respectively for TKP. These values were also higher than what was obtained in this study.

Scientists have stated that tamarind and baobab are good sources of iron (Obizoba and Amaechi, 1993; SCUC, 2006). However results from this study shows that 100 grams tamarind and baobab will contribute just about 13.2% and 30.78% of the RDI (18mg) respectively. It has also been reported that 100 grams of fresh baobab pulp powder can contribute on average 23-45% of the iron RDI (18mg) for women and children (De Cawule *et al.*, 2010).

4.2.2 Calcium content

The calcium content of yam flour as shown in Table 4.2 is 16.05 mg/100g. Work done by other scientists such as Polycarp *et al*. (2012), Udensi *et al*.(2008), Senanyake *et al*. (2012), Wireko-Manu *et al.* (2013) and Alinnor and Akalezi (2010) have reported values of 6.50-16.50mg/100g, 22.16-80.16mg/100mg, 8.13-8.15 mg/100g, 260-535 mg kg^{-1} and 87.1-32.02mg/100g.

The results from this study are closely comparable to what Polycarp *et al*. (2012) stated. The results of Udensi *et al.* (2008) are higher as compared to Senanyake *et al*. (2012) which were lower than what was reported in this work. This could be attributed to varietal differences as well as sample source/location variations, composition of the soil in which it was grown, cultural practices, time of planting and water available (Osagie, 1992).

Minerals are essential constituent of meals because of their physiological and metabolic purposes in the body. Calcium is an important mineral required for bone formation and neurological function of the body. The RDI of calcium by WHO is 800 mg for both adult and children (Knoth, 1993). This study indicates that *D. alata* calcium level can contribute 2% of RDA.

The results from this study revealed that the calcium content of baobab pulp was 14.55mg/100g. This value was lower than what has been reported by Manfredini *et al*. (2002); Täufel *et al*. (1993) and Oyeleke *et al*. (2012) whose results have indicated that the pulp could have calcium content of about 293mg/100g and 78.18mg/100g respectively. Baobab is known to be rich in calcium (Manfredini *et al*., 2002) but the results from this work are comparatively lower. This may be due to source of sample and soil composition. Baobab has been used as a substitute for milk in some parts of the world due to its high levels of calcium. Calcium is essential in bone and teeth formation. The absorption of calcium is however dependent on the presence of vitamin D, oxalic and phytic acid (Natural Standard, 2011).

Tamarind seed kernel also showed calcium content of 16.05 mg/100g. Results from Manfredini *et al*. (2002); Täufel *et al*. (1993) and Pugalenthi *et al.* (2004) show calcium content of 120mg/100g and 248.56mg/100g respectively. These values are comparatively higher than what was obtained in this study. This could be attributed to varietal differences, soil composition and treatment methods. Leaching might have also occurred during the flour preparation stage of the seeds (seeds were soaked to ease pulp removal) (Ogbonna *et al.*, 2013).

Table 4.2 Iron, calcium and phosphorus content of of flour samples

	Fe (mg/100g)	Ca (mg/100g)	Phosphorus(mg/100g)
Yam flour	2.11 ± 0.06	38.84 ± 1.27	43.00 ± 0.23
Baobab pulp powder	5.54 ± 0.16	14. 55 ± 2.23	38.40 ± 1.80
Tamarind Kernel Powder	2.37 ± 0.28	16.05 ± 0.04	52.37 ± 1.27

* Analysis was done in duplicates

4.2.3 Phosphorus Content

Results from Table 4.2 reveals that the phosphorus content of yam flour, baobab pulp and tamarind seed kernel were 43.00mg/100g, 38.40mg/100g and 52.37g/100g. TKP had the least whiles BPP had the highest phosphorus content. Research done by Polycarp *et al*. (2012) and Udensi *et al*. (2008) on water yam revealed a range of

219239mg/100g and 20.16-80.16mg/100g respectively. Values obtained from this study were lower than what other scientists had reported.

Manfredini *et al.*(2002), Sanful *et al.* (2013) and Oyeleke *et al.* (2012) have also reported values of 96-118mg/100g, 34.2 to 42.3mg/100gand 105.20mg/100g respectively for baobab pulp powder. The values of Sanful *et al.* (2013) were comparable to what was obtained in this study but was lower than what the other scientists had reported.

Tamarind Kernel powder in this study also had phosphorus content of 52.37mg/100g as shown in Table 4.2. Work done by Kumar & Bhattacharya (2008), Alinnor and Akalezi (2010) and Pugalenthi *et al.* (2004) showed phosphorus contents of 68.4165mg/100g, 34.2 to 42.3mg/100g**,** 17-61mg/100g and 369.47mg/100g respectively. The results in this study are similar to what Alinnor and Akalezi (2010) discovered but were quite lower than others have reported. As stated earlier these variations could be due to varietal differences, soil composition and treatment methods.

4.3 Physicochemical Characteristics on Composite Flours and Trial Extrudates

Table 4.3 (a, b), 4.4 (a, b) and 4.5(a, b) show the physicochemical analysis of flour composites. Flour composites have been coded F1 to F6 whiles the trial extrudates have been coded E5 and E6.

4.3.1 Moisture

Moisture contents of flour composites were within the range of 3.01-5.61% (Table 4.3a). Forty percent tamarind (F2) had the highest moisture content of 5.61 whiles 30% baobab pulp (F4) had the least value of 3.01. Samples with tamarind kernel powder (TKP) substitutions had higher moisture contents than those substituted with baobab pulp powder (BPP). This can be explained by the fact that the moisture content of TKP was higher than that of BPP as seen in Table 4.1 and this influenced the overall moisture content after substitution. The low moisture contents of flour composites can also be attributed to the initial low moisture content of the individual flour samples (Table 4.1).There were significant differences ($p<0.05$) between moisture contents of flour blends.

Table 4.3a Moisture and Water Binding Capacity of Composite FlourBlends

Composite flours /samples	Moisture (%)	WBC (%)
F1(100Y)	5.51±0.21[a]	87.50±3.54[a]
F2(40T:60Y)	5.61±0.11[a]	112.50±3.53[b]
F3(40B:60Y)	3.01±0.11[b]	132.50±3.54[c]
F4(30B:10T:60Y)	3.08±0.03[b]	111.50±3.53[b]
F5(10B:30T:60Y)	4.28±0.08[c]	107.50 ±5.30[b]
F6(20B:20T:60Y)	4.02±0.10[c]	123.80±1.77[c]
Baobab pulp powder	9.54 ± 0.23	189.0± 1.76
Tamarind Kernel Powder	2.68 ± 0.03	136.31 ± 5.35

* Analysis was done in triplicates *Y= Yam T=Tamarind B= Baobab
*Means with the same superscripts within the column are not significantly different ($p>0.05$)

Water injection rate (70 l/hr) for F5 and F6 during extrusion cooking was the same. Moisture contents of composite flours (F5 and F6) were generally higher than the extrudates (E5 and E6) even though 10% baobab substituted extrudates had lower (1.12) moisture content than 20% baobab substituted extrudates (2.03). This is basically because the flours were subjected to heat (200ºC) within a short time during extrusion cooking. There were significant differences ($p<0.05$) between moisture contents of extrudates.

The low moisture content of flour blends and extrudates indicates that they will have a long shelf life during storage (Pushpa and Narayanasamy, 2013; Haritha *et al.*, 2014; Filli and Nkama, 2007).

Table 4.3b Moisture and Water Binding Capacity of Trial Extrudates

Extrudates	Moisture (%)	WBC (%)
E5(10B:30T:60Y)	1.12±0.03[a]	85.00±7.00[b]
E6(20B:20T:60Y)	2.03±0.07[b]	62.50±3.54[a]

* Analysis was done in triplicates *Y= Yam T=Tamarind B= Baobab
*Means with the same superscripts within the column are not significantly different (p>0.05)

4.3.2 Water Binding Capacity (WBC)

The WBC of flours varied between 87.50- 132.50% (Table 4.3a). Thirty percent tamarind (F5) showed the highest WBC whiles 40% baobab (F3) had the least WBC with values of 121% and 72% respectively. There were significant differences (p<0.05) within flour composites. In the development of ready-to-eat foods water binding capacity is an imperative functional feature since high water absorption capacity may guarantee product cohesiveness (Addy, 2012). Particle size, protein content and protein denaturation of foods greatly affects water binding capacity of flours (Granito *et al.*, 2004). Addy (2012) reported that the water binding capacity values of yam flour varieties ranged from 215.20 - 232.45%. A range between 159.7 and 202.0% was reported by Baah *et al.* (2009) for *D. alata*however these values are quite higher than what was observed in this study. Water binding capacity of *D. Alata* flour (100% Y) was 87.50%. This may be because of the difference in source of materials and cultivar of *D. alata*.

Tamarindus indica is a legume known to have high jellose and protein content. Jellose in tamarind seeds has a gelling ability, which makes it suitable as a stabilizer and thickener in food products. The proteins also have both hydrophilic and hydrophobic properties thereby can interact with water and oil in food (Marathe *et al.*, 2002; El-Siddig *et al.*, 2006). However in Table 4.3a, 40% baobab (F3) had higher WBC than 40% tamarind (F2) even though they had equal level of substitution. This means that baobab improves WBC in flours than tamarind kernel powders because sugars and pectin in baobab may be absorbing more water than the proteins and jellose in tamarind. This is evident in Table 4.3a which indicates that the WBC of Baobab Pulp Powder (BPP) was 189.0% whiles that of TKP was 136.31%.

Larrea *et al*. (2005) indicated that water binding capacity increases after extrusion (Table 4.3b), but with this study it was not the case for the trial samples (E5, E6). Extrudates had lower (85.00%, 62.50%) WBC than the flour blends (107.50%, 123.80%). This may indicate that product composition may also affect the WBC of products after extrusion.The extrusion cooking led to loss of hydration capacity in extrudates (Fernandez-Gutierrez *et al.*, 2004). The higher WBC value for F5 (10B:30T:60Y) as compared to F6 (20B:20T:60Y) could be attributed to the fact that the F5 was able to withstand higher heat and shearing better than F6. The low WBC values after extrusion could also be because molecules engaged a lot of water during extrusion and so their capacity to bind to extra water after extrusion reduced (Ding *et al*. 2005). As a result of this, if extrudates should be milled into flour for food products such as baby foods breakfast meal, pudding or porridges, they will not be appropriate for unit high yield, syneresis may occur after heating, during retorting or freezing unless product composition and extrusion parameters are altered (Ellis *et al.*, 2003; Oduro *et al.*, 2001).

4.3.3 Acidity and alkalinity

pH of composite flours was within the range of 3.90 to 5.39.There were significant differences in pH in composite flours ($p<0.05$). One hundred percent yam flour (F1) had a pH of 5.26 which is quite lower than the 7.27, 6.53, 6.4 and 6.15 reported for *D. alata* by Sarpong (2013), Harijono *et al.* (2013), Obadina *et al.* (2014), Onwuka and

Ihuma (2007), respectively. The differences could be attributed to varietal and flour preparation differences.

The amount of hydrogen ions in a particular solution gives an indication of the acidity or alkalinity. This parameter termed pH is vital in the assessment of eating quality since it contributes to taste and also determines the products susceptibility to the growth of microorganisms (Oduro *et al.*, 2001; Nummer, 2008). pH of the feed material may influence, colour, texture, nutritional content, enzyme activity, volatile compounds, viscosity, solubility and ultimately the final characteristics of the extruded product when altered because pH influences the activity of proteins (ElSamahy *et al*., 2007).

Yam flour only had a pH of 5.26 (Table 4.4a) but upon substitution with 40% of baobab pulp (F3) and 30% baobab pulp (F4) the pH decreased to 3.90 and 3.91 respectively. However there was an increase in pH when tamarind kernel powder was substituted at high levels of 40% (F4) and 30% (F5) with pH values of 5.39 and 5.29 respectively this was influenced by the individual pH of flour samples (Table 4.4a).

As shown in Table 4.4a TKP had a pH of 6.56 whiles baobab had a pH 3.36 which was close to results stated by Patel (2014) and Ndabikunze*et al.* (2011) with values of 3.4 for baobab pulp and 6-7 for tamarind respectively. Lower pH of baobab (3.36) could be due to the presence of ascorbic acids (Chadare *et al.*, 2009), however the high temperature (200°C) during extrusion may have destroyed some of the ascorbic acids which caused a slight increase in pH 20% baobab/20% tamarind (E6). The same can not be said for the pH value for E5 20% baobab/20% tamarind.

A pH value of 4.0 to 5.8 has been recommended for baked bread in order to extend shelf life (MBH, 2008). An article written by Tummimburg (2014) revealed that coconut flavoured pan de sal, extruded snack curls and cookies also had pH values of 5.0, 6.0 and 6.3 respectively. In this trial experiment extrudates (E5 and E6) had pH values of 4.83 and 4.91 respectively. It can be concluded that the extrudates are safe for consumption and would have a good shelf life (MBH, 2008) due to its low moisture level as well the pH: yeasts and moulds prefer pH within a range of 5-6.

Table 4.4a pH and Swelling Power of Composite Flours

Composite Flours/ Samples	pH	Swelling power (ml/100g)
F1(100Y)	5.26±0.02[a]	201.43±2.33[a]
F2(40T:60Y)	5.39±0.06[b]	213.7±4.88[a]
F3(40B:60Y)	3.90±0.06[c]	214.63±7.31[a]
F4(30B:10T:60Y)	3.91±0.01[cd]	221.51±2.09[b]
F5(10B:30T:60Y)	5.29±0.01[e]	222.66±1.96[b]
F6(20B:20T:60Y)	4.21±0.02[f]	237.95±9.41[b]
Baobab pulp powder	3.36±0.04	
Tamarind Kernel Powder	6.56±0.02	

* Analysis was done in triplicates *Y= Yam T=Tamarind B= Baobab
*Means with the same superscripts within the column are not significantly different (p<0.05)

Table 4.4b pH and Swelling Power of Trial Extrudates

Extrudates	pH	Swelling power (ml/100g)
E5(10B:30T:60Y)	4.83±0.06[a]	359.94±5.17[b]
E6(20B:20T:60Y)	4.91±0.11[a]	261.08±1.93[a]

* Analysis was done in triplicates *Y= Yam T=Tamarind B= Baobab
*Means with the same superscripts within the column are not significantly different (p<0.05)

4.3.4 Swelling Power

Swelling power of samples ranged from 201.43 to 237.95% (Table 4.4a). Yam flour (F1) had the least swelling power whiles 20% baobab (F6) had the highest swelling power. There were significant differences in the swelling power of flour composites. Swelling power shows the hydration ability of starch granules and also indication of hydrogen bonding and association within the granules of starches (Jimoh, 2009;

Katekhong 2012; Harijono *et al.*, 2013). Water binding capacity is an indicator of the swelling power of flours. Results from Table 4.4a shows that generally a blend of TKP and BPP gave higher values than for single substitutions of either tamarind or baobab. This could be as result of the synergistic effects and a phenomenon known as phase separation of pectin from baobab and jellose from tamarind. This phenomenon is generally due to excluded volume effects and water distribution between the phase (Turgeon *et al.*, 2003).

Generally the swelling power of extrudates increased after extrusion (Table 4.4b). 10% baobab and 20% baobab had swelling powers of 222.66% and 237% before extrusion and 359.94% and 237.95% respectively after extrusion. Extrusion cooking had an impact on the degree of exposure to the internal structure of the gelling polysaccharides and proteins in the extrudates, specifically their action to water (Kafilat, 2010). From the results extrusion improved the swelling power of flour samples. This implies that in order to incorporate any of the flour blends as a thickener or bulking agent in food formulations or products, subjecting it to some level of extrusion cooking before application is an advisable alternative. Gels are known to boost the body, texture and cohesiveness of a food product (Ubbor and

Akobundu, 2009).

4.3.4 Bulk Density

The bulk density of composite flours varied between 0.74- 0.93g/cm^3 (Table 4.5a).

The results show that there were significant differences (P≤ 0.05) between the flour blends. The bulk density of the flour blends with tamarind flour only (F2) had higher bulk densities as compared to those substituted with baobab flour only (F3). As seen in Table 4.5a, TKP had higher bulk density (0.74 g/cm^3) than BPP (0.61g/cm^3). However yam flour only (F1) had the highest bulk density of 0.93 g/cm^3.

Generally composite flours had higher bulk densities than the extrudates (Table 4.5a, 4.5b). Fletcher *et al.*(1985) as seen in Gui *et al.*,(2001) found that during extrusion increased temperature in the barrel resulted in an increased degree of superheated water which encourages bubble formation and a decrease in melt viscosity, thus leading to the material being fully cooked and allows for more expansion and reduced density.

Low bulk density of extrudates (0.19- 0.24g/cm^3)as shown in Table 4.5b could also havebeen influenced by the structure of the starch polymers, loose structure of the starch polymers (Olu *et al.*, 2012) and may be the jellose and pectin structure change after subjection to heat. The bulk density of the extrudates gives is also a determining factor to its packaging requirement and material handling in the food industries in the food industry (Karuna *et al.*, 1996).

Table 4.5a Bulk Density and Expansion Ratio of Composite Flours

Composite flour/ flour samples	**Bulk density (g/cm^3)**
F1(100Y)	0.93 ± 0.05^a
F2(40T:60Y)	0.87 ± 0.03^a
F3(40B:60Y)	0.74 ± 0.04^b
F4(30B:10T:60Y)	0.77 ± 0.02^b
F5(10B:30T:60Y)	0.82 ± 0.03^a
F6(20B:20T:60Y)	0.80 ± 0.05^b
Baobab pulp powder (BPP)	0.61± 0.03
Tamarind Kernel Powder (TKP)	0.74 ±0.04

*Y= Yam T=Tamarind B= Baobab

* Analysis was done in duplicates, *Means with the same superscripts within the column are not significantly different (p<0.5)

Table 4.5b Bulk Density and Expansion Ratio of Trial Extrudates

Extrudates	Bulk density (g/cm^3)	Expansion Ratio
E5(10B:30T:60Y)	0.24 ± 0.02^a	4.15 ± 0.15^a
E6(20B:20T:60Y)	0.19 ± 0.01^b	3.45 ± 0.19^b

*Y= Yam T=Tamarind B= Baobab

* Analysis was done in duplicates, *Means with the same superscripts within the column are not significantly different ($p<0.5$)

4.4 Sensory Evaluation and Expansion Ratio of Extrudates

Sensory evaluation results (aroma, taste, shape, texture, colour, puffiness) of trial extrudates are shown in Table 4.6. Sensory evaluation is a very important element in the food industry used on the basis that using equipments to measure certain attributes of foodcan only identify a part of the overall characteristic or attribute of a specified food product. The results of the preference test using a 9-point hedonic scale where 9=Like extremely, 5= like nor dislike and 1= Dislike extremely are presented in Table 4.6

4.4.1Puffiness

Extrudates had expansion ratios of 4.15 and 3.45 for 10% baobab (E5) and 20% baobab (E6) respectively (Table 4.5b). It has been shown according to Balasubramanian *et al.* (2012) and Alavi (1999) that heating of ingredients to a temperature above 100ºC will result in direct expanded snacks hence puffing was expected in the extrudates as flour mixtures were extruded at a temperature 200°C. In the process of extrusion, there was a rapid pressure loss as the steam vaporized from water, thus, causing stretching and expansion of thestarch/jellose/pectin matrix that allowed the products to have a low density and light texture (Guy, 2001, Duizer, 2001). In spite of the fact that high puffing is good, when the air cell wall is too thin the extrudates will break easily. A few of the consumers complained about the thinness and large air cells of the extrudates because someeasily crushed when pressed with fingers.These results show that consumers desired some level of puffiness in the samples however their expansion should not lead to easy breakage of extrudates. Thus expansion should be within a certain limit, too much of it counteracts product's preference

4.4.2 Aroma

Ten percent baobab (E5) had a higher preference value of 6.16 while 20% baobab/tamarind extrudates (E6) had a lower value of 5.96 (Table 4.6). The interactive effect of the different formulations and treatments were found to be insignificant ($p>0.05$) with respect to aroma. Generally, the aroma of extrudates was liked slightly by consumers. Higher tamarind substitution (20% tamarind, E5) had preferable aromadue to its seed oil which is said to be appetizing and has culinary preeminence (Morton, 1987 cited in El-Siddig, 2006).

Aroma is an essential attribute in consumer's opinion of food and purchasing assessment. It is evident from the results obtained that inclusion of tamarind and baobab had an impact on the aroma of the extrudates. The high temperature (200ºC) also affected the taste of the extrudates.

Enhancement of flavour is due to the secondary compounds that contribute to nonenzymatic browning reactions, causative to development of new flavours complex molecules (Rhee *et al.*, 2004). Flavours affect both the sense of taste and smell and so in effect it also affects the aroma of foods (Fahlbusch *et al.,* 2003). Panellists commented on the aroma of the extrudates. Eleven consumers out of fifty stated that the extrudates had a distinct aroma. Six of eleven said the aroma was like that of cocoa and five said it was coffee-like.

4.4.3 Taste

It was observed from Table 4.6 that the extrudates with higher percentage (20%) of tamarind had a preferred taste even though generally the taste was slightly disliked by the consumers principally because the BPP has an astringent taste which contributed to the undesirable taste when it was subjected to high heat. The taste is attributed to the presence of citric acids and tannins in the baobab pulp (Gruenwald and Galizia, 2005; Tal Dia *et al*,. 1997).

One of the key features consumers look out for when buying foods is 'taste'. Taste judgment is perceived when salty, sweet, sour, or bitter elements dissolve in solution are sensed by the taste buds. Extrusion processing variables like screw speed cooking temperature and moisture level have huge impact on the taste of extrudates. A harsh condition (high temperature and screw speed) during food extrusion causes different degrees of granular and molecular changes in the samples flours which may affect the taste of extrudates (Kokini, 2002). However the taste of foods is minimally affected by processing but is largely determined by the formulation used for a particular food It may be inferred from the study that the taste of extrudates was mainly affected by the products composition aside the extrusion parameters (Fellows, 2009).

Table 4.6 Sensory Characteristics of Trial Extruded 'Yammy Pops'

	Aroma	Taste	Shape	Texture	Crunchiness	Colour	Puffiness
E5(10B:30T:60Y)	6.16 [a]	4.92 [a]	5.96 [a]	6.40 [a]	6.66 [a]	6.24 [a]	6.48 [a]
E6(20B:20T:60Y)	5.96 [a]	4.60 [a]	5.36 [a]	6.44 [a]	6.04 [a]	5.52 [a]	5.92 [a]

*Hedonic rating : 1= "Dislike Extremely", 9= "Like extremely"; the higher the value the higher the attribute.
*Y= Yam T=Tamarind B= Baobab
* Analysis was done in duplicates, *Means with the same superscripts within the column are not significantly different (p<0.05)

4.4.4 Shape

Most of the extrudates assumed cylindrical shapes because the shape of the die was circular. Generally the panellists liked the shape of extrudates. Ten percent baobab (E5) was preferred to 20% baobab/20% tamarind (E6) with preference values of 5.96 and 5.36 respectively. The die, rotating knife and the speed of rotation of the knife largely affects the shape of extrudates. In addition the melt rheology, which is affected by the formulation and operating conditions, also affects the shape of an extrudates (Chessari and Sellahewa, 2001). However in this study, the extruder used did not have a rotating knife. Size reduction was done manually using a kitchen scissors. Results of expansion ratio as shown in Table 4.5b indicates that extrudates had varying circular sizes.

4.4.5 Texture and Crunchiness

In terms of texture 20% baobab/ tamarind (E6) with a value 6.44 was preferred to 10% baobab (E5)which had a score of 6.40 (Table 4.6). Generally, the textures of all samples were slightly liked by the consumers.In this study the textural attribute was hardness.Theresults show that the sample composition and extrusion parameters had effect on the texture of extrudates (Barbosa-Canovas and Juliano, 2006; Zasypkin and Lee (1998) cited in Forsido and Ramaswamy, 2011) even though it was not significant ($p<0.05$).

The texture of a product is an essential attribute in consumer's examination of food and buying judgment. Razzaq *et al*. (2012) defined texture as the "sensory expression for the structure of products in terms of their reaction to stress by the kinaesthetic sense.

Crunchiness of food products gives an indication of their freshness. Duizer (2001) reported on the connection that auditory sensations have with the perception of texture. These attributes are perceived by sounds or noises produced during mastication. Research done by Szczesniak (1988) cited in Spence (2015) shows that crisp and crunchy foods demonstrate evidence of a crunchy sound. The disparity between the two sensations is that crispy food has a higher pitch and is louder than the ones derived from crunchy foods (Vickers, 1985 cited in Spence, 2015).

Higher tamarind seed kernel substitution (30% tamarind, E5) may have inferred a desired crunchiness in 30% tamarind (E5) with preference value of 6.66. Plasticizing effect in the presence of moisture during extrusion also allows starch–protein matrix and this result in a boost in hardness of the products (Biliaderis, 2003). Amongst the three flour samples, TKP has the highest crude protein content of 15% as shown in Table 4.1a.

However consumers indicated that the texture of these extrudates could be improved.
A higher screw speed may reduce the hardness and fracturability by increasing the cooking temperature that generally leads to a higher expansion ratio of extruded product. Riaz *et al.* (2000) found that a soft texture product resulted from a fine granulation and a coarse meal led to a hard product. Generally the incorporation of TKP and BPP may have had an impact on the texture of extrudates specifically their crunchiness.

4.4.6 Overall Acceptability

Results from the overall acceptability frequency table (Appendix 2C and 2D) shows that a higher percentage, 63.3% (19 panellists), preffered E5 most whiles 36.7% (11 panellists) preffered E6 most. This shows that the E5 was most accepatable (Fig 4.1 and Fig 4.2)

4.4.7 Conclusion on the sensory evaluation of extruded snacks

The desired qualities of extruded snacks are most of the time specified as having a texture of crispy and most importantly, a light and puffy texture. Sensory characteristics of yam, baobab and tamarind extrudates developed in this study could be used by the snack industry to understand the similarities and differences of extruded snacks produced at different extrusion conditions and feed compositions. From this study extrusion of highly substituted tamarind in yam flour, with added cereals (rice, corn), milk, sugar and other additives will improve upon the sensory characteristics of the yam based extrudates (especially its taste and hardness/texture).

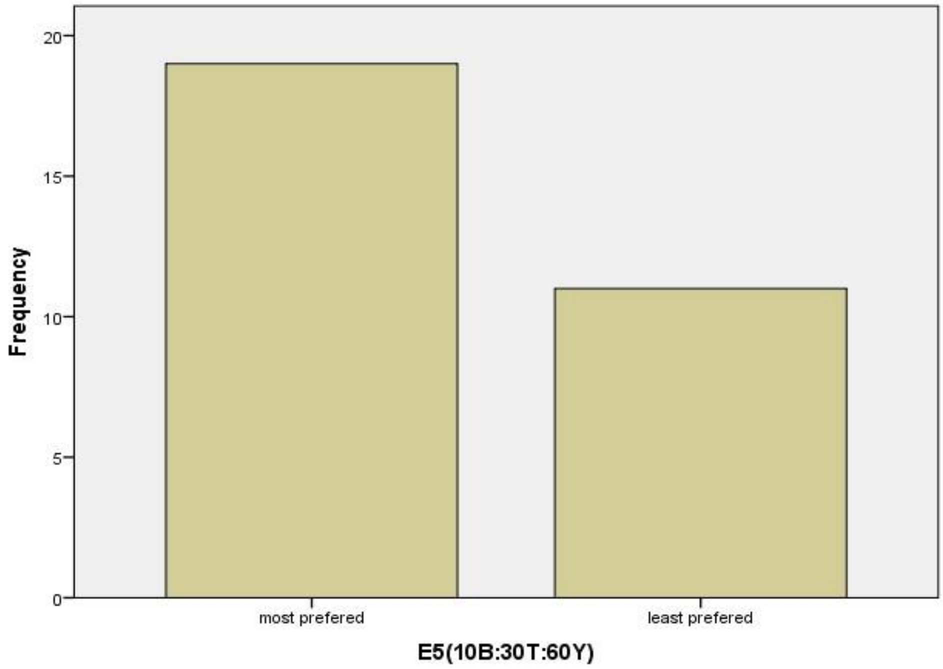


Fig 4.1 Frequency of Preference for E5 (10B : 30T : 60Y)

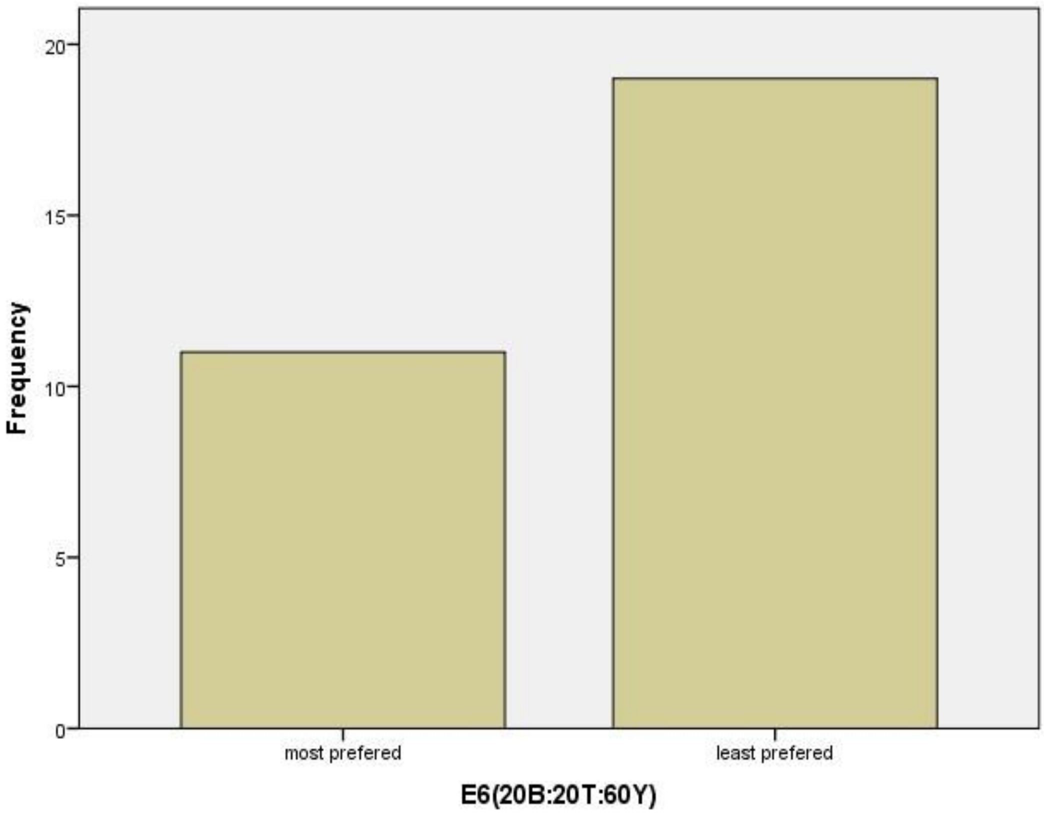


Fig 4.2 Frequency of Preference for E6 (20B : 20T : 60Y)

4.5 Colour Characteristics of Composite Flours and Extrudates

The L, a, b values of the yam based flour composites and extrudates are shown inTable 4.7a and Table 4.7b respectively.

Statistically there were significant differences between the mean values of colour measurements for flour samples as well as the extrudates ($p \leq 0.05$). Generally, the lightness of flour samples was significantly higher than extrudates ($p \leq 0.05$). Lightness (L values) for flour samples was in the range of 84.67 to 85.73. Ten percent baobab (E5) and 20% tamarind/ baobab (E6) had L values of 63.72 and 63.11 respectively. L values (lightness) decreased with the addition of tamarind and baobab to the yam flour (Table 4.7a).

The ‘a’ values of composite flours was in a range of (-0.28 to 0.2). With the exception of yam flour which had a positive a value (redness) of 0.2, all other flour composites (F2-F6) had negative a values (Table 4.7a). This means that the addition of tamarind and baobab flour made the flours attain some level of greenness due to the high heat of extrusion. However the ‘a’ values of 10% baobab (E5) and 20% tamarind/ baobab (E6) trial extrudateswas 3.83 and 4.18 respectively (Table 4.7b). Results from Table 4.7a and 4.7b shows that extrusion cooking increased the levels of redness after extrusion.

In terms of the degree of yellowness/blueness (b), incorporation of tamarind and baobab flour to yam flour increased the yellowness of flour samples (Table 4.7a). Even though there was no particular trend for the L and ‘a’ values of flour blends, results from Table 4.7a showed that the level of yellowness increased with increasing baobab flour substitution.One hundred percent yam flour had b value of 8.25 which increased to a range of 10.68-11.85 for other flour blends. Results from Table 4.7b also indicates that the level of yellowness further increased to 13.63- 13.88 after extruding the trial samples.

The change in the degree of yellowness or rednessafter extrusion could be attributed to the effects of extrusion cooking which causes nonenzymatic browning , pigment destruction reactions and chemical reactions between amino acids and reducing sugars (maillards reaction) in the presence of heat (Pedreschi and Zuñiga, 2009).Caramel colour formed during the extrusion is common to brown breads and buns during production (Griffith, 2005).

The hue angle (H) of composite flours (F2-F6) ranged from (88.53- 88. 89) as compared to the control sample (F1) which was 88.37.

Results from Table 4.7a and 4.7b also there were significant differences ($p \leq 0.05$) between the mean hue values of both flour samples and extrudates. Hue is the colour from the rainbow or spectrum of colours and so the value of hue gives an idea of the colour of the product. Despite the fact that there were some variations in lightness, red/greenness, yellow/blueness, intensity and saturation of colour for extrudates, the closeness of preference for colour during sensory evaluation is evident in the statistical results of hue shown in Table 4.7b

Table 4.7a Colour Characteristics of Composite Flours

Sample code	L	a	b	Hue angle	ΔC	ΔE
F1 (100Y)	85.73± 0.21 ^{a}	0.20± 0.01 ^{a}	8.25± 0.05 ^{a}	88.37±1.06 ^{a}		
F2(40T:60Y)	85.49± 0.06 ^{b}	-0.26± 0.02 ^{b}	10.68±0.29 ^{b}	88.60±0.38 ^{a}	2.64±0.02 ^{b}	2.26±0.02 ^{a}
F3(40B:60Y)	85.20± 0.09 ^{c}	-0.21± 0.08 ^{b}	11.03±0.13 ^{c}	88.89±-0.39 ^{b}	2.82± 0.13 ^{c}	2.87±0.13 ^{b}
F4(30B:10T:60Y)	85.08±0.09 ^{cd}	-0.28± 0.03 ^{b}	11.85±0.12 ^{d}	88.63±0.05 ^{a}	3.64±0.12 ^{a}	3.69±0.13 ^{c}
F5(10B:30T:60Y)	84.67± 0.03 ^{e}	-0.17± 0.04 ^{c}	10.83±0.06 ^{bc}	89.10±0.25 ^{b}	2.61±0.06 ^{b}	2.82±0.05 ^{b}
F6(20B:20T:60Y)	84.94± 0.08 ^{d}	-0.28± 0.04 ^{b}	10.92±0.31 ^{bc}	88.53±0.25 ^{a}	2.89±0.10 ^{bc}	3.01±0.12 ^{d}

*Y= Yam T=Tamarind B= Baobab
* L = lightness a = (negative= green; positive = redness) b = (negative=blue; positive=yellow)
Chroma (C) = saturation or vividness of color. Hue angle (H)= basic unit of color E= colour intensity
*Analysis was done in triplicates, *Means with the same superscripts within the column are not significantly different (p<0.05

Table 4.7b Colour Characteristics of Trial Extrudates

Sample code	L	A	b	Hue angle
E5(10B:30T:60Y)	63.72±0.08 ^{a}	3.83±0.05 ^{a}	13.63± 0.56 ^{a}	74.31±0.63 ^{a}
E6(20B:20T:60Y)	63.11±0.17 ^{a}	4.18±0.03 ^{b}	13.88±2.23 ^{a}	72.98±-2.02 ^{b}

*Y= Yam T=Tamarind B= Baobab
* L = lightness a = (negative= green; positive = redness) b = (negative=blue; positive=yellow)
Hue angle (H)= basic unit of color
*Analysis was done in triplicates, *Means with the same superscripts within the column are not significantly different (p<0.05)

4.6 Pasting Characteristics of Extrudates

Results of the pasting properties of flour composites and extrudates have been summarized in Table 4.9, 5.0, 5.1 and 5.2. There were significant differences ($p<0.05$) in the viscosities of flour blends.

Pasting results for F5 and E5 are not available due to some technical challenges.

4.6.1 Pasting Temperature (PT) and Pasting Time (Ptime)

Results from Table 4.9 suggest that pasting time and temperature were in the range of 0.08-25.21min and 50.15– 80.75°C for flour composites respectively. There were significant differences ($p < 0.05$) in pasting time and temperature for flour blends.

Forty percent tamarind (F2) and 40% baobab (F3) flour composites had the highest pasting time while 30% baobab (F4) and 20%baobab (F6) flour composites had the shortest pasting time. Flours with higher pasting temperatures indicate that the granules resisted swelling better (Seetharaman *et al.*, 2001). Also it could be inferred that a few of the gelling compounds (starct, jellose, pectin) in the composite flours had been slightly gelatinized after processing and drying as compared to the extrudates which due to heating/cooking during extrusion had some level of gelatinisation. Shimelis *et al*. (2006) also indicated that pasting temperature is one of the pasting properties which present an indication of the minimum temperature needed for sample cooking, energy costs involved and other components stability. The extrudates need minimal temperature within a very short time to be cooked.

The pasting time and temperature of the trial extrudates, 20% tamarind/baobab, was 50.30bu and 0.08min respectively (Table 5.2). This suggests that extrudates had lower resistance to swelling.

4.6.2 Peak Viscosity (PV)

The peak viscosity of flour samples was in the range of 2.5 for 30% baobab (F3) baobab to 291bu for 40% tamarind (F2) as shown in Table 4.9 and Table 5.0.

Peak viscosity values were significant ($p < 0.05$) in flour blends. Viscosity measurement is necessary to predict the starch or polysaccharide structural changes that occur during cooking as well as the extent of starch change (conversion).

Trial extrudate (E6) had lower PV value (14.67bu) as shown in Table 5.2which connotes degradation and gelatinization of starch/ jellose/ pectin. This effect results from the depolymerization and molecular entanglement which occurred when samples were subjected to high heat during extrusion cooking (Hagenimana, *et al.*, 2006). Italso means that flour blend (F6) had higher quantities of ungelatinized starch/ jellose/ pectin.

Peak viscosity of 40% tamarind (F2) flour composite was higher than 100% yam flour (F1) whiles 40% baobab pulp substitute (F3) had lower in peak viscosity than 100% yam flour.This may be as a result of the fact that jellose in tamarind may have influenced the higher values for peak viscosity. This is supported by work done by Lineback and Ke (1975) who reported that legume starches (tamarind in this case) have higher viscosity than cereal starches. This also may imply that jellose may have been more resistant to swelling and rupture towards shear stress and heat.

The peak viscosity is related to the water binding capacity of starch/jellose/pectin in samples. The peak viscosity indicates the ability of starch to swell freely before their physical breakdown (Ikegwu *et al.*,2010).Samples substituted with baobab/tamarind had higher WBC values than 100% yam flour (Table 4.4 and Table 4.5). The comparatively high peak viscosity exhibited by tamarind substituted flours is suggestive that they may be suitable for products requiring high gel strength and viscosity (puddings, purees, smoothies, porrigde).

Other factors which could have affected the peak viscosity are the size and shape of the starch granules, ionic charge on the starch, kind and degree of crystallinity within the granules, presence or absence of fat and protein and perhaps, molecular size and degreeof branching of the starch fractions (Schoch and Maywald, 1968 cited in Shemilis *et al.,*2006). However these characteristics were not measured in this study.

Extrusion cooking had an impact on peak viscosity of trial extrudates. Carvalho *et al.* (2009) reported that at high temperature and low feed moisture the extrudates encounter great starch degradation, increased compression, increased mechanical effort and consequently resulting in lower viscosity values.

The trial extruded product (20% tamarind/baobab), E6, had low PV (14.67bu). This may be attributed to the protein denaturation, modification of the conformation of the proteins and also starch-protein interactions which generates structures with lower ability for interaction with water and consequently low viscosity (Lampart-Sczapa *et al.*, 2006). The low values for peak viscosity of extrudates means that the samples have been pre-cooked and if milled into flour, could be reconstituted easily with warm water (60^{o}C) or they could be taken as ready to eat snacks (Nicole *et al.*, 2010).

Table 4.9 Pasting Temperature, Pasting Time and Peak Viscosities of Composite Flours

Composite Flours	F1(100Y)	F2(40T:60Y)	F3(40B:60Y)	F4(30B:10T:60Y)	F6(20B:20T:60Y
Ptemp (°C)	80.60±1.41^{a}	76.45±2.05^{b}	80.75±0.35^{a}	50.15±0.07^{c}	80.75±2.76^{a}
Ptime (min)	21.54±1.22^{a}	25.21±0.30^{b}	21.59±0.58^{a}	0.08±0.00^{c}	19.68±0.34^{d}

PV (bu)	282.00±4.24 [a]	291.00±1.41 [b]	145.50±0.71 [c]	2.50±0.71 [d]	166.00±2.83 [e]

*Y= Yam T=Tamarind B= Baobab
*Ptemp=Pasting Temperature Ptime=Peak Time PV=Peak Viscosity
*Analysis was done in triplicates,
*Means with the same superscripts within the column are not significantly different (p>0.05)

4 .6.3 Minimum Viscosity (MV)

The minimum viscosity which measures the ability of paste to resist breakdown during cooling were significantly higher ($p < 0.05$) for flour samples than extrudates. Minimum viscosity is also termed as trough viscosity. MV values were in the range of 2.50bu to 289bu for flour composites. Forty percent tamarind (F2) had the highest (289bu) MV whiles 30% baobab had the least (2.5bu) amongst flour composites. A higher breakdown viscosity value indicates lower ability of the sample to withstand heating and shear stress during cooking (Adebowale *et al*., 2006). The results show that twenty percent baobab (F6) and 40% baobab (F3) substituted flours had the ability to withstand heating and shear stress better the tamarind substituted flours and 100% yam flour (F1).

The trial extrudates (E6) had MV of 5.33bu which was lower than that obtained for (F6) its flour sample (164.00bu). This implies that extrudates had a better ability to withstand breakdown as compared to the flour samples.

This imples samples with higher MV easily breakdown when subjected to heat and consequently syneresis and retrogration may occur easily if the gelatinization temperature is exceeded.

4.6.4 Final Viscosity (FV)

The mean final viscosity (FV) values for flour composites had significant differences ($p < 0.05$).Composite flours had mean FV values within a range of 10bu for 30% baobab (F3) to 440bu for 40% tamarind (Table 5.0).

The most commonly used parameter to determine starch-based samples quality is final viscosity (Dufour *et al*., 2009). FV is a measure of starch re-association after cooling which depends on modifications that occur in the structure of granules and molecules during extrusion and pre-treatment processes. It could give an indirect clue of how much resistant starch are formed via retrogradation of starch (Liu *et al*., 1997). It also indicates the ability to form viscous paste or gel after cooling and less stable of starch paste commonly accompanied with high value of breakdown.

Samples with higher tamarind substitution had higher FV than those with baobab substitutions. This means that highly substituted tamarind flour samples had an increase in starch/jellose content as well as the extent of re-association tendency of these gelling polysaccharides. However, the extrudates had low FV value (14.33bu) because during cooling the starch and the protein may have produced a weaker and less stable gel (Liu *et al*., 1997). The final viscosity indicates the ability of the etrudates to easily to form a viscous paste when milled into flour.

Table 5.0Minimum and Final Viscosities of FlourComposites

Flour composites	F1(100Y)	F2(40T:60Y)	F3(40B:60Y)	F4(30B:10T:60Y)	F6(20B:20T:60Y
MV(bu)	264.00±5.66 [a]	289.50±2.12 [b]	138.00±1.41 [c]	2.50±0.71 [d]	164.00±4.24 [e]
End of cooling(bu)	197.50±3.54 [a]	455.00±1.41 [b]	131.50±0.71 [c]	11.00±1.41 [d]	212.00±4.24 [e]
FV(bu)	174.00±4.24 [a]	440.00±2.83 [b]	122.50±3.54 [c]	10.00±1.41 [d]	192.00±2.83 [e]

Y= Yam T=Tamarind B= Baobab MV=Minimum Viscosity FV=Final Viscosity
* Analysis was done in triplicates, *Means with the same superscripts within the column are not significantly different ($p<0.05$)

4.6.5 Breakdown Viscosity (BV)

Break down viscosity mean values were generally low for either flour samples or extrudates. Composite flours had mean BV values within a range of 0.00bu for 30% baobab (F3) baobab to 2.50bu for 100% yam flour (F1) (Table 5.1). Extrudates (E6) had mean BV value of 7.67bu (Table 5.2).

One hundred percent yam flour (F1) had high break down viscosity (20.50bu) but as tamarind or baobab was added the breakdown viscosity decreased (0.00-6.50bu). The results show that TKP has the potential to reduce breakdown viscosity than BPP. However for the trial extrudates, there was an increase in BV value.

The breakdown is a measure of the extent of disintegration (Newport Science, 1998). It indicates the starch's tendency for disintegration. The higher breakdown of viscosity indicates substantial disruption or weakening of the bonding forces (hydrogen bonds) in the starch granules during heating (Barimah *et al.*, 2009).

Low values of breakdown viscosity suggest that during the pasting process which involves mechanical shearing and heating, the composites were more resistant to the swelling and disintegration. This also indicates that swollen granules of the composite samples had good stability against the mechanical shearing (Adebowale *et al.*, 2006and Zobel, 1984).

4.6.6 Setback Viscosity (SBV)

The setback viscosity values (measure of syneresis of starch upon cooling of the cooked starch pastes) of flour composites were in the range of –7.00 to 148bu. The higher the setback value, the lower the retrogradation during cooling of the products made from the flour. Setback values varied significantly ($p<0.05$) for flour composites.

Results from Table 4.9 shows that addition of TKP increased setback viscosity of flour composites. It may indicate that TKP minimized the starch chain reassociation to occur readily during the cooling stage, and caused increased viscosity during cooking (Wang and Copeland, 2013; Ragaee and Abdel-Aal, 2006).

Trial extrudates, 20% tamarind/baobab (E6) had a decrease in setback viscosity with a value of 8.33bu. This may have been reduced by temperature (Duarte *et al.*, 2009). Low setback values indicate high rates of starch retrogradation and syneresis, by rearrangement of the stretched amylose molecules into a low energetic level forming new entanglements amongst them. The setback viscosity shows the syneresis of starch upon the cooling of the cooked starch pastes (Sandhu and Singh, 2007).

Table 5.1 Break Down and Set Back Viscosities of Composite Flours

Flour composites (bu)	F1(100Y)	F2(40T:60Y)	F3(40B:60Y)	F4(30B:10T:60Y)	F6(20B:20T:60Y
BV(bu)	20.50±2.12 [a]	1.50±0.71 [b]	6.50±0.71 [c]	0.00±0.00 [b]	2.50±0.71 [b]
SBV(bu)	-69.50±3.54 [e]	148.00±2.83 [b]	-7.00±1.41 [a]	8.00±1.41 [c]	47.50±2.12 [d]

Y= Yam T=Tamarind B= Baobab BV=Breakdown viscosity SBV=Setback Viscosity
* Analysis was done in triplicates, *Means with the same superscripts within the column are not significantly different (p<0.05)

Table 5.2 Pasting properties of extrudates

Extrudates	Ptemp (°C)	Ptime (min)	PV (bu)	MV (bu)	FV (bu)	BV (bu)	SBV (bu)
E6 (20B:20T:60Y)	50.30±0.02	0.08±0.01	14.67±0.79	5.33±0.58	14.33±2.08	7.67±1.53	8.33±1.15

*Y= Yam T=Tamarind B= Baobab
*Ptemp=Pasting Temperature Ptime=Peak Time PV=Peak Viscosity MV=Minimum Viscosity
FV=Final Viscosity * BV=Breakdown viscosity SBV=Setback Viscosity
* Analysis was done in triplicates,

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

It has been shown from this study that flour blends with tamarind kernel powder (TKP) and baobab pulp powder (BPP) have improved physiochemical and pasting properties. Coupled with enhanced nutrients and aroma of flour composites, the flour blends could be used in varying food formulations such as drinks, puddings, sauces, ice-creams, pastries and yoghurts for the reason that they could serve thickening and stabilizing functions (high WBC and swelling power).

D. alata (water yam) has a promising future in the snack industry using the technology of extrusion cooking. With the increasing surge for healthy snacks, supplementation of water yam with legumes such as *Tamarindus indica* and fruits such as *Adansonia digitata* will provide extruded healthy snacks that can equally compete with extruded cereal snacks on the market.

Sensory evaluation performed on extrudates revealed that consumers would prefer highly substituted yam flour with TKP to BPP. In terms of overall acceptability ….preferred E5 (10B:30T:60Y) to E6 (20B:20T:60Y)

Finally, the results for pasting and physicochemical after extrusion show that the extrudates are ready to be eaten with low moisture values.

5.2 Recommendations

Further studies could be performed in the following areas

1. Optimization of most preferred extrudates targeting its taste and crunchiness (higher particle size improves crispiness) using response surface methodology.

2. Shelf life study, moisture sorption and desorption curve, cellular structure and descriptive analysis could be performed on extrudates.

3. Comparative study on cereal and root and tuber based extrudates could be done

4. Due to the sharp astringent taste of baobab pulp powder when subjected to high heat, it is suggested that the BPP could be used as coating/ filling on/in extrudates with minimal/no heat. This will also help to retain most of its vitamin C (ascorbic acid).

5. Determination of the impact/effect of processing on the bioavailability of trace elements in extrudates.

6. Rheological studies could be done on interactions of the polysaccharides (starch, jellose, pectin) of flour blends and extrudates.

REFERENCES

Abdalla, A. A., Mohammed, M. A and H.A. (2010). Production and Quality Assessment of Instant Baobab (Adansonia digitata L.) *Advanced Journal Advance Journal of Food Science and Technology* 2(2): 125-133.

Abioye, V. F., Ade-Omowaye, B. I. O., Babarinde G. O. and Adesigbin, M. K. (2011).Chemical, Physico-Chemical and Sensory Properties of SoyPlantain Flour. *African Journal of Food Science*. Vol. 5(4), pp. 176 – 180.

Abulude, F. O. and Ojediran V. A. (2006) Development and Quality Evaluation of fortified Amala.*Acta Sci Pol. Technol.*, Ailment Vol. 5(2), 127 – 134.

Achi, O. K. (1999). Quality attributes of fermented yam flour supplemented with processed soy flour Plant Foods. Hum. Nutr. 54:151-158.

Addy, Ransford Nii Amoo (2012). Comparative Study on the Properties of Yam (Dioscorea Rotundata) Varieties in Ghana: A Case Study in Asante Mampong. MSc. Thesis. Kwame Nkrumah University of Science and Technology. http://hdl.handle.net/123456789/4745

Adebowale, Y. A., Adeyemi, A., and A. A. Oshodi. (2006) Functional and Physicochemical Properties of Flours of Six Mucuna Species. *African Journal of Biotechnology*. 4 (12), 1461-1468.

Adejumo, B. A., Okundare, R. O., Afolayan, O. I. and Balogun, S. A. (2013) Quality Attributes of Yam Flour (Elubo) as Affected by Blanching Water Temperature and Soaking Time.*The International Journal of Engineering and Science* , 2(1): 216-221.

Adekunle, A. I. and Adenike J. O. (2012) Comparative Analysis of Proximate, Minerals and Functional Properties of *Tamarindus indica* pulp and *Ziziphusspina christi* Fruit and Seed. *Greener Journal of Agricultural Sciences*, 2 (1), 21-25.

Adeleke, R. O. (2010). Current Position in Sanitations in Nigerian Food Industries. *Pakistan Journal of Nutrition* 9: 664-667.

Adeleke, S. I. (2009). Food Poisoning Due To Yam Flour Consumption In Kano (Northwest) Nigeria. *Online J Health Allied Scs*, 8(2):10

Adeola, A. A., Otegbayo, B. O. and Ogunnoiki, S. (2012). Preliminary Studies on the Development and Evaluation of Instant Pounded Yam from *Dioscorea alata*. *Journal of Applied Science and Environmental Management*. 16 (3):

287 – 290

Agbisit, R., Alavi, S., Cheng, E., Herald, T. and Trater, A. (2007). Relationships between Microstructure and Mechanical Properties of Cellular Cornstarch Extrudates. *J. Texture Stud.* 38, 199–219.

Ahmed, J., Ramaswamy, H.S. and Sashidhar, K., C. (2007). Rheological characteristics of tamarind (*Tamarindus indica* L.) juice concentrates. *LWT – Food Science and Technology*, 40, pp. 225–231

Aidoo, R. (2009) "An analysis of yam consumption patterns in Ghanaian urban communities", Ph.D thesis submitted to the Department of Agricultural Economics, Agribusiness and Extension, Kwame Nkrumah University of Science & Technology, Kumasi, Ghana.

Ajayi, I.A., Dawodi, F.A., Oderinde, R.A. (2003). Fatty acid composition and metal content of Adansonia digitata seeds and seed oil. *La Rivista Italiana delle Sostanze Grasse*, 80, 41-43

Akdogan, H. (1999). High moisture food extrusion. *International Journal of Food Science and Technology,* 34(3): 195-207

Akin-Idowu, P. E., Asiedu, R., Maziya-Dixon, B., Odunola, A., Uwaifo A. (2009). Effects of Two Processing Methods on Some Nutrients and AntiNutritional Factors in Yellow Yam (Dioscorea cayenensis). *Afr. Journal Fd. Sci*. 3(1): 022-025.

Akinoso, R. and Olatoye, K. K. (2013) Energy utilization and conservation in instant- pounded yam flour production.*International Food Research Journal* 20(2): 575-579

Akissoe, N., Mestres, C., Hounhouigan , J., Nago, M (2006). Prediction of the sensory texture of a yam thick paste (amala) using instrumental and physicochemical parameters. *Journal of Texture Studies*, 37(4), 393-412.

Alavi* S.H., B.K. Gogoi, M. Khan, B.J. Bowman, S.S.H. Rizvi (1999) Structural properties of protein-stabilized starch-based supercritical fluid extrudates Food Research International 32 107- 118

Alexandros, N. (2006). World Agriculture: towards 2030/50, interim report. An FAO Perspective. London, UK: Earthscan; Rome, Italy: FAO

Alinnor, I.J. and Akalezi C.O. (2010). Proximate and Mineral Compositions of *Dioscorea rotundata* (White Yam) and *Colocasia esculenta* (White Cocoyam) *Pakistan Journal of Nutrition* 9 (10): 998-1001.

Al-Marzooqi, W. and Wiseman, J. (2009). Effect of extrusion under controlled temperature and moisture conditions on ileal apparent amino acid and starch digestibility in peas determined with young broilers. *Anim. Feed Sci. Technol.*, 153 (1-2): 113-130

Alonso, R., Aguirre, A. and Marzo, F. (2000) Effects Of Extrusion And Traditional Processing Methods On Antinutrients And In Vitro Digestibility Of Protein And Starch In Faba And Kidney Beans. *Journal ofFood Chemistry* vol. 68, no. 2, pp. 159-165

Alonso, R., Rubio, L., Muzquiz, M. and Marzo, F. (2001). The effect of extrusion cooking on mineral bioavailability in pea and kidney bean seed meals. Animal Feed Science and Technology, 94(1-4): 1-13, ISSN 0377-8401.

Aluna, G. (2013). Organic raw baobab fruit powder from South Africa. Certified by The Organic Farmers & Growers.http://www.aluna-gena.com /store/p 7/Organic_Raw_Baobab_Fruit_Powder,_Premium_Quality_.html. Accessed 6th August, 2015

AMANI (2005). Stability of Yam Starch Gels During Processing. *African Journal of Biotechnology*. 4:1

Amusa, N.A., Ashaye, O.A. and Oladapo, M.O. (2003). Biodeterioration of the African Star Apple (Chrysophylum albidum) in Storage and the Effect on Its Food Value. *Afr. J. Biotechnol*, 2(3): 56-59

Amza, T., Amadou, I., Kamara, M.T., Zhu, K.X. and Zhou, H.M. (2011). Nutritional and functional characteristics of gingerbread plum (*Neocarya macrophylla*): An underutilized oilseed. Grasas y Aceites 62 (3): 290–298.

Anaadumba, P. (2013). Analysis of incentives and disincentives for yam in Ghana. Technical notes series, MAFAP, FAO, Rome.

Anderson, J.W., Smith, B.M and Gustafon, N. J. (1994). Health Benefits and Practical Aspects of High-Fibre Diets.*Am J Clin Nutr* , 59

Anon (1976). Tamarindus indica L.In:The Wealth of India(Raw Materials Series) Vol.X: 144-122.*Council of Scientific and Industrial Research,* New Delhi

AOAC, 1990. Official Methods of Analysis. Association Official Analysis Chemists, Washington D.C. 15th edition

Appiah, P. (2015) Awaiting the rains – maize production under constraint .http://www.myjoyonline.com/news/2015/october-13th/awaiting-the-rainsmaize-production-under-constraint.php Accessed December 2015

Arnold, T.H., Wells, M.J., Wehmeyer, A.S (1985). *Khoisan* food plants: taxa with potential for future economic exploitation.In: Plants for Arid Lands, Wickens, G.E.; Goodin, J.R.; Field, D.V. (eds.), Allen and Unwin, London, UK, 69-86

Asante, K. B. (2008) Daily Graphic Online: Ghana can and should feed herself https://www.modernghana.com/news/166095/k-b-asante-ghana-can-andshould-feed-herself.html Accessed January 2014

Aseidu-Larbi, J. (2010). Production and Storage of Minimally Processed Chips from Water Yam (Dioscorea Alata). MSc. Thesis. Kwame Nkrumah University of Science and Technology. http://hdl.handle.net/ 1234 567 89/172

Asiedu, R., Wanyera, N. M., Ng, S. Y. C. and Ng, N. Q. (1997). Yams In: Biodiversity in trust. Fuccillo, D. Sears, L. and Stapleton, P. (eds).Cambridge University Press, Cambridge, U.K. pp.57-66.

Azam-Ali, S.; Peiler, E. (2005). Improved utilisation of Tamarind and Baobab: Manuals for Local Communities in Malawi.

Baah, F., Maziya-Dixon, D.,Asiedu, R., Oduro, I. and Ellis, W. O. (2009) Nutritional and biochemical composition of *D. alata* (*Dioscorea spp.*) tubers *Journal of Food, Agriculture & Environment,* 7 (2) : 3 7 3 - 3 7 8.

Babalola, M. and Oyenuga, V.A (2001). Value of Yam (Dioscorea spp.) in Nigeria Food andFeeding Stuff, Ibadan.University Press, Ibadan, Nigeria. pp.110114.

Baik, B., Powers, J. and Nguyen, L. (2004). Extrusion of regular and waxy barley flours for production of expanded cereals. *Cereal Chemistry,* 81(1): 94-99, ISSN 0009-0352

Bailey, L. N.; Huack, B. W.; Sevatson, E. S.; Singer, R. E. (1991). Systems for manufacture of ready-to-eat breakfast cereals using twin-screw extrusion. *Cereal Foods World,* 36(10): 863-869, ISSN 0146-6283.

Balasubramanian S, Borah A, Singh KK, Patil RT (2012) Effect of selected dehulled legume incorporation on functional and nutritional properties of protein enriched sorghum and wheat extrudates. *J Food Sci Technol* 49:572–579

Balunkeswar, N., (2011). Effect of Thermal Processing on The Phenolic Antioxidants of Colored Potatoes. A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor Of Philosophy Washington State University, Department of Biological Systems Engineering.

Barbosa-Canovas, G. V. and Juliano, P. (2005). “Physical and chemical properties of food powders”. In *Encapsulated and Powdered Foods*, Edited by: Onwulata, C. 40–71. Boca Raton, FL: CRC Press.

Barimah, J., Amankwah, E.A., Oldham, J.H. and Pecku, S., (2009). Effect of acetylation and varietal differences on the pasting properties of some corn starches. *J. Ghana Sci. Assoc*. 11, 106–107.

Barua, A. (2014) The Tamarind Love. http://www.cravebits.com/tamarind-love/ accessed January, 2015

Beach, G. (2015) http://inhabitat.com/can-this-tree-provide-financial-security-for10-million-people-in-africa/Accessed 27th November, 2015.

Besco, E., Bracioli, E., Vertuani, S., Ziosi, P., Brazzo, F., Bruni, R., Sacchetti, G., Manfredini, S. (2007).The use of photochemiluminescence for the measurement of the integral antioxidant capacity of baobab products. *Food Chemistry*, 102, 1352-1356.

Beuchat, L.B., (1977). Functional and electro phoneticcharacteristics of succinylated peanut flour proteins. *J. Agric Food Chem*., 25: 258-261.

BFCS (Baobab Fruit Company Senegal), (2011). Baobab leaves Micronised 40 Micron-Instant

Bhandari, M. R., Kawabata, J., Kassi, T. (2003) Nutritional evaluation of wild (Dioscorea spp.) tubers of Nepal. *Food Chem,* 80: 619-623

Bhattacharya, S., Bal, S., Mukherjee, R. K. and Bhattacharya, S. (1994). Studies On The Characteristics of Some Products from Tamarind (*Tamarindus indica*) kernel. *J Food Sci Technol*. 31:372–376

Bianchini, J.-P., Ralaimanarivo, A., Gaydou, E.M., Waegell, B., (1982). Hydrocarbons, Sterols and Tocopherols in the Seeds of Six Adansonia Species. *Phytochemistry,* 21, 1981–1987.

Borejszo, Z. B. and Khan, K. H (1992), Reduction of Flatulence-Causing Sugars By High Temperature Extrusion Of Pinto Bean High Starch Fractions.

Journal of Food Science, 57: 771–777. Doi: 10.1111/J.13652621.1992.tb08093.

Bourke, R.M. and Vlassak, R. (2004). Estimates of Food Crop Productionin Papua New Guinea. Australian National University, Canberra, Australia.

Brand-Miller, J.,Wolever, T. M., Vorster, H. H., Björck, I., Brighenti, F., Mann, J. I., Ramdath, D.D. (2003). Determination of the glycaemic index of foods: interlaboratory study.*Eur J Clin Nutr*.*Mar*; 57(3):475-82.

Burkill, H. M. (1985). The Useful Plants of West Tropical Africa, Royal Botanic Gardens, Kew, Richmond.

Camire M. E., Camire, A., Krumbar, K. (1990). Chemical and Nutritional Changes in Foods During Extrusion. *CRC Critical Reviews of Food Science and Nutrition.* 29: 35-57.

Carvalho, A., Vasconcelos, M., Silva, P. &Aschieri, J. (2009).Produção de snacks de terceirageraçãoporextrusão de misturasdefarinhas de pupunha e mandioca. *Brazilian Journal of Food and Technology*, Vol.12, No.4, pp.277-284.

Castells, M., Marín, S., Sanchis, V. and Ramos, A. (2005). Fate of mycotoxins in cereal during extrusion cooking: a review. *Food Additives and Contaminants,* 22(2): 150-157, ISSN 1944-0049

Chadare, F.J., Linnemann, A.R., Hounhouigan, J.D., Nout, M.J.R., van Boekel, M.A.J.S. (2009). Baobab Food Products: A Review on Their Composition and Nutritionalvalue. *Crit. Rev. Food Sci*. 49, 254–274.

Chandramouli, Y., Firoz, S., Vikram, A., Mahitha, B. Rubia B., Hemanthpavankumar, K. (2012). Tamarind Seed Polysaccharide (Tsp) - An Adaptable Excipient For Novel Drug Delivery Systems *International Journal Of Pharmacy Practice & Drug Research*

Chessari, C. J. and Sellahewa, J. N. (2001). Effective Control Processing. In: Extrusion cooking: technologies and application, R. Gay, (Ed.), CRC Press, Boca Raton, United States of America, 83-107.

Chimvuramahwe J, Musara JP, Mujuru L, Gadzirayi CT, Nyakudya IW, Jimu L, Katsvanga CA T, Mupangwa JF and Chivheya R (2011). Effect of Feeding Graded Levels of Adansonia Digitata (Baobab) Seed Cake on the Performance of Broilers. *Journal of Animal & Plant Sciences*. 11 (3)1442-

1449
Chinnaswamy, R. (1993). Basis of Cereal Starch Expansion. *Carbo. Polym.*, 21(23): 157-167
Chinnaswamy, R. and Hanna, M.A. (1988). Relationship between amylose content and extrusion-expansion properties of corn starches. *Cereal Chem.*, 65(2): 138-143.
Cissé, M., Dornier, M., Sakho, M., N'Diaye, A., Reynes, M. and Sock, O. (2009) Le bissap (Hibiscus sabdariffa L.): composition et principalesutilisations. Fruits 64 (3): 179-193
Colonna, P. and Mercier, C. (1985). Gelatinization and Melting Of Maize Starches with Normal and High Amylose Phenotypes. *Photochemistry*, 24, 1667–1674.
Commission Decision (2008). Authorising the Placing on the Market of Baobab Dried Fruit Pulp as a Novel Food Ingredient Under Regulation (EC) No 258/97 of the European Parliament and of the Council. Official J EU, L 183(38):1–2
De Caluwé, E., Halamová, K., Van Damme, P., (2009). Baobab (Adansonia digitata L.): a review of traditional uses, phytochemistry and pharmacology.In: Rodolfo, H., Simon, J.E., Ho, C.-T. (Eds.), African natural plant products: new discoveries and challenges in chemistry and quality. Oxford University Press, USA, 51–84.
De Caluwé, E., Halamová, K., Van Damme, P., Botanik, A., (2010) *Tamarindusindica* L. – A review of traditional uses, phytochemistry and pharmacology73, 202–205Volume 23, Nr. 1, pp. 53-83
De Cindio, F., Gentile, O., Grew, P. and Redolfi, D. (2003). Community Networks: Rules of Behavior and Social Structure. The Information Society, 19: 395406.
Degras, L. (1993). The Yam, a Tropical Root Crop. Macmillan Press, London. 1408
Delcour JA, Vanstelandt J, Hythier MC, Abecassis J, (2000). Fractional and Reconstitution experiment providing insight into the role of starch gelatinization and pasting properties in pasta quality. *J. Agric. Food Chem.* 48: 377 -378.
Denloye, A.A.B., Teslim, K.O., Fasasi, O.A., (2006). Insecticidal And Repellency Effects Of Smoke From Plant Pellets With Or Without D-Allethrin 90 EC Against Three Medical Insects. *Journal of Entomology* 3, 9–15.

Deshpande, H. W., and Poshadri, A., *(2011)*, Physical and sensory characteristics of extruded snacks prepared from Foxtail millet based composite. *International Food Research Journal* 18: 751-756.

Ding, Q, Ainsworth, P., Plunkett, A., Tucker, G. and Marson, H. (2005). The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice-base expanded snacks. *Journal of Food Engineering*, 66(3): 283-289, ISSN 0260-8774.

Diop, A.G., Saho, M., Dornier, M., Cisse, M., Reynes, M., (2005). Le baobab Africain (*Adansonia digitata L.*): principal escaracteristiques etutilisations .Fruits 61, 55–69.

Duarte, G., Carvalho, C. W. P. and Ascheri, J. L. R. (2009) Effect of soybean hull, screw speed and temperature on expanded maize extrudates *Braz. J. Food Technol.*, 12(3): 205-212

Dufour, D., Gibert, O., Giraldo, A., Sanchez, T., Reynes, M., Pain, J. P. Gonzalez, A. Fernadez, A. and Diaz, A. (2009). Differentiation between cooking bananas and dessert bananas. *J. Agric. Food Chem.* 57: 7870-7876.

Duizer, L. (2001). A review of acoustic research for studying the sensory perception of crisp.crunchy and crackly textures. Trends in Food Science & Technology, 12, 17-24

Eke, M., O., Olaitan, N., I. and Sule, H., I.(2013) Nutritional Evaluation of Yoghurt-Like Product from Baobab (Adansonia digitata) Fruit Pulp Emulsion and the Micronutrient Content of Baobab Leaves. *Advance Journal of Food Science and Technology*, 5(10):1266-1270

Ellis, W. O., Oduro I., Barimah J. and Otoo J. A. (2003). Quality of starch from six Japanese sweetpotato varieties in Ghana. African Journal of Root and Tuber Crops,5 (2): 38-41.

El-Samahy, S. K., Abd El-Hady, E. A., Habiba, R. A., and Moussa-Ayoub, T. E., (2007). Some Functional, Chemical, and Sensory Characteristics of Cactus Pear Rice-Based Extrudates. *J. PACD*

El-Siddig, K., Gunasena, H.P.M., Prasa, B.A., Pushpakumara, D.K.N.G., Ramana, K.V.R., Vijayan and. P., Williams, J.T. (2006). Tamarind – *Tamarindus indica* L. Fruits for the future 1. Southampton Centre for Underutilized Crops, Southampton, UK, 188p.

Eromosele, I. C., Eromosele, C. O.,Kuzhuzha, D. M. (1991). Evaluation of mineral elements and ascorbic acid contents in fruits of some wild plants. *Plant Foods for Human Nutrition:* 41,151 – 154

Ezeocha V. C. and Ojimelukwe P. C. (2012).The Impact of Cooking on the Proximate Composition and Anti-Nutritional Factors Of Water Yam (Dioscoreaalata) Journal Of Stored Products And Postharvest Research, 3(13): 172 – 176

Fahlbusch, K.-G., Hammerschmidt, F.-J., Panten, J., Pickenhagen, W., Schatkowski, D., Bauer, K., Garbe, D. and Surburg, H. (2003). Flavors and Fragrances. *Ullmann's Encyclopedia of Industrial Chemistry.* .

FAO (2010). Strengthening potato value chains: Technical and Policy Options for Developing Countries. Food and Agriculture Organization of the United Nations and common Fund for Commodities. Accessed 10/5/14 http://www.fao.org/docrep/013/i1710e/i1710e00.pdf

FAO (2015a). Storage and Processing of Roots and Tubers in the Tropics: Handling and Storage Methods for Fresh Roots and Tubers. Agriculture and Consumer Protection. http://www.fao.org/docrep/ x5415e/x 5415e0 4. htm

FAO (2015b). Food loss prevention in perishable crops: Post-harvest losses in perishable crops. Agriculture and Consumer Protection. http://www. fao.org/ docrep/s8620e/s8620e06.htm

Fellows, P. (2000). Food processing technology: principles and practice, (2nded.), CRC Press, ISBN 978-084-9308-87-1 Boca Raton, United States of America.

Fellows, P., J. (2009), ExtrusionChapter 16 Food Processing Technology (Third Edition) Principles and Practice. A volume in Woodhead Publishing Series in Food Science, Technology and Nutrition Pages 456–477

Fernández-Gutiérrez, J. A. et al. 2004 Physicochemical propertiesof casein-starch interaction obtained by extrusion process. Starch/Starke, (56): 190-198.

Filli, K. B and Nkama, I. (2007) Hydration Properties of Extruded Fura from Millet and Legumes. *Food J.* 109 (1): 68-80

Fletcher, S. I., Richmond, P., Smith, A. C., (1985). An experimental study of twinscrew extrusion cooking of maize grits. *J Food Eng*. 4:291–312.

Forsido, S. F and Ramaswamy, H. S (2011). Protein Rich Extruded Products from Tef, Corn and Soy Protein Isolate Blends*Ethiopian Journal of Applied Sciences and Technology* (EJAST) 12; 2(2):75-90.

Gebauer, J., K. El Siddig and G. Ebert (2002). Baobab (Adansoniadigitata L): a Review on a Multipurpose Treewith Promising Future in the Sudan. Gartenbauwissenschaf 67(4):155-160.

Gidley, M. J., Lillford, P. J., Rowlands, D. W., Lang, P., Dentini, M., Crescenzi, V., et al. (1991). Structure and Solution Properties of Tamarind-Seed Polysaccharide. *Carbohydrate Research*, 214, 299–314.

Glicksman, M. (1986). Tamarind seed gum in food hydrocolloids. CRC Press Florida, 3: 191

Granito, M., Brito, Y. and Torres, A., (2007). Chemical Composition, Antioxidant Capacity and Functionality of Raw And Processed (Phaseoluslunatus). *J.*

Griffith, C.J. (2005), "Are we making the most of inspections: a glimpse into the future", *BritishFood Journal,* (107) 132-9.

Gruenwald, J. and Galizia, M. (2005). "Market Brief in the European Union for Selected Natural Ingredients Derived from Native Species, Adansonia digitata L. Baobab," In The United Nations Conference on Trade and Development (UNCTAD) BioTrade Initiative/BioTrade Facilitation Programme (BTFP) UNCTAD/DITC/TED

Gui Y., Ryu G.H. (2001). Effects of extrusion condition on the physicochemical properties of extruded red ginseng. *Prev Nutr Food Sci. ;*17: 203–209.

Gunasena, H.P.M. and Hughes, A. (2000) Tamarind . *Tamarindus indica L. Fruits for the Future 1, International Centre for Underutilised Crops , Southampton, UK . pp 169*

Guy, R. (2001). Extrusion cooking: technologies and applications, Woodhead Publishing, ISBN 978-185-5735-59-0, Cambridge, United Kingdom.

Hagenimana A, Ding X and Fang T. (2006). Evaluation of Rice Flour Modified by Extrusion Cooking. *J Cer Sci.* 43:38–46. doi: 10.1016/j.jcs.2005.09.003

Harijono, T., Dinar, E., Saputri, S. and Joni, K. (2013) Effect of Blanching on Properties of Water Yam (*Dioscoreaalata*) Flour Department of Food Science and Technology, Brawijaya University, Malang, Indonesia.

Haritha, D., Vijayalakshmi, V., and Gulla, S. (2014). Development and Evaluation of Garlic Incorporated Ready-to-Eat Extruded Snacks. *Journal of Food*

Science and Technology, *51*(11), 3425–3431. http://doi.org/10.1007/ s131 97-012-0853-2

Hemant. B. Pagar., Shashikant. D. Barhate., Manoj M. Bari., Utkarsh. P. Shinde., Minakshi V. Janjale, Chandrashekhar B. Borase. (2011). Development and Evaluation of Muco Adhesive Buccal Patches of Miconazole Nitrate by Using Tamarind Gum and HPMC. Pelagia *Research Library Der Pharmacia Sinica*, 2 (6):93-101

Huber, G. R. and Rokey, G. J.(1990). Extruded snacks. In: Snack food, R. G. Booth, (Ed.), pp.107-138, Van Nostrand Reinhold, ISBN 978-044-2237-455, New York, United States of America.

Hunter, D. G. and Frisken, B.J. (1998). Effect of Extrusion Pressure and Lipid Properties on the Size and Polydispersity of Lipid Vesicles. *Biophysical Journal* 74 (6) , pp 2996–3002.

ICRAF – World Agroforestry Centre (2007). ICRAF *Agroforestry Tree Database: Tamarindus indica* L., URL http://www.worldagroforestrycentre.org , Accessed 23rd August, 2014.

ICUC (2001). Tamarind (*Tamarindus Indica L.*).Fruits For the Future. Field Manual for extension workers ICUC Southampton, UK.

IITA. (2009). Yam production in Africa. InternationalInstitute of Tropical Agriculture

Ikegwu, O.J., Okechukwu, P.E. and Ekumankana, E.O. (2010) Physico-Chemical and Pasting Characteristics of Flour and Starch from Achi Brachystegiaeurycoma Seed. *Journal of Food Technology*. 8(2): 58-66

Ilo, S., Schoenlechner, R. and Berghofe, E. (2000). Role of Lipids in the Extrusion Cooking Processes. *Grasas Aceites.;*51(1-2):97–110.

Iqbal, A., Khalil, I. A., Ateeq, N. and Khan, M. S. (2006). Nutritional quality of important food legumes. Food Chem.;97(2):331–335.

Ishola, M. M., Agabaji,E.B. and Agbaji, A.S. (1990). A Chemical Study of Tamarindusindica (Tsamiya) Fruits Grown in Nigeria. *Journal of Science, Food Agriculture*, 51:141-143.

Iwuoha, C. I.(2004). Comparative evaluation ofphysicochemical qualities of flours fromsteam-processed yam tubers. *Journal of FoodChemistry* 85: 541-551.

Jayakody, L., Hoover, R., Liu, Q. and Donner, E. (2007).Studies on tuber starches. II. Molecular structure, composition and physicochemical properties of yam

(Dioscorea sp.) starches grown in Sri Lanka.Carbohydrate Polymers 69: 148–163.

Jimoh, K. O., Olurin, T. O. and Aina, J. O. (2009). Effect of drying methods on the rheological characteristics and colour of yam flours. *African Journal of Biotechnology* Vol. 8 (10), pp. 2325-2328.

Jisha, S., Sheriff, J. T., and Padmaja, G. (2010). Nutritional, Functional and Physical Properties of Extrudates from Blends of Cassava Flour with Cereal and Legume Flours.*International Journal of Food Properties* 13(5):1002-1011.

Jones JR, Benton J and Vernon CW. (1990). Sampling handling and analyzing plant tissue samples. In soil testing and plant analysis. 3rd ed. Wesbermann. R.L., Soil Sci. Soc. Am. Inc. Madison Wisconsinum, USA: 389-428.

Kafilat, A. (2010). Physical, Functional, and Sensory Properties of Yam Flour 'Elubo' Obtained from Kuto Market –Abeokuta (Unpublished Undergraduate Thesis).Department of Food Science and Technology, College of Food Science and Human Ecology, University of Agriculture, Abeokuta, Nigeria. Accessed 9/12/14 <http://www.unaab.edu.ng /ug projects /2010bscadedejikk.pdf>

Kamatou, G. P. P., Vermaak, I., and Viljoen, A. M. (2011). An updated review of *Adansonia digitata*: A commercially important African tree.

Kannadhason S, Muthukumarappan K, Rosentrater KA (2009). Effects of ingredients and extrusion parameters on aquafeeds containing DDGS and tapioca starch. *J. Aquac. Feed Sci. Nutr.* 1(1):6-21.

Karuna D, Noel G. and Dilip K. (1996) United Nation University. *Food and Nutrition Bulletin*, p. 2.

Karuna, D., Noel, G., Dilip, K., (1996). Food and Nutrition Bulletin, 17: 2, United Nation University.

Katekhong, W. and Charoenrein, S. (2012). Effect of rice storage on pasting properties, swelling and granular morphology of rice flour. *Asian Journal of Food Agro-Industry* 5(4):315-321

Kirk and R. Sawyer, Egan, H., R.S.(1981). Pearson's Chemical Analysis of Food. 8th Edn., Churchill Livingstone, Edinburgh, UK.

Knoth, J. (1993). Traditional Storage of Yams and Cassava and Its Improvement. Deutsche.

Kokini, J. L. and Zimeri,J.E. (2003). Rheological properties of inulin–waxy maize starch systems. Carbohydrate Polymers 52. pp 67–85.

Komolafe, A.O. and Akinoso, R. 2005). Design, Fabrication And Testing Of A 50kg Yam Parboiler. *Nigerian Food Journal*, 23: 225–230.

Kumar, C.S. and Bhattacharya, S. Tamarind Seed: Properties, Processing and Utilization (2008). *Critical Reviews in Food Science and Nutrition*. 48, 120

Kurebgaseka, N. (2005). Report and research into Africasmootie market and The Potential for Baobob Fruit Pulp as an Ingredient in Smoothies. PhytoTrade Africa (1): 1 -35

Lampart–Szczapa, E., Konieczny, P., Nogala–Kalucka, M., Walczak, S., Kossowska, I. and Malinowska, M. (2006). Some Functional Properties Of Lupin Proteins Modified By Lactic Fermentation And Extrusion. *Food Chemistry* 96, 290–296.

Larrea, M. A, Chang, Y. K. and Bustos, F. M. (2005). Effect of some operational extrusion parameters on the constituents of orange pulp.*Food Chemistry*, Vol.89, No.2, pp.301-308

Lasekan O. O., Lasekan, W., Idowu, M. A. and Ojo, O. A. (1996). Effect ofextrusion cooking conditions on the Nutritional Value, StorageStability and Sensory Characteristics of maize-based snack food, *J. Cereals Sci*., 24:79-85.

Leach, H. W., McCowen, L. D. and Scoch, T. J. (1959). Structure of the starch granule. I. Swelling and solubility patterns of various starches. Cereal Chemistry 36: 535 – 545.

Lebot, V., Champagne, A., R. Malapa and D. Shiley (2009) NIR Determination of Major Constituents in TropicalRoot and Tuber Crop Flours. *Journal of Agricultural and Food Chemistry*, 57: 10539–10547.

Lebot, V., Malapa R., Molisale T. and J.L. Marchand. (2005). Physico-chemical characterisation of yam (Dioscoreaalata L.) tubers from Vanuatu. Genetic Resources and Crop Evolution, 53 (6) : 1199-1208

Lee, S. Y., (2001), Physico-chemical characteristics of flour and extruded snacks fromtwo sweetpotato varieties, Jalomas and Telong *J. Trop. Agric. and Fd. Sc. 29(2)(2001): 197–203*

Lewis, Y. S. and Neelakantan, S. (1964). The chemistry,biochemistry and technology of tamarind. *Journal of Scientific and Industrial Research* 23:204–6.

Liu D., Diorio J.,Tannenbaum, B. and Caldji, C. (1997).Maternal Care, Hippocampal Glucocorticoid Receptors, and Hypothalamic-PituitaryAdrenal Responses to Stress. 277(5332): 1659-1662.

Lockett, C.T., Calvert, C.C. and Grivetti, L.E. (2000). Energy And Micronutrient Composition Of Dietary And Medicinal Wild Plants Consumed During Drought. Study of Rural Fulani, Northeastern Nigeria. *International Journal of Food Sciences and Nutrition*, 51, 195-208.

Magaia, T., Uamusse, A., Sjöholm, I. and Skog, K. Analysis of Five Wild Fruits of Mozambique (2013), *The Scientific World Journal*, 601435, 6.

Magdi, O.A. (2004). Chemical and Nutrient Analysis of Baobab (Adansoniadigitata) Fruit and Seed Protein Solubility. *Plant Food for Human Nutr.* 59:1-5

Makinde, F.M. and Ladipo, A.T. (2012). Physicochemical and microbial quality of sorghum based complementary food enriched with soybean (Glycine max) and Sesame (Sesamum indicum). *J. Food Technol.* 10(2): 46-49

Malomo, O., Ogunmoyela, O. A. B., Adekoyeni, O. O., Jimoh, O., Oluwajoba, S.O., Sobanwa, M. O., (2012),Rheological and Functional Properties of Soy-Poundo Yam Flour.*International Journal of Food Science and Nutrition Engineering, 2012*, 2(6): 101-107

Manchanda, R., Arora, S. C. and Manchanda, R. (2014). Tamarind Seed Polysaccharide and its Modification Versatile Pharmaceutical Excipients- A Review, *International Journal of Pharm Tech Research*, 6(2) : 412

Manfredini, S., Vertuani, S., Braccioli, E. and Buzzoni, E. (2002). Antioxidant capacity of *Adansonia digitata* fruit pulp and leaves. *Acta Phytotherap eutica*, 2: 2-7.

Marangoni, A., Ali, L., Kermasha, S. (1988). Composition and properties of seeds of the true legume *Tamarindus indica*. J Food Sci 53: 1452-1455.

Marathe, R.M., Annapure, U.S., Singhal, R.S. and Kulkarni, P.R. (2002). Gelling behaviour of polyose from tamarind kernel polysaccharide. Food Hydrocolloids, 16(5): 423-426.

Martha, G. R., Carlos, A. Q., Esther, P., Juan, G. B., and Carmen, O. M., (2015) Effect of Extrusion Cooking on Bioactive Compounds in Encapsulated Red Cactus Pear Powder *Molecules 20*, 8875-8892

MBH (2008). The Importance of pH in Food Quality and Production. MBH

Engineering Systems. http://www.mbhes.com/ph_&_food.htm Accessed 16th June, 2014

McAnuff, M. A., Omoruyi, F. O, Morrison, E. Y., an Asemota, H. N. (2005). Changes in Some Liver Enzymes in Streptozotocin-Induced Diabetic Rats Fed Sapogenin Extract from Bitter Yam (Dioscoreapolygonoides) or Commercial Diosgenin. *West Indian Med J.* 54(2): 97-101.

McKevith, B. (2005), Nutritional aspects of oilseeds. *Nutrition Bulletin,* 30: 13–2

Meilgaard, Morten, Gail Vance Civille and B. Thomas Carr. (1999). "Sensory Evaluation Techniques", 3rd edition, Chapters 2 and 6. CRC Press LLC, Boca Raton, Florida

Méndez-Garcia, S., Martinez-Flores, H.E., and Morales-Sánchez, E. (2011), Effect of extrusion parameters on some properties of dietary fiber from lemon (*Citrus aurantifolia* Swingle) residues, *African Journal of Biotechnology*. 10(73), 16589-16593.

Mercier, C. And Feillet, P., 1975. Modification of Carbohydrate Components by Extrusion Cooking of Cereal Products. *Cereal Chem.,* 52: 283- 297.

Morton, J. (1987). Breadfruit. p. 50–58. In: Fruits of warm climates. Julia F. Morton, Miami, FL..

Murray, S.S., Schoeninger, M.J., Bunn, H.T., Pickering, T.R., Marlett, J.A. (2001). Nutritional Composition of Some Wild Plant Foods and Honey Used by Hadza Foragers of Tanzania. *Journal of Food Composition and Analysis*, 14, 3-13

Muzac-Tucker, I., Asemota, H.N. and Ahmad, M.H. (1993). Biochemical composition and storage of Jamaican yams (Dioscorea sp). *Journal of the Science of Food and Agriculture* 62:219-224.

NAS (1979). Tropical Legumes: Resources for the Future. National Academy of Science, Report of an Ad Hoc Panel of The Advisory Committee on Technology Innovation.

Natural Standard (2011) www.naturalstandard.com): http://www.clarksnutrition .com /ns/ DisplayMonograph.asp?DocID=basic-interactions calcium & store ID =2691B1FE187D41ACB869A85CA5957A0A. Accessed 15th May. 2015.

Ndabikunze, B. K., Masambu, B.N., Tiisekwa, B. P. M, Issa-Zacharia, A. (2011). The Production of Jam from Indigenous Fruits Using Baobab (*Adansonia digitata L.*) powder as a substitute for commercial pectin. *Afr. Journal of Food Science.* 5: 168-175.

Newport Scientific (1998). Applications Manual for the Rapid Visco Analyzer Using Thermocline for Windows. Newport Scientific Pty Ltd., 1/2 Apollo Street, Warriewood NSW 2102, Australia, pp. 2-26.

Nhukarume, L., Chikwambi, Z., Muchuweti, M. and Chipurura, B. (2008). Phenolic content and antioxidant capacities of Parinari curatelifolia, Strychnos spinosa and Adansonia digitata. *Journal of Food Biochemistry,* 34, 207 – 221.

Nicole, M., Fei, H.Y. and Claver, I.P. (2010) Characterization of Ready-to-Eat Composite Porridge Flours Made by Soy-Maize-Sorghum-Wheat Extrusion Cooking Process. *Pak J Nutr*. 9, pp. 171-178.

Noorakmar, A. W., Cheow, C. S., Norizzah, A. R., Mohd, Z. A., and Ruzaina, I.,(2012). Effect of Orange Sweet Potato *(Ipomoea Batatas)* Flour on the Physical Properties of Fried Extruded Fish Crackers. *International Food Research Journal 19(2): 657-664.*

Nikmaram, N., Kamani, M. H and Ghalavand, R. (2015). The Effects Of Extrusion Cooking on Antinutritional Factors, Chemical Properties and Contaminating Microorganisms of Food.. *International Journal of Farming and Allied Sciences* 4 (4) pp 352-354

Nour, A. A., Magboul, B. I., Kheiri, N. H. (1980). Chemical composition of baobab fruit (*Adansonia digitata)*. Trop. Sci.; 22:383–388.

Nummer, B., A. (2008). Food Acidity and Food Safety. Utah Sate University. http://extension.usu.edu/files/publications/publication/FN_Food_Safety_2008-01.pdf .Accessed 20th February, 2014.

O'Sullivan J.N. (2010). Yam nutrition: nutrient disorders and soil fertility management.ACIAR Monograph No. 144. *Australian Centre for Inte-r national Agricultural Research:* Canberra. 112.

Obadina, A., O.,Babatunde, B., O. and Olutu, I. (2014) Changes in nutritional composition, functional, and sensory properties of yam flour as a result of presoaking. *Food Science and Nutrition*, 2(6)

Obizoba, I.C., Amaechi, N.A. (1993). The Effect of Processing Methods on the Chemical Composition of Baobab (*Adansonia digitata L*.) pulp and seed. Ecology of Food and Nutrition, 29, 199-205.

Odetokun, S.(1996). The Nutritive Value of Baobab Fruit *(Andonsonia digitata*). La RivistaItalianoDelleSostanze Grasse 73: 371 – 371

Oduro, I., Ellis, W. O., Nyarko, L., Koomson, G. and Otoo, J. A. (2001). Physicochemical and pasting properties of flour from four sweetpotato varieties in Ghana. Proceedings of the Eigth Triennial Symposium of the International Society for Tropical Root Crops (ISTRC-AB), Ibadan, Nigeria.1216 November

Ofosu, S.B (2010). Assesment of Three White Yam (*Dioscorea rotundata*) Varieties for Possible Development into Flour. MPhil. Thesis. Kwame Nkrumah University of Science and Technology. http://ir.knust.edu.gh/ bitstream/123456789/6220/1/SAMPSON%20BOATENG%20OFOSU.pdf

Ogbonna, A. C., Abuajah, C. I, Akpan, M. F., and Udofia, U. S. (2013). A Comparative Study of the Nutritional Values of Palmwine and Kunu-Zaki. Annals Food Sci. Technol. 14:39–43.

Okaka, J. C. (1997). Cereals and legumes: Storageand Processing Technology. Data and microsystem publishers, Enugu, Nigeria, p 11-124.

Oladebeye, A.O., Oshodi, A. A. and Oladebeye, A. A. (2008). Proceedings of International Conference of Chemical Society of Nigeria.

Olu M, Ogunyele OAB, Adekoyeni OO Jimoh O, Oluwajoba SO,Sobanwa MO (2012) Rheological and functional properties of soy-pondo yam flour. International journal of food science and nutrition engineering. 2: 101 –107

Oluwole, O. B., Olapade, A. A., Awonorin, S. O., and Henshaw, F. O., (2013). Physicochemical properties of extrudates from white yam and bambara nut blends. *International Agrophysics* (27(1):69-74.

Onayemi, O., and Potter, N. N., (1974), Preparation And Storage Properties Of Drum Dried White Yam (*Dioscorea rotundata Poir*) Flakes. *J. Food Sci.*, 39, 559-562

Onwueme, I.C. (1977). Field comparison of West African planting and harvesting practices in yam (Dioscorea rotundata): pre-sprouting, dry season planting, and double-harvesting. *J. Agric. Sci., Camb.* 84: 503-505.

Onwueme, I.C., W.B. Charles. (1994). Tropical root and tuber crops. Production, perspectives and future prospects. *FAO Plant Production and Protection Paper* 126. FAO, Rome.

Onwuka G.I. and C. Ihuma , (2007). Physico-Chemical Composition and Product Behaviour of Flour and Chips from Two Yam Sp. (Dioscorea rotundata and Dioscorea alata). *Research Journal of Applied Sciences*, 2: 35-38.

Orwa C., Mutua, A., Kindt, R. , Jamnadass, R., Anthony, S. (2009) Agroforestree Database:a tree reference and selection guide version 4.0 (http://www. world agroforestry. org/sites/treedbs/treedatabases.asp

Osagie, A. U. (1992). The Yam Tuber in Storage. Post-harvest Research Unit, University of Benin, Nigeria, pp107 – 173.

Osman, M. (2004). Chemical And Nutrient Analysis of Baobab (*Adansonia digitata*) Fruit and Seed Protein Solubility. *Plant Food Hum. Nutr.* 59(1):29-33.

Otegbayo, B. O., Achidi A. U., Asiedu, R. and Bokanga, M. (2001). Food quality attributes of Ponayams. Proceedings of the Eighth Triennial Symposium of the International Societyfor Tropical Root Crops, Ibadan, Nigeria. 12-16 November, 2001

Oyeleke G.O., Salam M.A and Adetoro R.O. (2012). Some Aspects of Nutrient Analysis of Seed, Pulp and Oil of Baobab (*Adansonia digitata* L.) *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT),* 1(4): 32-35

Panigrahi, S.; Plumb, V. E.; Machin, D. H., (1989). Effects of dietary cottonseed meal, with and without iron treatment, on laying hens. *Br. Poult. Sci*., 30 (3): 641-651

Parvez, S.S., Parvez, M.M., Nishihara, E., Gemma, H. and Fujii, Y. (2003) *Tamarindus indica* L. Plant Growth Regulation, 40(2):107-115.

Patel, A. (2013). Uses of Tamarind Gum Powder in Food, Pet Food, Textile, Mining and Pharmaceutical Industries. http://www.altrafine. com/blog/ category/tamarind-kernel-powder/accessed November

Pedreschi, F. and Zuñiga, R. N. (2009) Acrylamide and Oil Reduction in Fried Potatoes: *A Review, Global Science Books Food 3* (Special Issue 2), 82-92

Pelembe L. A. M., Erasmus, C. and Taylor J. R. N. (2002). Development of a Protein-rich Composite Sorghum–Cowpea Instant Porridge by Extrusion Cooking Process. Elsevier Science Ltd.

Phytotrade (2009). Baobab Fruit Powder .http://phytotrade.com/download/scilit/baobab/PhytoTrade_Afriplex-Baobab_Powder_sept_09.pdf

PhytoTrade. (2005). PhytoTrade technical specification sheet on Baobab Fruit Pulp.

PhytoTrade. (2010). Baobab Fruit Powder Info Sheet. http://baobabsuperfruit. com/wp-content/uploads/PhytoTrade-Baobab-Fruit-Powder-Info-Sheetcopyrighted-LR.pdf

Pitchaon, M., Tanawan, W., and Thepkunya, H. (2013). "Tamarind Kernel Powder, Gum Arabic And Maltodextrin as a Novel Combination for Encapsulating Agents of Phenolic Antioxidants," *International Food Research Journal*, vol. 20 (2), pp. 645–652.

Polycarp, D., Afoakwa, E. O., Budu, A. S. and Otoo, E. (2012) Characterization of chemical composition and anti-nutritional factors in seven species within the Ghanaian yam *(Dioscorea)* germplasm : *International Food Research Journal 19 (3): 985-992*

Prentice, A., Laskey, M.A., Shaw, J., Hudson, G.J., Day, K.C., Jarjou, L.M.A., Dibba, B., Paul, A.A. (1993). The calcium and phosphorus intake of rural Gambian women during pregnancy and lactation. *British Journal of Nutrition*, 69, 885-896.

PRWEB. UK (2012). Baobab Fruit.(Adonsonia digitata L.) a Unique Super Fruit with High Level of Natural VitC, Potassium, Calcium and Much More, Retrieved from http:/www.prweb.com/release/2012/6/prweb9549269.html London United Kingdom

Pugalenthi, M., V. Vadive, P. Gurumoorthi and K. Janardhanan. (2004). Comparative nutrional evalution of little known legumes, *Tamarindus indica*, *Erythrina indica* and *Sesbaniabis pinosa*, 107-123.

Pushpa M. Devi and Narayanasamy Sangeetha (2013) Extraction and dehydration of millet milk powder for formulation of extruded product IOSR *Journal Of Environmental Science, Toxicology And Food Technology* (IOSRJESTFT), 7 (1) 63-70

Ragaee, S. and Abdel-Aal, E. M. (2006). Pasting Properties of Starch and Protein in Selected Cereals and Quality of Their Food Products," *Food Chemistry*, 95 (1): 9-18.

Ramachandrarao, H. G. and Thejaswini, M.L. (2015). Extrusion Technology: A Novel Method of Food Processing *IJISET - International Journal of Innovative Science, Engineering & Technology*, 2(4) April. www.ijiset. comISSN 2348 – 7968 358

Rasala, T.M. and Kale, V.V. and Lohiya, G.K. and Moharir, K.S. and Ittadwar, A.M. and Awari, J.G. (2011). Chemistry and Pharmaceutical Applications of Excipients Derived from Tamarind. *Asian Journal of Chemistry*. 23(4): 1421-1423.

Rava, V., Aked, J. and Balagopalan, C. (1996). Review on tropical root and tuber crops: storage methods and quality changes. *Critical Reviews in Food Science and Nutrition*,36: 661-709

Razzaq, M. R., F. M. Anjum, M. I. Khan, M. R. Khan, M. Nadeem, M. S. Javed, and M. W. Sajid. (2012). Effect of temperature, screw speed and moisture variations on extrusion cooking behavior of maize (Zea mays. L). *Pakistan Journal Food Sciences* 22(1): 12-22

Rhee KS, Kim ES, Jung BM, Rhee KC. (2004) Extrusion of minced catfish with corn and defatted soy flours for snack foods. *J Food Process Pres*.;28:288–301. doi: 10.1111/j.1745-4549.2004.23069.x

Riaz, M. N. (2000). Introduction to extruders and their principles. In: Extruders in food applications, M. N. Riaz, (Ed.), CRC Press, Boca Raton, United States of America, pp.1-23

Riaz, M. N., Barron, M. E. and Rokey, G. (2000) "Extrusion Technology for Aquaculture Feeds, Fullfat Soymeal and Other Feed Products: Short Course Manual for ASA China". Food Protein Research and Development Center, Texas A & M University, College Station, TX.

Rodriguez E, Jimenz A, Fernandex-Bolanos J, Guilten R, Heredia A (2006). Dietary Fiber from Vegetable Products as Source of Functional Ingredients. *Trends Food Sci. Technol.*, 17: 3-5

Rodríguez-Miranda, J., Ruiz-López, I. I., Herman-Lara. E., Martínez-Sánchez, C. E., Delgado-Licon, E., Vivar-Vera, M. A. (2011). Development of extruded snacks using taro (Colocasia esculenta) and nixtamalized maize (Zea mays) flour blends. LWT - Food Sci. Technol. 44:673-680.

Sahore, D.A., Amani, N. G and Kamenan, A. (2006). Anitinutritional Factors in Wild Yam tubers. *Trop. Sci.*, 46: 113-115.

Salda, V.B., Ramsden, L., Sun, M. and Corke, H. (1998), Genetic variation in physical properties of flour from selected Asian yams (Dioscorea spp.). *Tropical Agriculture* 75:212-216.

Sandhu, K. S. and Singh, N. (2007) Some properties of corn starches II: Physicochemical, gelatinization, retrogradation, pasting and gel textural properties. *Food Chem* 10: 1499-1507.

Sanful, R. E., Oduro, I., and Ellis, W. O. (2013). Effect of Pre-treatment and Drying on the Nutritional and Mineral Composition of *D. bulbifera* flour. *Journal of Biological and Food Science Research*

Sanni, L.O, Oyewole, O. B., Adebowale, A. A. and Adebayo, K., (2003), Current trends in the utilization of roots and tubers for sustainable development, 2nd international workshop, Food based approaches for a healthy nutrition, Ouagadougou, 23-28 / 11 / 2003.

Sarpong, A., A. (2014) Effect Of Different Drying Methods On The Functional And Physicochemical Properties Of The Flour Of Selected Yam Cultivars In Ghana. Msc Thesis. Kwmae Nkrumah University of Science and Technology.

Sawant, A. A., Thakor, N. J.,. Swami, S. B., A. D. Divate Balasaheb Sawant Konkan Krishi Vidyapeeth., (2013), Physical and sensory characteristics of Ready-To-Eat foodprepared from finger millet based composite mixer by extrusion. Agric Eng Int: CIGR Journal Open access at http://www. cigrjournal.org Vol. 15, No.1

Schoch, I.J. and E.C. Maywald, (1968). Preparation and Properties of Various Legume Starches. *Cereal Chem.*, 45: 564-573.

Scott, G., Best, R., Rosegrant, M.W. and Bokanga, M., (2000). Roots and Tubers in the Global Food System - A vision statement to the year 2020. CIAT- CIP-IFPRI-IITA -IPGRI-CIP. 45

Scott, G.J., Rosegrant, M. and Ringle. C. (2000). Roots and tubers for the 21st century: Trends, projections and policy options. Food, Agriculture and the

Environment Discussion Paper Washington, D.C.: International food policy research institute (IFPRI) and International potato Centre (CIP)

SCUC (2006), Baobab Manual, Field Manual for Extension Workers and Farmers, University of Southampton, Southampton, UK.

Sebio, L. and Chang, Y. (2004), Effect of processing conditions on the extrusion of white yam flour (*D. rotundata*). Trop. Sci., 44: 190–195. doi: 10.1002 /ts. 167

Seetharaman, K., Tziotis, A., Borras, F., White, P. J., Ferrer, M. and Robutti J. (200). Thermal and Functional Characterization of Starch from Argentinean Corn, *American Association of Cereal Chemists*, Inc.78 (4).

Sefa-Dedeh, S. (1995). Process and Product Characteristics of Agbelima, a Fermented Cassava Product. *Tropical Science.* 36(4): 359-64.

Senanayake S. A., Ranaweera, K. K. D., Bamunuarachchi, A. and Gunaratne, A. (2012). Proximate Analysis And Phytochemical And Mineral Constituents In Four Cultivars Of Yams And Tuber Crops In Sri Lanka.*Tropical Agricultural Research & Extension* 15(1)

Shadan, M.R., Waghray, K. and Khoushabi, F. (2014) Formulation, Preparation and Evaluation of Low-Cost Extrude Products Based on Cereals and Pulses. *Food and Nutrition Sciences*, 5, 1333-1340. http://dx.doi.org/ 10.4236/ fns.2014.514145

Shankaracharya, N.B. (1998). Tamarind - Chemistry, Technology and Uses - a critical appraisal. *Journal of FoodTechnology*, 1998,35(3): 193-08.

Shimelis, A. E., Meaza, M. and Rakshit, S.(2006). Physico-chemical properties, pasting behavior and functional characteristics of flours and starches from improved bean (Phaseolus Vulgaris L.) varieties grown in East Africa. CIGR e-journals, 8: 1- 18.

Shubhang (2013). The Tamamrind Tree. https://abetterwordbangalore. wordpress. com/2013/04/19/the-tamarind-tree/ Accessed 20th July 2015

Shukla, Y.N., Dubey, S., Jain, S.P. and Kumar, S. (2001). Chemistry, Biology and Uses of Adansonia digitata – a review. Journal of Medicinal and Aromatic Plant *Sciences*, 23, 429-434.

Sidibe, M and Williams J. T. (2002). Baobab, Adansonia digitata L. Southampton, UK: International Centre for Underutilised Crops. 96p.

Sidibe, M., Scheuring, J. F., Kone, M., Schierle, J. and Frigg, M. (1998b). A (and C) for Africa: The baobab tree as a source of vitamins. *Agroforestry Today*, 10, 7–9.

Sidibe, M., Scheuring, J. F., Tembley, D., Sidibe, M. M., Hofman, P. and Frigg, M. (1996). Baobab – homegrown vitamin C for Africa. *Agroforestry Today* 8, 13–15.

Singh, S., Gamlath, S. and Wakeling, L. (2007), Nutritional aspects of food extrusion: a review. *International Journal of Food Science & Technology*, 42: 916–929.

Sobukola, O.P., Babajide, J.M., and Ogunsade, O., (2013), Effect Of Brewers Spent Grain Addition And Extrusion Parameters On Some Properties Of Extruded Yam Starch-Based Pasta. *Journal of Food Processing and Preservation*, 37: 734–743.

Spence, C. (2015) Eating With Our Ears: Assessing the Importance of the Sounds of Consumption on our Perception and Enjoyment Of Multisensory Flavour Experiences, *Flavour*, 4, 1, 3.

Sukhawanli, S. and Thamakorn, P. (2014). Extraction Of Tamarind Seed Jellose Under Different Conditions And Their Rheological Properties. *Food and Applied Bioscience Journal*. 2 (1): 61-68

Szczesniak, A.S. (1988) 'The Meaning of Textural Characteristics—Crispness' in *J. Text. Stud.*19, 51 –59

Szczesniak, A.S. The meaning of textural characteristics–crispness (1988) *Journal of Texture Studies*, 19, 51–59.

Tal-Dia, A., Toure, K., Sarr, O., Sarr, M., Cisse, M. F., Garnier, P., and Wone, I. (1997). A Baobab Solution for the Prevention and Treatment of Acute Dehydration in Infantile Diarrhea. Dakar Med, 42(1):68-73.

Täufel, A., Ternes. W., Tunger, L., Zobel, M. Lebensmittel-lexikon, 3.Aufl., 1500 S., Behr's Verlag, Hamburg, 1993, gebunden DM 229,–ISBN-3-860022122-1. *J Prakt Chem* 1993; 337: 78.

Trater, A.M., Alavi, S, and Rizvi, S.S.H. (2005). Use of Non-Invasive X-Ray Microtomography for Characterizing Microstructure of Extruded Biopolymer Foams. *Food Research International*. 38: 709-719.

Turgeon, S.L., S.F. Gauthier and P. Paquin, (1992). Emulsifying property of whey peptide fractions as a function of pH and ionic strength. *J. Food Sci*., 57: 601-604.

Ubbor, S.C. and Akobundu, E.N.T. (2009). Quality Characteristics of Cookies from Composite Flours of Watermelon Seed, Cassava and Wheat. *Pakistan Journal of Nutrition*. 8 (7): 1097-1102

Udensi, E. A., Oselebe, H. O. and Iweala, O.O. (2008). The Investigation of Chemical Composition and Functional Properties of Water Yam (Dioscoreaalata): Effect of Varietal Differences. *Pakistan Journal of Nutrition* 7 (2): 342-344

Udensi, E. A., Oselebe, H. O. and Onuoha, A. U. (2010). Antinutritional Assessment of D. alata Varieties. *Pak. J. Nutr*. 9(2):179-181

Ukpabi, U. J., (2010). Farmstead bread making potential of lesser yam(D. esculenta) flour in Nigeria. *Aust. J. Crop*, 4: 68 – 73.

USDA,. (2011). National Nutrient Database for Standard Reference. Available at http://ndb.nal.usda.gov/ndb/foods/list

Van Duyn, M. A and Pivonka, E (2000). Overview of the Health Benefits of Fruit ond Vegetable Consumption for the Dietetics Professional. *J Am Diet Assoc* 99 (10): 1241-1248.

Van Wyk, B. E., Van Outshroom, B., Gericke, N., (1997), Medicinal plants of South Africa. *Briza Publications*, Pretoria.

Vasantha, K. P., and Narayanasamy, S. (2013).Effect of Processing Techniques on the Physical and Nutritional Properties of Extruded Product Using Multicereal Composite Mix *IOSR Journal Of Environmental Science, Toxicology And Food Technology*, 5(4) 2319-2399.

Vertuani, S., Braccioli, E., Buzzoni, V., Manfredini, S. (2002). Antioxidant Capacity Of Adansonia Digitata Fruit Pulp and Leaves. *Acta Phytotherapeutica*, 2 (V), 2-7

Vickers, Z. M. (1985). The relationships of pitch, loudness and eating technique to judgments of the crispness and crunchiness of food sounds. *J Texture Stud*.16:85-95.

Wanasundera,J.P.D. and Ravindran,G. (1994). Nutritional assessment of yam(Dioscorea alata) tubers. *Plant Foods for Human Nutrition* ,46 (1): 3339

Wang S, Copeland L. (2013). Molecular disassembly of starch granules during gelatinization and its effect on starch digestibility: a review. *Food Functions*4*:*1564–80.

Wickens G. E. (1982). The baobab - Africa's upside-down tree. Kew Bulletin. 37(2).

Wickens, G. E. and Lowe, P. (2008). The baobab: Parchycauls of Africa. Madagascar and Australia, Springer.

Wioletta, D., Ewa, T., Ewa, Z., Hanna, B., Tomasz, B., and Piotr, R. (2014). Effect of apple and rosehip pomaces on colour, total phenolics and antioxidant activity of corn extruded snacks *Polish Journal of Chemical Technology, 16, 3, 7*

Wireko-Manu F. D**.,** Oduro, I**.,** Ellis, W. O., Asiedu, R., B. Maziya Dixon (2013) Potential Health Benefits of Water Yam (Dioscorea alata). *Food and Function.* 4(10):1496-1501

Wongnaa, C. A. and Awunyo-Vitor, D. (2013). Factors Affecting Loan Repayment Performance among Yam Farmers in the Sene District, Ghana Agris on-line Papers in Economics and Informatics, 2

Yusha'u, M., Hamza, M. M. and Abdullahi, N. (2010). Antibacterial activity of Adansonia digitata stem bark extracts on some clinical bacterial isolates. *International Journal of Biomedical and Health Sciences* 6, 129 – 135.

Yusha'u, M., Hamza, M. M. and Abdullahi, N. (2010). Antibacterial activity of Adansonia digitata stem bark extracts on some clinical bacterial isolates. *International Journal of Biomedical and Health Sciences* 6, 129 – 135.

ZOBEL, H.F. (1984). Gelatinization of starch and mechanical properties of starch pastes. In Starch: Chemistry and Technology (R.L. Whistler, J.N. Bemiller and E.F. Paschall, eds.) *Academic Press, New York, NY*. 285–309,

APPENDICES

Appendix 1.0 Formulas

3.3.1 Determination of Moisture %

Moisture =

$$\frac{\text{Weight of can + fresh sample – (Weight of can + dry sample)}}{\text{Weight of sample}} \times 100$$

3.3.2 Determination of ash

$$\% \text{ Ash} = \frac{\text{Weight of crucible + ash - Weight of empty crucible}}{\text{Weight of sample} \times 100}$$

3.3.3 Determination of crude fat

$$\% \text{ Crude fat} = \frac{\text{Weight of extracted matter}}{\text{Weight of sample} \times 100}$$

3.3.4 Determination of crude fibre

$$\% \text{ Crude fibre} = \frac{\text{Weight of dried sample - Weight of ash}}{\text{Weight of sample} \times 100}$$

3.5.3 Determination of swelling power

$$\text{Swelling power} = \frac{\text{weight of the paste x 100}}{\text{Weight of dry sample}}$$

3.5.4 Determination of Bulk Density

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of the sample}}{\text{Volume of the sample after tapping}}$$

Water binding capacity (grams of water per gram of flour) was calculated as % Water Binding Capacity = $\frac{(W_2 - W_1)}{W_0} \times 100$

where, W_0 is the weight of the dry sample (g), W_1 is the weight of the tube plus the dry sample (g), and W_2 is the weight of the tube plus the sediment (g).

Appendix 2.0A Sensory Evaluation Forms

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Please evaluate each sample and indicate how much you like the intensity of each attribute listed for each sample using the nine point hedonic scale below. Please rinse your mouth with water in between samples.

1. Dislike Extremely	6. Like Slightly
2. Disike Very Much	7. Like Moderately
3. Disike Moderately	8. Like Very Much
4. Dislike Slightly	9. Like Extremely
5. Neither Like or Dislike	

ATTRIBUTE	SAMPLE CODES						
Aroma							
Texture (firmness)							
Shape							
Crunchiness							
Colour							
Puffiness							
After taste							

Appendix 2.0B Overall Acceptatbility

Please rank the TWO samples in order of your overall preference, from **MOST** preferred (1) to **LEAST** preferred (2)

Rank	Sample Code
………………	……………………..
………………	……………………..

Appendix 2.0C: Sensory Evaluation of Trial Extrudates

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Aroma	Between Groups	.600	1	.600	.221	.640
	Within Groups	157.133	58	2.709		
	Total	157.733	59			
Texture	Between Groups	1.667	1	1.667	.704	.405
	Within Groups	137.267	58	2.367		
	Total	138.933	59			
Shape	Between Groups	4.267	1	4.267	1.570	.215
	Within Groups	157.667	58	2.718		
	Total	161.933	59			
Crunchiness	Between Groups	4.267	1	4.267	1.715	.196
	Within Groups	144.333	58	2.489		
	Total	148.600	59			
Colour	Between Groups	1.350	1	1.350	.493	.485
	Within Groups	158.833	58	2.739		
	Total	160.183	59			
Puffiness	Between Groups	5.400	1	5.400	1.603	.210
	Within Groups	195.333	58	3.368		
	Total	200.733	59			
Taste	Between Groups	2.817	1		.625	.432

				2.817		
	Within Groups	261.367	58	4.506		
	Total	264.183	59			

Appendix 2.0D: Frequency Tables of Overall Acceptability of Trial Extrudates

Statistics

E5(10B:30T:60Y)

N	Valid	30
	Missing	30
Mode		1.00

E5(10B:30T:60Y)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	most prefered	19	31.7	63.3	63.3
	least prefered	11	18.3	36.7	100.0
	Total	30	50.0	100.0	
Missing	System	30	50.0		
Total		60	100.0		

Statistics

E6(20B:20T:60Y)

N	Valid	30
	Missing	30
Mode		2.00

E6(20B:20T:60Y)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	most prefered	11	18.3	36.7	36.7
	least prefered	19	31.7	63.3	100.0
	Total	30	50.0	100.0	
Missing	System	30	50.0		
Total		60	100.0		

Appendix 3.0 Plates

Plate 7.0 A bowl of "yammy pops" (EXTRUDED YAM-BAOBAB-TAMARIND)

Plate 8.0 Extrudates displayed for sensory evaluation

Appendix 4.0A Proximate Composition of Flour Samples

		Sum of Squares	Df	Mean Square	F	Sig.
	Between Groups	326.013	2	163.007	7768.138	.000
MOISTURE	Within Groups	.063	3	.021		
	Total	326.076	5			
	Between Groups	8.310	2	4.155	549.134	.000
	Within Groups			.008		
ASH	Total	.023	3			
	Between Groups	8.333	5	16.743		
	Within Groups	33.485	2	.001		
CRUDE FAT	Total				24501.244	.000
	Between Groups	.002	3	86.524		
	Within Groups	33.487	5	.001		
	Total	173.048	2			
					123605.881	.000
	Between Groups			18.872		
CRUDE PROTEIN	Within Groups	.002	3	.054		
	Total	173.050	5			
	Between Groups	37.743	2	18.705	349.475	.000
	Within Groups			7.645		
CRUDE FIBRE	Total	.162	3			
	Between Groups	37.905	5	9153.032		
	Within Groups			440.244		
CARBOHYDRATES	Total	37.410	2		2.447	.234
		22.935	3			
		60.345	5			
ENERGY		18306.063	2		20.791	.017
		1320.732	3			
		19626.796	5			

Appendix 4.0B Mineral composition of Flour samples

		Sum of Squares	df	Mean Square	F	Sig.
Iron	Between Groups	14.588	2	7.294	205.363	.001
	Within Groups	.107	3	.036		
	Total	14.694	5			
Calcium	Between Groups	741.092	2	370.546	693.128	.000
	Within Groups	1.604	3	.535		
	Total	742.696	5			
Phosphorus	Between Groups	203.034	2	101.517	167.111	.001
	Within Groups	1.822	3	.607		
	Total	204.857	5			

Appendix 5.0 Anova Tables for Physicochemical Properties of Composite Flours and Extrudates

Appendix 5 A: Physicochemical Properties of Composites Flours

		Sum of Squares	df	Mean Square	F	Sig.
MOISTURE CONTENT	Between Groups	13.136	5	2.627	642.073	.000
	Within Groups	.025	6	.004		
		13.160	11			
	Total	11733.854	5	2346.771	300.387	.000
WATER BINDING CAPACITY	Between Groups	46.875	6	7.813		
	Within Groups					
	Total					

		11780.729	11			
pH	Between Groups	4.325	5	.865	451.259	.000
	Within Groups	.011	6	.002		
	Total	4.336	11			
SWELLING POWER	Between Groups	1468.554	5	293.711	38.918	.000
	Within Groups	45.282	6	7.547		
	Total	1513.835	11			
BULK DENSITY	Between Groups	.060	5	.012	8.087	.012
	Within Groups	.009	6	.001		
	Total	.068	11			

Appendix 5B: Physichochemical Characteristics of Trial Extrudates

		Sum of Squares	df	Mean Square	F	Sig.
MOISTURE CONTENT	Between Groups	.066	1	.066	8.746	.098
	Within Groups	.015	2	.008		
	Total	.081	3			

WATER BINDING CAPACITY	Between Groups	506.250	1	506.250	16.200	.057
	Within Groups	62.500	2	31.250		
	Total	568.750	3			
SWELLING POWER	Between Groups	9773.300	1	9773.300	642.040	.002
	Within Groups	30.445	2	15.222		
	Total	9803.744	3			
pH	Between Groups	.168	1	.168	672.400	.001
	Within Groups	.000	2	.000		
	Total	.169	3			
BULK DENSITY	Between Groups	.003		.003	24.200	.039
	Within Groups	.000		.000		
	Total	.003				

Appendix 5 C: Expansion Ratio of Trial Extrudates

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.098	1	.098	3.459	.079
Within Groups	.510	18	.028		
Total	.608	19			

Appendix 6.0 Anova Table for Pasting Properties of Composite Flours and Extrudates

Appendix 6A: Pasting Properties of Composite Flours

		Sum of Squares	df	Mean Square	F	Sig.
PTEMP	Between Groups	1418.344	4	354.586	127.183	.000
	Within Groups	13.940	5	2.788		
	Total	1432.284	9			
PTIME	Between Groups	801.183	4	200.296	491.873	.000
	Within Groups	2.036	5	.407		
	Total	803.219	9			
PV	Between Groups	111167.400	4	27791.850	4791.698	.000
	Within Groups	29.000	5	5.800		
	Total	111196.400	9			
MV	Between Groups	104306.600	4	26076.650	2287.425	.000
	Within Groups	57.000	5	11.400		
	Total	104363.600	9			
ENDCOOLING	Between Groups	211157.400	4	52789.350	7541.336	.000
	Within Groups	35.000	5	7.000		
	Total	211192.400	9			
FINAL VISCOSITY	Between Groups	199379.600	4	49844.900	5138.649	.000
	Within Groups	48.500	5	9.700		
	Total	199428.100	9			
BREKDWN VIS	Between Groups	557.600	4	139.400	116.167	.000
	Within Groups	6.000	5	1.200		
	Total	563.600	9			
SETBACK VIS	Between Groups	51755.400	4	12938.850	2230.836	.000
	Within Groups	29.000	5	5.800		
	Total	51784.400	9			

Appendix 7A: Anova Table of Colour Characteristics of Composite Flours

lightness	Between Groups	2.193	5	.439	39.100	.000
	Within Groups	.135	12	.011		
	Total	2.327	17			
Red-green	Between Groups	.204	5	.041	28.077	.000
	Within Groups	.017	12	.001		
	Total	.221	17			
Yellow-blue	Between Groups	22.322	5	4.464	125.465	.000
	Within Groups	.427	12	.036		
	Total	22.749	17			
Chroma	Between Groups	22.322	5	4.464	125.465	.000
	Within Groups	.427	12	.036		
	Total	22.749	17			
Colour Intensity	Between Groups	1.387	5	.277	29.480	.000
	Within Groups	.113	12	.009		
	Total	1.500	17			
Hue	Between Groups	14.385	5	2.877	.921	.500
	Within Groups	37.482	12	3.124		
	Total	51.868	17			

Appendix 7B: Anova Table of Colour Characteristics of Trial Extrudates

		Sum of Squares	df	Mean Square	F	Sig.
lightness	Between Groups	.558	1	.558	32.832	.005

	Within Groups	.068	4	.017		
	Total	.626	5			
red/green	Between Groups	.184	1	.184	109.158	.000
	Within Groups	.007	4	.002		
	Total	.190	5			
blue/yellow	Between Groups	.094	1	.094	.036	.858
	Within Groups	10.277	4	2.569		
	Total	10.370	5			
hue	Between Groups	2.653	1	2.653	.596	.483
	Within Groups	17.795	4	4.449		
	Total	20.449	5			