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PROXIMATE COMPOSITION, PHYSICOCHEMICAL AND FUNCTIONAL PROPERTIES OF DRIED OKRA SEED FLOUR

BY

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DECLARATION

I hereby declare that, this thesis herein is my own work towards the award of Master of Science (MSc.) degree in Food Quality Management and that, to the best of my knowledge, it contains no material previously submitted to or published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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DEDICATION

This work is dedicated to the Almighty God, glory be to his name for the courage and direction he gave in the ordering of my steps; to my supervisor I say "ayekoo" for the love, patience, advice and corrections you gave me throughout this work. God richly bless you.

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ABSTRACT

Some okra genotypes have been identified in Ghana and projects are ongoing to extract pectin from the okra pods leaving the seeds wasted. There is the need to evaluate and explore alternative uses for dreid okra seeds based on the quality attributes. The physicochemical properties of dried okra seed flour of two genotypes (Agbagoma and Balabi) were evaluated. The proximate composition, functional and physicochemical properties of okra seed flour were determined to ascertain the quality attribute of the okra seed flour samples using standard procedures. On the dry basis, the samples (Agbagoma and Balabi) had 8.90- 9.00% moisture, 16.80-17.40% protein, 47.80-48.00% fat, 7.70-7.80% ash and 18.20-18.40% carbohydrate. The mean values of functional properties revealed significant difference ($p < 0.05$) between okra seed flour samples. There were found as bulk density of 0.80-0.83) g/ml. Water absorption capacity and Oil absorption capacity of 511.65-504.32% and 88.38-160.67%, respectively. The solubility was 14.10% for Agbagoma and 10.97% for Balabi, whereas swelling power was 16.37% and 14.68% for Agbagoma and Balabi, respectively. All pasting properties except peak time and pasting temperature of Agbagoma seed flour were higher than those of Balabi seed flour. The study revealed that okra seed flour is rich in nutrients which could be used for baking and fortification as well.

TABLE OF CONTENTS

Contents **Page**

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

LIST OF PLATES

Plate page

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Notwithstanding increasing threats of nutritional and food security due to climate change and associated factors, there still exist many food crops that are under-utilized to the developing world. For such crops research work is needed to ascertain their potential and application in food in other to derive their full benefits. Okra is one of the many under-utilized crops that have shown to have high nutritional value (Gopalan *et. al.*, 2007).

Okra *(Abelmoschus esculentus L.*) is one of the most widely known and utilized species of the family *Malvaceae*. Okra is an economically important vegetable crop grown in tropical and subtropical parts of the world. It is mostly grown for its green leaves and pods which is consumed as green vegetable (Naveed *et al.*, 2009).

Abelmoschus esculentus is known by many local names in different parts of the world. It is known as lady's finger in England, gumbo in the United States of America, guino-gombo in Spanish, guibeiro in Portuguese and bhindi in India (Benchasri, 2012). Okra is suitable for cultivation as a garden crop as well as on large commercial farms (Rubatzky and Yamaguchi, 1997).

Okra fruits are a green capsule containing numerous white seeds when not matured (Jesus *et al.*, 2008) and the flowers and upright plants give okra an ornamental value (Duzyaman, 1997). The okra fruit can be classified based on the shape, angular or circular (Mota *et al.*, 2005).

Nutritionally, one hundred grams (100 g) of okra contain moisture 89.6g, minerals 0.7g, protein 1.9g/100g, carbohydrates 6.4g, fat 0.2g, calcium 66 mg, fiber 1.2g, calories 35 potassium 103 mg, phosphorus 56 mg, magnesium 53.0 mg and sodium 6.9 mg (Gopalan *et al.*, 2007). Okra is abundant with several vitamins, minerals that handle the health advantages the plant provides.

Okra *(Abelmoschus esculentus L.*) has traditionally been used as an alternative treatment for diabetes. It is assumed that this effect of okra is due to the presence of large amount of soluble dietary fibers which retard glucose absorption from the gastrointestinal tract. Okra seed is known to be rich in high quality protein especially with regard to its essential amino acids relative to other plant protein sources. Seeds are rich in phenolic compounds with derivatives, catechin oligomers and hydroxycinnamic derivatives (Arapitsas, 2008; Manach *et al.,* 2005; Ngoc *et al.*, 2008).

Dried seed from okra are the richest part of the okra plant, although oil from okra seed is nutritious and significantly rich in protein, it is not only processed for oil or protein as the production of seed is limited to seedling and regeneration purposes. However large quantities of okra seeds are discarded as unfit for seedling purposes (Martin and Ruberte, 1979). A study by (Woodruff, 1927), reported that a high protein meal remains after oil extraction of okra seed similar to that of cottonseed meal.

Removal of the okra seed hull from the kernel has not been sufficiently studied. Despite of the high protein and oil contents of okra seed, the potential of the seed as a new source of vegetable protein is yet to be fully exploited in Nigeria due partly to the problem of removal of the okra seed hull from the kernel and also a dearth of knowledge about the effect of variety on the nutritional status. Therefore, attempts were made in this study to determine the influence of variety on protein and fat contents on different fractions of okra seed. In addition, some physical properties relevant for the dehulling process design were evaluated for the different varieties studied. (Oyenuga, 1968).

Seeds of mature okra can be roasted, ground and used as a coffee substitute in Turkey. (Calisir *et al.*, 2005). Also Okra seed can be dried, and the dried seeds are a nutritious material that can be used to prepare vegetable curds, (Moekchantuk and Kumar 2004). The seeds can be a source of antioxidant, which is essential in maintaining health. Okra seeds contain about 20 to 40% oil. Okra seed flour has huge potential of being used to enrich foods in order to provide adequate nutritional daily needs (Adelakun and Oyelade, 2011).

Okra seed is made up of oligomeric catechins (2.5 mg/g of seeds) and flavonol derivatives (3.4 mg/g of seeds), while the mesocarp is mainly composed of hydroxycinnamic and quercetin derivatives (0.2 and 0.3 mg/g of skins). The pods and seeds are rich in phenolic compounds with important biological properties like quartering derivatives, catechin oligomers and hydroxycinnamic derivatives (Arapitsas, 2008). These properties, along with the high content of carbohydrates, proteins, glycol-protein, and other dietary elements enhance the importance of this foodstuff in human diet (Arapitsas, 2008; Manach *et al*., 2005).

Okra pods can be consumed in many ways as fresh (raw), dried, cooked, frozen, fried and pickled. Okra also has industrial applications and is used in confectionary (Adetuyi *et al.,* 2011).

1.2 Problem Statement and Justification

Some okra genotypes have been identified in Ghana and projects are ongoing to extract pectin from the okra pods, leaving the seeds wasted (Kpodo *et al.*, 2017). There is the need to evaluate and explore alternative uses for dried okra seeds based on the quality attributes. This would ultimately contribute to food and nutrition security.

1.4 Objectives

1.4.1 General Objective

The objective of this research was to evaluate the physicochemical properties of dried okra seed flour from two genotypes (Agbagoma and Balabi).

1.4.2 Specific Objectives

1. To determine the proximate composition of the dried okra seed flour.
2. To determine the functional and pasting properties of the dried okra seed flour.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1 Okra Production

Okra (*Abelmoschus esculentus L.)* is a plant of the Malvacae family cultivated for its immature pods. The crop is grown in many tropical, sub-tropical and warm temperate regions around the world. The top ten major okra producing countries in the world are India, Nigeria, Iraq, Cote d'Ivoire, Pakistan, Egypt, Benin, Cameroon, Ghana and Saudi Arabia (Oyelade *et al.,* 2003;

FAOSTAT, 2012). This vegetable is an important part of the diet of Africans and Indians as well as of other countries with the worldwide production of okra estimated to be close to 7 million Mt whereas that of Ghana alone is about 60,000 Mt (FAOSTAT, 2012). The vegetable is known by several names in West and Central Africa and some of these names are Gombo (French), Miyangro (Hausa), La (Djerma), Layre (Fulani), Gan (Bambara), Kandia (Manding), Nkruma (Akan) and Fetri (Ewe) (Negi and Mitra, 1999). In Ghana, Brong Ahafo, Ashanti, Northern, Volta, Greater Accra and Central regions are the largest producers of okra (NARP, 1993).

Okra has a huge potential as one of the foreign exchange earning crops and accounts for about 60% of the export of fresh vegetables excluding potato, onion and garlic in India (Kalloo, 1998). In Nigeria, this vegetable is specially valued in different parts of the country for its delicious fruits and it is consumed alone or in combination with other foods.

2.2 Insect Pests and Diseases in Okra Production

Okra production is constrained with severe pest and disease attacks. Insect pests reported to infest okra production on Ghana include flea beetles *(Podagrica sp.),* cotton stainers *(Dysdercus superstitus)*, white fly *(Bemisia tabaci)* and green silk bug *(Nezera viridula)* among others (Senjobi *et al.,* 2013).

There are some major diseases which are affecting the production of okra, i.e. powdery mildew, okra mosaic virus, cercospora leaf spot, fusarium wilt, verticillum wilt etc. Symptoms may include the curling of leaves, yellowing of leaves and reduction in yield. The okra mosaic virus also induces mosaic, vein chlorosis, banding and stunting growth (Krishnareddy *et al.,* 2003).

Insect pests like crickets can be a problem during germination/seedling stage of the crop while the whitefly and other phloem feeders are common during vegetative stage (Fajinmi and Fajinmi, 2010). Chemicals and insecticides are used to control pests and insects in many countries (Dabire-Binso *et al.,* 2009).

2.3 Nutritional and Health Benefits of Okra

Okra is an oligo purpose crop due to its various uses of the fresh leaves, buds, flowers, pods, stems and seeds (Mihretu *et al.,* 2014). Okra is a very good source of calcium and potassium. Polysaccharides in okra lowers cholesterol level in blood and may prevent cancer by its ability to bind bile acids (Kahlon *et al.*, 2007).

Okra is rich in foliate which are helpful for the fetus while pregnant. Foliate is a vital nutrient that increases the growth and development of the fetus' brain. The high quantity of folic acid within okra performs a huge role within the neural tube formation of the fetus through the fourth to the 12th week of pregnancy (Zaharuddin *et al.,* 2014).

Additionally, okra contains pectin that can help in reducing high blood cholesterol simply by modifying the creation of bile within the intestines ((Ngoc *et al.,* 2008). It is high in fiber, which helps to stabilize blood sugar by regulating the rate at which sugar is absorbed from the intestinal tract. Okra is also high in iodine which is considered useful for the control of goiter. Okra is also used in folk medicine as antiulcerogenic, gastroprotective, diuretic agents in some countries (Gurbuz, 2003). Regular consumption of okra can improve heart health and the body's cholesterol level.

The polysaccharides present in immature okra pods possessed considerable anti-adhesive properties (i.e. they help remove the adhesive between bacteria and stomach tissue, preventing the cultures from spreading). The okra pods contains substantial amount of Vitamin A and also beta carotene that are both important nourishment for sustaining an excellent eye-sight along with healthy skin (Lengsfeld *et al.*, 2004).

According to (Liu *et al.,* 2005), tests conducted in China suggest that an alcohol extract of okra leaves can eliminate oxygen free radicals, alleviate renal tubular-interstitial diseases, reduce proteinuria, and improve renal function. Also, Okra seed has blood glucose normalization and lipid profiles lowering action in diabetic condition (Sabitha *et al.,* 2011). Okra leaves are used for the preparation of medicine to reduce inflammation.

Okra can also be used to treat digestive issues. The polysaccharides that are present in immature okra pods contain considerable antiadhesive properties (i.e. they help remove the adhesive between bacteria and stomach tissue, preventing the cultures from spreading). Okra's polysaccharides were particularly effective at inhibiting the adhesion of Helicobacter pylori, a bacterium that dwells in the stomach and can cause gastritis and gastric ulcers if left unchecked. Therefore, eating more okra can keep our stomach clean and create an environment that prevents destructive cultures from flourishing (Messing *et al.,* 2014). Okra is used to support colon health.

It smoothly sails down our colon, absorbing all toxins and excess water in its path. Okra is filled with dietary fiber that is required for colon health and digestive health all together. The Okra fiber helps to cleanse the intestinal system, letting the colon to operate at higher amount of effectiveness. In addition, the vitamin A plays a role in wholesome mucous membranes, which assists the digestive system to function adequately (Georgiadisa *et al.*, 2011).

2.4 Other Uses of Okra

Non-food applications include use of the root and stem of okra for cleaning the cane juice from which Jaggary (brown sugar) is prepared (Chauhan, 1972). Mature fruits and stems containing crude fiber are used in the paper industry (Martin, 1982). It can also be used for biogas and fuel (Dahiya and Vasudevan, 1987). Okra is used as brightening agents in electro deposition of metals, as a deflocculant in paper and fabric production, and as a protectant to reduce friction in pipe-flow (Ndjouenkeu *et al.*, 1996).

2.5 Okra Seeds

The okra fruit contains numerous oval, smooth, striated and dark green to dark brown seeds. Okra seeds are tiny in size and the fibrous seed coat contains high amount of crude fiber. They are power house of nutrients. Okra seeds can be dried, and the dried seeds are very nutritious and can be used to prepare vegetable curds, or roasted and ground to be used as coffee additive or substitute (Agbo *et al.*, 2008).

Nutritionally, the richest part of okra plants is the dried seed (Adelakun *et al.*, 2009) as it is very rich in protein, oil and antioxidant. Okra seeds are rich in unsaturated fatty acids such as linoleic acid (Savallo *et al.*, 1980). Fiber of okra seeds is an important nutrient for intestine microorganisms. Seed mucilage of okra may be responsible for getting rid toxic substances and bad cholesterol which loads the liver.

2.6 Okra Seed Flour

Okra seed flour has been reported to be rich in minerals and vitamins and to addition to high carbohydrate foods enrich such foods with vital nutrients (Oyelade *et al.*, 2003). Okra seed flour has been used to supplement corn flour for a very long time in countries like Egypt to make better quality dough (Kumar *et al.*, 2010). The chemical composition of okra seed flour revealed a predominance of moisture (6.96%), total carbohydrates (30.81%), protein (22.14%), oil (14.01%) and crude fiber (27.30%) (Moyin-Jesu, 2007).

2.6.1 Functional Properties of Flours

Functional property as applied to food ingredients can be defined as any property, aside its nutritional attributes, and that influences the ingredient's usefulness in food. Functional properties play a key role in the way foods or food ingredients behaves during their preparation, processing, or storage (Fennema, 1985).

2.6.2 Bulk density

Bulk density can be defined as the weight of many particles of a material or product divided by the total volume they occupy; it is a reflection of the load a sample would carry if allowed to sit directly on top of one another. (Ikpeme *et al.* 2010) looked at the difference between loose bulk density and packed bulk density, the minute differences according to them shows that the incorporation of taro did not cause a significant decrease in bulk densities of flour blends. They also pointed out that smaller bulk densities are more desirable as they imply the sample would pack better during storage or distribution. High bulk density is a good physical attribute when determining the mixing quality of a particular product.

(Edema *et al*. 2005) discovered that their values for bulk density were generally lower (between 0.38 g/ml for commercially sold soybean flour and 0.55 g/ml for Maize soya blend) than those values obtained by (Amarjeet *et al*.,1993) for durum wheat blends (0.80 to 0.82). (Butt and Batool, 2010) also reported that the defatting process resulted in very porous texture of the defatted product that can be attributed to low bulk density. This would be an advantage in the formulation of complementary foods (Akpata and Akubor, 1999).

2.6.3 Water and oil absorption capacity

Soaking up of water is an important functional quality in foods such as sausages, custards and doughs. Oil absorption capacity is important in structure interaction in food especially in flavour retention, improvement of palatability and the extension of shelf life particularly in bakery or meat products (Adebowal and Lawal, 2004). Proteins are solely responsible for the bulk of the water uptake and to a minor extent the starch and cellulose at room temperature (Afoakwa, 1996).

According to (Ikpeme *et al.* 2010) their result shows that indeed addition of taro flour affected the water absorption. In their case the taro starch actually slowed the absorption of water as the 90:10 wheat: taro blend had the highest absorption of water.

Importance of oil absorption is that oil acts as a flavour retainer and helps to increase the mouth feel of food. Protein is the main chemical component that affects the oil absorption capacity because it is composed of both hydrophilic and hydrophobic parts. Non polar amino acid side chain can form hydrophobic interactions with hydrocarbon chains of lipid (Jitngarmkusol *et al.*, 2008).

2.6.4 Swelling, Swelling Volume Power and Solubility

Swelling power can be defined as the wet mass of a sedimented gel divided by its dry mass (Leach *et al.*, 1959). The swelling power and solubility of flour and starch are temperature dependent (Loos *et al.*, 1981). Swelling volume is the ratio of sedimented gel to the dry mass of starch. Solubility is the percentage amount of starch leached into the supernatant in determining of the swelling volume (Singh *et al.*, 2005).

2.6.5 Moisture content

Moisture content of flour is crucial for some reasons; the higher the moisture content, the lower the amount of dry solids in the flour and also flours with higher moisture content higher than 14% are prone to microbial spoilage. A study found at that flour having low moisture content had the highest resistance against fungal growth and pest infestation when stored (Nasir *et al.*, 2003).

2.6.5 Pasting Characteristics

As heating of flours or starch continues more granules become bigger or swollen and the viscosity of the product increases. The paste viscosity reaches the maximum when the highest percentage of swollen intact granules is present; this is termed as peak viscosity. At this stage the starch is known to be completely pasted.

Pasting is the process after gelatinization in the dissolving of starch. It includes granular swelling, exudation of the molecular components away from the granule and finally total disruption of the granules (Singh *et al.*, 1993).

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 MATERIALS

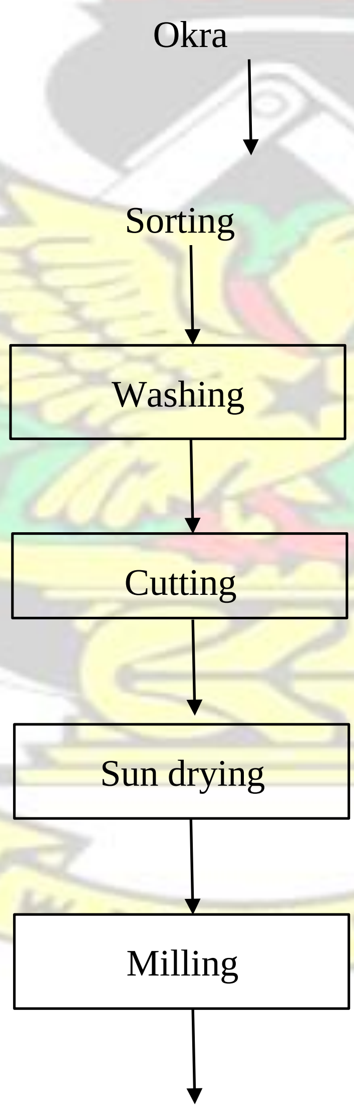
3.1.1 Sources of Raw Materials and Reagents

Two varieties of okra (Agbagoma and Balabi) were cultivated at Akrofu (Volta Region) from September to November 2016 and all agricultural practices including thinning; weed control and watering were carried out under controlled environmental conditions. All chemicals used were analytical grade reagents.

3.1.2 Preparation of Okra Seed Flour

Two varieties of okra (Agbagoma and Balabi) were sorted to get rid of infected ones and other debris. They were washed with distilled water, cut opened using a knife to remove seeds. Seeds were then sun dried for 6 h. The sun dried seeds were ground into powder of particle size of 450µm, packaged in zip-lock bags and stored at -20°C in a freezer (Protech PRCF-500, China) for further analysis.

A flowchart on the preparation of okra seed flour is shown in Figure 1.



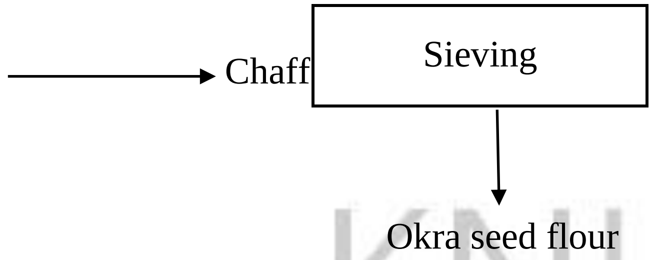


Figure 1: Flowchart on preparation of okra seed flour.

3.2 METHODS

3.2.1 Proximate Composition

3.2.1.1 Determination of Moisture Content

Moisture content was determined by AOAC (2005) by drying the sample in an oven until a constant weight was obtained. Two grams (2 g) of dried okra seed flour was accurately weighed into previously dried and weighed moisture cans. The cans with the samples were then placed in thermostatically controlled oven (Gallenkamp, England) at 105 °C overnight till a constant weight of solid material was obtained. The cans were then removed and cooled in a desiccator and then weighed. The moisture content of the samples were calculated (Appendix 1a) by difference in weights and expressed as a percentage.

3.2.1.2 Determination of Crude Protein Content

Crude protein was determined by AOAC (2005). Two grams (2 g) of dried okra seed flour was placed in a Kjeldahl digestion flask also containing a Selenium based catalyst and 25 ml of concentrated H_2SO_4 added in a fume chamber. The flask was swirled gently to effect proper mixing and heated in a digestion chamber until digestion was complete after 5 h. The digest was cooled and transferred into a 100 ml volumetric flask and made up to the mark with distilled water. Ten milliliters (10 ml) of the diluted digest was put in the steam distillation unit, which was previously flushed with distilled water. 18 ml of 40% NaOH was then added to the solution in the steam distiller. Twenty milliliters (25 ml) of 2% boric acid was pipetted into a conical flask and two drops of bromocresol green- methyl red mixed indicator added. This mixture was placed under the condenser outlet of the distillation system, with the tip of the condenser completely immersed in it. The distillation was carried out until all the boric acid solution turned from pink to yellowish green. The solution in the conical flask was titrated against 0.1 M HCl solutions and the end point recorded. The distillation and titration processes were done with triplicate samples of the diluted digest. A blank was also taken through the same procedure using distilled water in place of the sample. The crude protein content was then calculated using a factor of 6.25 (Appendix 1b).

3.2.1.3 Determination of Crude Fat Content

Crude fat was determined based on the soxhlet extraction method of AOAC (2005). Two grams (2 g) of the dried sample was weighed into each of two paper thimbles. The thimbles were sealed and placed in soxhlet extractors. Fifty milliliters (50 ml) of petroleum ether was poured into each of the previously dried and weighed round-bottomed flasks attached to the extractors. Extraction was carried out for 4 h. After this the petroleum ether was recovered from the soxhlet with only small amounts left in the flasks. The flasks were then removed and placed in an oven (with the door partially closed) for the ether to completely evaporate. The flasks were cooled in a desiccator, weighed and the fat content calculated (Appendix 1c).

3.2.1.4 Determination of Ash Content

Ash was determined by AOAC (2005). Two grams (2 g) of sample was weighed into previously dried and weighed porcelain crucibles and heated for about 20 min over a boiling water bath till they were visibly dry. The crucibles with their contents were then transferred into a muffle furnace (Gallenkamp, England) at 600 °C and incinerated for 2 h. The crucibles were removed, placed in a desiccator to cool then weighed and the ash content calculated (Appendix 1d) and expressed as a percentage.

3.2.1.5 Determination of Total Carbohydrate Content

The percentage carbohydrate of okra seed flour was determined by subtracting the percentage of moisture, ash, protein and fats obtained from 100 (Appendix 1e).

3.2.2 Physicochemical Properties

3.2.2.1 Determination of pH

The pH was determined by the method described by AOAC (2005). Two grams (2 g) of okra seed flour was poured into three beakers containing 20 ml of distilled water and allowed to stand for a while and an electric digital pH meter (BECKMAN Φ340 pH/Temp. Meter) was used to determine the pH of the samples. The pH meter was dipped into the sample and the reading was taken after about 4 min when it was stable.

3.2.2.2 Determination of Color

The color of the okra seed flour was measured using the CR-400 Chroma Meter which is a handheld, portable measurement instrument designed to evaluate the color of objects.

The colour meter coordinates system L* a* and b* values were recorded and the Light index was calculated as (100/0). The white tile used for calibrating the Hunter L*, a*, b* colour scale had L* = + 97.51, a* = + 0.29 and b* = 1.90 as standards.

3.2.3 Functional Properties

3.2.3.1 Determination of Bulk Density

Bulk density was determined with modifications by the gravimetric method described by (Asoegwu *et al.*, 2006). Fifty grams (50 g) of sample was weighed into 100 ml measuring cylinder.

The bottom of the cylinder was tapped repeatedly on a firm pad on a laboratory bench until a constant volume was observed. The packed volume was recorded. The bulk density (BD) was calculated by using a ratio of sample weight to constant volume obtained.

3.2.3.2 Determination of Water and Oil Absorption Capacity

Water and oil absorption capacity was determined by the method of Beuchat (1977). One gram (1 g) of sample was mixed with 10 mL distilled water for 30 seconds. The samples were then allowed to stand at room temperature (25 ± 2 °C) for 30 minutes after which they were centrifuged at 3000 rpm for 30 minutes. The volume of the supernatant was noted in a 10 mL graduated cylinder. Water absorption ($mg.mL^{-1}$) was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant. The same procedure was carried out to determine the oil absorption capacity.

3.2.3.3 Determination of Water Binding Capacity

Water binding capacity was determined by the method of (Yamazaki 1953) as modified by (Medcalf and Gilles 1965). An aqueous suspension was made by dissolving one gram (1 g) of sample in 10ml of water. The suspension was agitated for 1 h on Griffin flask shaker (HS501, digital, Janke 7 Kinkel GMBH & CO.KG) after which it was centrifuged for 10 min at 2200 rpm. The free water was decanted from the wet starch and drained for 10 min. The water binding capacity sample was then calculated

3.2.3.4 Determination of Swelling Capacity, Swelling Volume and Solubility

Swelling capacity, swelling volume and solubility determinations were carried out based on a modification of the method of (Leah *et al* 1959). One gram (1 g) of sample was transferred into a weighed graduated 15 ml centrifuge tube. Ten milliliters (10 ml) of distilled water was added.

The suspension was stirred sufficiently and uniformly with a stirrer avoiding excessive speed. The sample was heated at 85 ^{o}C in a thermostatically regulated temperature bath for 30 min with constant stirring. The tubes were removed wiped dry on the outside and cooled to room temperature. It was then centrifuged for 15 min at 2200 rpm in a centrifuge. The solubility was determined by evaporating the supernatant in a hot air oven at 105 ^{o}C (Gallenkamp, England) and weighed the residue. The swelling volume was obtained by directly reading the volume of the swollen sediment in the tube. The sediment paste was weighed.

3.2.4 Pasting Properties

3.2.4.1 Determination of Pasting Properties

Rapid Viscos Analyzer Model 4500 (RVA) was used in the analysis of the pasting properties of the fresh okra seed flour samples. The calculated moisture content was inputted into the RVA which gives the mass of flour and water to be measured. The masses displayed by the instrument were measured into a dried empty canister. The starch solution was mixed thoroughly and then placed into the RVA. The starch slurry was heated from 50 to 95℃.

3.3 Statistical Analysis

Results obtained from analyses were subjected to Analysis of Variance (ANOVA) in SPSS (Version 21). Two samples independent Test was used for mean comparison to identify significant differences between the samples. Statistical significance was accepted at 5% probability level ($p<0.05$).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Proximate Composition of Okra Seed Flour

The results of the proximate nutrients composition of okra seed flour samples are shown in Table 1.

Table 1: Proximate composition of okra seed flour samples

	Parameters				
Sample	**Moisture (%)**	**Protein (%)**	**Fat (%)**	**Ash (%)**	**Carbohydrate (%)**
Agbagoma	9.00 ± 0.00^{a}	16.80 ± 0.70^{b}	48.00 ± 3.50^{a}	7.80 ± 0.00^{a}	18.40 ± 0.01^{a}
Balabi	8.90 ± 1.80^{a}	17.40 ± 0.50^{a}	47.80 ± 0.20^{a}	7.70 ± 0.10^{a}	18.20 ± 0.06^{a}

**Values are means ± standard deviations of triplicate determinations. Values in the same column with different superscript letters are significantly different (p<0.05)*

Moisture content of the okra seed flour samples ranged from 8.90 % to 9.00 % (Table 1). Balabi had the lower average moisture content than Agbagoma although the difference is not significant ($p>0.05$). The moisture content of flour studied (8.9%- 9.0%) falls within the acceptable range of 0-13% as reported by (James 1995). This moisture content range has been reported to be unfavorable for spoilage organisms to thrive (James 1995), therefore extending the shelf life of flours and other food products.

Protein content was in the range of 16.80-17.40% for the okra seed flour samples (Table 1). The protein content was however higher in Balabi (17.40%) than Agbagoma (16.80%) ($p<0.05$). These values were generally low when compared to other variety (iwo agborin) with protein content of 41.11% (Adelakun *et al.*, 2009a). Also, these values are lower than those reported by other researchers: (Oyelade *et al.*, 2003) 45%; (Calisir *et al.*, 2005) 19.10%. This clearly shows that variety has influence on the protein content.

Agbagoma had the slightly higher fat content (48.00%) as compared to Balabi which had the lowest (47.80%) though the difference was insignificant (p>0.05; Table 1). However, the fat values were generally higher when compared to other variety (iwo agborin) with fat content of 31.04 % (Adelakun *et al.*, 2009a). Higher fat values of the okra seed flour samples may be attributed to the high fat content of okra seed.

The ash content ranged from 7.70-7.80 % with higher value in Agbagoma and lower in Balabi (p<0.05). The ash content represents the total mineral content of the food. Although minerals represent a small proportion of dry matter, often less than 7% of the total, they play an important from a physicochemical, technological and nutritional point of view. Thus it can be assumed that the Okra seed flour samples investigated are richer in minerals than cowpea, pigeon pea and jack bean flours, which have ash contents of 4.73, 4.58 and 6.51% respectively (Olalekan and Bosede, 2010).

There was no significant difference (p>0.05) between carbohydrate content of the two okra seed flour samples ranging from 18.20 % in Balabi to 18.40 % in Agbagoma. However, the carbohydrates values were generally lower than the value reported by (Pacheco-Delahaye et. al., 2008) for unripe plantain flour also studies by (Akintayo *et al.* 2002) and (Oyeleke *et al.* 2013) reported very low carbohydrate contents (6.53 % and 6.86 % respectively) for oven-dried and sun-dried ackee arils respectively.

4.2. Physicochemical Properties of Okra Seed Flour Samples

The results of the pH and colour properties of okra seed flour samples are shown in Table 2.

Table 2: pH and Colour properties of okra seed flour samples

		Parameters		
Sample	**pH**	**Color**		
		L	**a**	**b**
Agbagoma	6.41± 0.02^{a}	60.29± 0.77^{b}	0.26± 0.06^{a}	12.83± 0.17^{b}
Balabi	6.48± 0.02^{a}	65.37± 0.07^{a}	0.09± 0.02^{b}	14.06± 0.02^{a}

**Values are means ± standard deviations of triplicate determinations. Values in the same column with different superscript letters are significantly different (p<0.05)*

The pH values of the okra seed flour samples ranged from 6.41 to 6.48 with no significant different between all okra seed flour samples ($p > 0.05$; Table 2). According to (Harold Egan *et al.*, 1981) wheat flour has a pH between 6.0 and 6.8 which is in a good agreement with the present results for okra seed flours.

Color value was between the ranges of 60.29 to 65.37 in all okra seed flour samples. The color (**L a b**) values were significantly higher in Balabi as compared to Agbagoma okra seed flour samples ($p < 0.05$; Table 2). The colour brightness coordinate L* measures the degree of whiteness, ranging between black (0) and white (100). The chromaticity coordinate a* measures red when positive and green when negative, and b* measures yellow when positive and blue when negative. Consumer acceptability is affected by the presence of colour in starch, which is an indication of low quality (Galvez *et al.*, 1993). The colour brightness (L*) of the Balabi extract was significantly higher ($p<0.05$) than that of the flour from Agbagoma. The L colour brightness of both flours can be improved by preventing enzymatic browning by washing the okra seeds with ascorbic acid solution or 1% sodium metabiosulphite solution before sun drying.

4.3 Functional Properties of dried Okra Seed Flour Samples

The results of the functional properties of okra seed flour samples are presented in Table 3.

Table 3: Functional properties of okra seed flour samples

	Dried okra seed flour	
Parameters	**Agbagoma**	**Balabi**
BD (g/ml)	0.80± 0.01[a]	0.83± 0.02[a]
WAC (%)	511.64± 19.52[a]	504.99± 30.10[b]
SP (%)	16.37± 0.21[a]	14.68± 0.77[b]
SI (%)	14.10± 1.27[a]	10.97± 1.41[b]
OAC (%)	88.37± 8.62[a]	159.24± 20.76[b]

**Values are means ± standard deviations of triplicate determinations. Values in the same column with different superscript letters are significantly different (p<0.005). BD: Bulk Density, WAC: Water Absorption Capacity, SP: Swelling Power, SI: Solubility Index, OAC: Oil Absorption Capacity.*

From Table 3, there was no significant difference (p>0.05) between the bulk densities of all okra seed flour samples. Bulk density ranged from 0.80 g/ml to 0.83 g/ml. Balabi had the highest bulk density of (0.83) g/ml. The results did not show significant difference (p > 0.05) between okra seed flour samples. However, bulk density values were slightly above those reported by (Adetuyi *et al.*, 2009) who evaluated maize soybean flour blends. Previous work done by (Adebowale *et al.*, 2005), values obtained ranged from 0.42 to 0.61 g/ml in full fat flours and 0.72 to 0.88 g/ml in defatted flours. High bulk density of the fresh okra seed flour indicates that they would serve as good thickeners in food products.

From the table WAC and OAC of Abgagoma was 511.64% and 88.37% respectively while that of Balabi shows 504.99 and 159.24%. There was a significant difference ($P<0.05$) between the two varieties. A lower WAC was recorded for local Nigerian wheat flour (140 - 150 %), sorghum flour (219 - 235 %), irradiated and non-irradiated cowpea flours (110 - 113 %), full fat and defatted mucuna flour (120 - 220 %) and different yam flours (194 - 207 %) by (Iwuoha, 2004; Abu *et al.*, 2005; Elkhalifa *et al*., 2005; Adejumo, 2013). Proteins and Carbohydrates have great influence on the WAC of food due to the presence of hydrophilic components like polar or charged side chains. Flours that have the ability to absorb water well and swell for improved consistency in food (high WAC) have beneficial applications in dough, processed meats and custards (Kinsella, 1979).

Proteins have influence on the OAC of food matrices. The absorption of oil by protein surfaces increases the hydrophobic interaction of proteins with flavor compounds as well as the binding of food to the inner walls of the mouth during chewing. Therefore, OAC of food determines the mouth-feel, flavour retention as well as shelf stability of baked or fried foods and especially meat products (Adebowale and Lawal, 2004).

The swelling power ranged from 14.68% to 16.37%. There was significant difference ($p<0.05$) between okra seed flour samples. The swelling capacity values were not in accordance with (Adetuyi *et al.*, 2009) who examined maize – soybean flour blends. The low swelling power value could be attributed to the low carbohydrate content of the okra seed flour because the ability to swell is a function of the carbohydrate content.

There was significant difference ($p<0.05$) between okra seed flour samples in terms of solubility index. However, the solubility of the Okra flours used were lower than those reported for the cassava and sweet potato cultivars (12.06 - 24.44 %) (Baah *et al*., 2005). Solubility and swelling power are influenced by the water binding capacity of the flour sample, which is a function of proteins and carbohydrates present in the flour (Baah *et al*., 2005).

4.4. Pasting Properties of Okra Seed Flour Samples

The results of the pasting properties of okra seed flour samples are shown in Table 4.

Table 4: Pasting properties of okra seed flour samples

	Okra Seed Flour	
Parameters	**Agbagoma**	**Balabi**
Peak viscosity (cP)	759.00± 28.28^{a}	85.50± 14.85^{b}
Trough (cP)	337.00± 1.41^{a}	74.00± 8.49^{b}
Breakdown (cP)	422.00± 26.87^{a}	11.50± 6.36^{b}
Final viscosity (cP)	437.50± 18.19^{a}	106.50± 3.54^{b}
Setback (cP)	100.50± 16.77^{a}	32.50± 4.95^{b}
Peak time (min)	1.97± 0.42^{b}	6.07± 0.19^{a}
Pasting temperature (°C)	50.20± 0.00^{a}	0.23± 0.04^{a}

**Values are means ± standard deviations of triplicate determinations. Values in the same column with different superscript letters are significantly different ($p<0.05$).*

The pasting property parameters of Agbagoma seed flour were higher than that of the Balabi seed flour (Table 4). Peak viscosity is an indication of extent of granule swelling and the strength of the associative forces between the molecules of the flour.

The high peak viscosity of the Agbagoma seed flour shows that water molecules penetrate easily causing enormous granular swelling which in turn weakens the associative forces of the flour, hence makes them susceptible to breakdown as compared to the Balabi seed flour with lower peak viscosity (Etudaiye *et al*., 2009).

Trough viscosity is the ability of starch to withstand long duration of hot temperature during processing or heating. Agbagoma seed flour with high hot paste stability would be preferably used in food processing than Balabi seed flour.

According to (Olufunmilola *et al*. 2009), flours with low break down are more stable under hot conditions and have strong cross-linking within the granules. It therefore implies that there is stronger cross-linking within the granules of the Balabi seed flour.

Agbagoma seed flour recording higher final viscosity suggests its ability to form gel/paste during cooling (Shimelis *et al*., 2006) and it would be more suitable in the processing of food products such as sauces, soups and dressings.

Setback value is a measure of gel stability and potential of retrogradation. The low setback value of the Balabi seed flour suggests its high resistance to retrogradation than the Agbagoma seed flour with a higher setback value. Balabi seed flour can be incorporated into wheat flour in the production of pastries such as bread, pie and others.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Investigation carried out on two genotype okra seed flour samples (Agbagoma and Balabi) revealed that carbohydrate, protein, fat and ash are significantly high. The high protein content shows they could be a valuable protein supplement for cereals based food products. Also when included in diet could contribute immensely to the amount of nutrients needed to meet the human nutritional needs.

The pH values of the okra seed flour were within the recommended range which makes it ideal for individual with ulcers related problems. Results of the functional properties of okra seed flour showed that, the two okra seed flour samples (Agbagoma and Balabi) have good and appreciable functional properties that could be exploited in food formulations such as cereals, wheat flour etc.

Also, all pasting properties except peak time and pasting temperature of Agbagoma seed flour were higher than that of Balabi seed flour this is due to the differences of the strength of the associative forces between the molecules of the flour. The study however showed that okra seed flour from Balabi could be used as composite for baby foods because of its low viscosity whereas flour from Agbagoma could be used as composite for high viscous food.

5.2 Recommendation

It is recommended that flour obtained from okra seeds should be considered as composite for baking and flour fortification for their nutritional and economic benefits. However, Shelf life studies should be conducted on the fresh okra seed flours to know how long they can be stored for and still be safe for consumption with/or without significant deterioration in nutritional and functional properties.

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APPENDICES

APPENDIX 1: PROXIMATE COMPOSITION FORMULAE

Appendix 1a: Percentage Moisture

$$\% \text{ Moisture} = \frac{Loss\ of\ weight}{Sample\ weight} \times 100$$

Appendix 1b: Percentage Crude Protein

$$\% \text{ Crude Protein} = \frac{(V2 - V1) \times N \times 1.4 \times 6.25}{W}$$

Appendix 1c: Percentage Fat

$$\% \text{ Crude Fat} = \frac{Weight\ of\ fat}{Weight\ of\ wet\ sample} \times 100$$

Appendix 1d: Percentage Ash

$$\% \text{ Ash} = \frac{Weight\ of\ ash}{Weight\ of\ sample} \times 100$$

Appendix 1e: Percentage Total Carbohydrate

Total Carbohydrate%= 100- (Moisture + Protein + Fat + Carbohydrate)

APPENDIX 2: FORMULAE FOR FUNCTIONAL PROPERTIES

Appendix 2a: Bulk density

$$\text{Bulk density} = \frac{Weight\ of\ sample}{constant\ volume}$$

Appendix 2b: Water and oil absorption capacity **WAC/OAC** $= \frac{\boldsymbol{Bound\ water/oil}}{\boldsymbol{weight\ of\ sample}} \times \mathbf{100}$

Appendix 2c: Swelling power, swelling volume and solubility

$$SP\ (\%) = \frac{Weight\ of\ sediment}{Weight\ of\ sample\ x\ (100 - Solubility)}\ x\ 100$$

$$Solubility(\%) = \frac{Weight\ of\ soluble\ fraction}{Weight\ of\ sample}\ x\ 100$$

APPENDIX 3: PICTURES OF PROJECT WORK

Plate 1: Okra seeds

Plate 2: Sun drying okra seeds

Plate 3: Flour obtained from okra seed

APPENDIX 4: ANOVA TABLE

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
BD	Between Groups	.002	1	.002	12.578	.024
	Within Groups	.001	4	.000		
	Total	.002	5			
WAC	Between Groups	66.267	1	66.267	.103	.764
	Within Groups	2574.293	4	643.573		
	Total	2640.560	5			
SP	Between Groups	4.301	1	4.301	13.518	.021
	Within Groups	1.273	4	.318		

	Total	5.574	5			
SI	Between Groups	14.695	1	14.695	8.158	.046
	Within Groups	7.206	4	1.801		
	Total	21.901	5			
OAC	Between Groups	7533.127	1	7533.127	29.823	.005
	Within Groups	1010.392	4	252.598		
	Total	8543.518	5			
pH	Between Groups	.007	1	.007	22.050	.009
	Within Groups	.001	4	.000		
	Total	.009	5			
L	Between Groups	38.608	1	38.608	127.721	.000
	Within Groups	1.209	4	.302		
	Total	39.817	5			
a	Between Groups	.045	1	.045	23.513	.008
	Within Groups	.008	4	.002		
	Total	.053	5			
b	Between Groups	2.257	1	2.257	157.104	.000
	Within Groups	.057	4	.014		
	Total	2.315	5			