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Proximate Composition and Functional Properties of Some New Groundnut Accessions

BY

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DECLARATION

I hereby declare that this thesis is the result of my own novel study with references to specific authors duly acknowledged and that it is neither in part nor whole been presented for another certificate in this university or elsewhere.

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DEDICATION

This work is wholeheartedly dedicated to my mother, Hawa Boahemaa.

ACKNOWLEDGEMENT

All praise to God Almighty, for His mercy and Blessings through my entire life and the life of my family and friends so far.

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ABSTRACT

In this study new accessions of groundnut (*Arachis hypogea*) were oven dried and processed into full fat powdered forms and analysed for proximate and functional properties. The crude protein was between 20.71 to 25.34%, crude fat 31 to 46%, ash 1.2 to 2.32%, crude fiber 1.4 to 3.9%, carbohydrate 21 and 37% and moisture 4.9 to 6.79 %. Energy values of accessions fell between 507.46 kCal/100 g and 592.97 kCal/100 g suggesting the accessions are very good energy store thst have the potential to be utilized in the development of energy-dense therapeutic foods with the ability to manage protein-energy malnutrition. In terms of functional properties, water absorption capacity, swelling power, solubility index and bulk density values ranged between (20-30) %, (2.98-4.18)g/g, (26.5-57) % and (0.625-0.877) g/cm^3 respectively with no significant difference ($p \leq 0.05$) existing between them. Foaming capacity and Stability ranged from (4.0 -16.2) %, (94 -100) % respectively. The high swelling power and solubility index of the accessions indicate how readily the flour constituent would re-orient under elevated temperature conditions in flour- based food systems especially ready- to- eat instant cereals which require some form of dissolution before eating. High foamability exhibited by the accessions indicates how suitable they would be in food formulations where foaming is highly desired such as ice cream products, cakes and sponge cakes. The results show that the proximate and functional properties of these groundnut accessions may bring about improvement in some food products when they are added to the food.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

There have been several improvements relating to different food items in the wake of tackling food insecurity. This has led to an increase in research to unveil accessions of groundnut with desirable qualities. In Ghana, groundnut (*Arachis hypogaea*) plays a significant role in the diet of the population first as a source of primary protein and secondary as a source of reliable cooking oil of high quality (Awuah, 2000).

Considering the rapid growth of the world's population today in relation to the wide range of products being developed, agronomic research must not only focus on the improvement in crop productivity but also on the nutritional, physicochemical as well as functional properties of the crop in question. In the case of groundnut (*Arachis hypogaea*) this cannot be overemphasized. According to Tshilenge-Lukanda *et al.*, (2012) assessing the genetic diversity of a crop species is a necessary step to its improvement and assists in generating diversified breeding populations.

In Ghana, though groundnut is grown in all the agro-ecologies, the crop is cultivated mainly in the northern sector and is put to many uses including food and feed for man and animals, respectively, extraction of oil for cooking and for the making of detergents. It is also used in cropping systems as a nitrogen restorer (NARP, 1993). Ghana is known to annually increase production of groundnut as its commercial value continues to increase with the country targeting international markets. Groundnut area grew by 47% between 1999 and 2010, while actual production grew by 69% over the same period. According to Ministry of Food and Agriculture (MOFA), in 2010 Ghana had a 187000 metric ton production surplus, equal to 39% of total production. This and some other information available to MOFA corroborates the hypothesis that Ghana can be

considered as a net exporter of groundnuts as at the year 2010 (Angelucci and Bazzucchi, 2013). Some processed forms of groundnut are *groundnut butter*, *groundnut oil* and *groundnut cake*.

As new accessions are produced, it is important to ascertain their nutritional basis as knowledge of the nutritive value is important to encourage increased cultivation and consumption of the nut. Besides, studies which investigated the chemical and functional properties of *Arachis hypogaea* have shown that nuts are a primary source of fat and protein (Atasie *et al.*, 2009). The uniqueness of functional properties specific to a particular groundnut accession is also essential to its incorporation in the ever unending food products that come to the market.

1.2 Problem Statement

In most instances, assessing the genetic makeup of a crop is a necessary step to its improvement and helps to bring about breeds of different diversities. Such improvement and diversified breeds come with new accessions with different characteristics such as nutritional, physicochemical and functional properties. Some Improved groundnut (*Arachis hypogaea*) accessions developed by the CSIR-Ghana have not been investigated in these areas. There is limited information on the nutritional, physicochemical and functional properties of these improved accessions.

1.3 Justification

Ascertaining the nutritional, physicochemical and functional properties of the improved groundnut accessions will make data available on these new accessions. Knowledge of the nutritional value will allow for the increment in both cultivation and consumption of this nutritious nut. This will help compliment the nutrient of most traditional based carbohydrate diets especially of the less privileged who may not always afford the cost

of adequate protein foods from animal sources. These in the long run augment the nutritional needs of the ever increasing population. Through the data that will be made available, the improved groundnut accessions can be an important commodity for both food security and income generation as groundnut exportations are still negligible and vast majority of production is absorbed by internal demand (Angelucci and Bazzucchi, 2013).

1.4 Objectives

- To evaluate the proximate composition of the groundnut genotypes
- To evaluate the functionality and physicochemical properties of the accessions

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Groundnut

Groundnuts as a leguminous crop have gained prominence locally as well as on the international market. Despite its name and appearance, groundnut is not a nut, but a legume. This is because in botanical terms, "nut" specifically refers to indehiscent fruit which means groundnut is not technically a nut (Ensminger and Esminger, 1986). According to Asiedu (1989), groundnut is herbaceous plant of which there are two major types, bunch and runner. Apart from the bunch and the runner types many intermediate forms of hybrid exist (Irvine 1974).

In Ghana, groundnut is an essential crop that is consummed in our houses and also cultivated for cash crop purposes (Debrah and Waliyer, 1996) and used in Ghanaian diet as one of the main sources of vegetable protein.

Groundnuts thrive well in a wide range of farming systems. They are either planted as a mono crop or intercropped with maize and sorghum. To prevent the occurrence of pests and other soil borne diseases, groundnuts should be grown as a single crop. All soils, other than very heavy clay soils are suitable for cultivating groundnuts, but the best are deep, well drained, sandy loam soils (Nyambok and Oyia 2011). Groundnut can be grown in both rainy and post –rainy seasons. The optimum air temperature for the growth and development of groundnut is between 25^{o}C and 30^{o}c. Groundnut plant thrives well if rainfall is between 500 to 1500 mm, and it should be well distributed during the growing period.

Moreover, yield of groundnut in the rainy season is lower than the post –rainy season as results of cloudy weather and presence of pests and diseases (Janila and Mula 2015).

2.1.1 Origin and Distribution of Groundnut

Groundnut (Arachis hypogaea) is believed to be the native of Brazil to Peru, Argentina and Ghana from where it was introduced into Jamaica, Cuba and other West Indies Islands.The plant was introduced by Portuguese into Africa from where it was introduced into North America Dissemination of the crop to Africa, Asia, and Europe and the Pacific Islands occurred presumably in the sixteenth and seventeenth centuries with the discovery voyages of the Spanish, British and Dutch (Krapovickas 1969).Today, it is grown in areas between 40 degrees South and 40 degrees North of the equator,

where average rainfall is 500 to 1200mm and mean daily temperatures are higher than 20^{o}C.The groundnut crop is cultivated in 108 countries on about 22.2 million hectares of which 13.69 million ha are in Asia, 7.39 million ha in sub –saharan Africa and 0.7 million ha in Central and South America. In Ghana, typical of the production regions of groundnuts are concentrated in the North. The Northern Region boasts of some of the major processing companies of groundnuts in the country. The Northern Regions also constitute major consuming places groundnuts. Techiman is a major producing and also a transit market for groundnuts from where groundnuts are distributed to Kumasi and Sekondi – Takoradi and Cape Coast in the coastal regions. (Sarpong *et al* 2013)

2.1.2 Production Trend of Groundnut in Ghana

Almost half of the production of groundnut is concentrated in the Northern Region of Ghana which made of three separate administrative regions (Northern, Upper West and Upper East Regions) which altogether accounts 94% of groundnuts production in Ghana. The region is located in the Guinea Savanna agro- ecological Zone. The rainy season is mono-modal, starting in April/May and ending in September /October. The majority of groundnuts production is made by small –scale farmers with less than two hectares of arable land (MOFA 1997). The large Northen Region now dominates total production,

with an estimated five- fold expansion from 40,000 to over 200,000 mt over a decade, followed by the Upper West Region that almost double from 68,000 to 124,000, displacing production from the Upper East Region which estimated to have declined from 100,000 to 86,000 mt. The shift may be attributed to intermittent ethnic conflicts in the Upper East Region.

2.1.3 Health Benefits of Groundnut

Resveratrol is a flavonoid that has long been associated to be with red grapes and red wines but has been revealed to be present in groundnuts. The function of this phytonutrient has been found to increase movement of blood in the brain by as much as 30%, thus greatly decreasing the risk of stroke, according to Lu *et al*,(2006).

Apart from this, we also obtain niacin, folate, fiber, vitamin E, magnesium and phosphorus. Niacin contributes to brain health and blood flow. It has been reported that regular intake of foods that are rich in niacin like peanuts prevents Alzheimer's disease and age-related cognitive decline. (Morris *et al*., 2004). In addition to the above, groundnuts are a good source of coenzyme Q10 (Sanders *et al*., 2000). Typically, women who consume at least 28.35 grams (1 ounce) of nuts, peanuts or peanut butter each week have a 25% lower risk of contracting gallstones. Many abstain from eating groundnuts because they are scared of weight gain due to the high fat content of groundnut. A study published in the *Journal of Obesity* reveals that such fears are baseless.

In spite of all the above benefits, some people are allergic to groundnuts. They tend to react to groundnuts after eating them. Too much groundnuts intake may lead to gas, heartburn and unexpectedly developed food sensitivity to groundnuts. The reaction typically starts with a itchy sensation in the mouth followed by enlargement of the face, esophagus and mouth. Its effects are that, there can be difficulty in inhalation, an asthma attack/ anaphalactic shock and death. (Snyder, 2012)

2.1.4 Groundnut and Aflatoxin

One negative issue about groundnuts (peanut) is the problem of Aflatoxin. This toxin (*Aflatoxin*) is caused by the activities of fungi *Aspergillus flavus* and *Aspergillus parasiticus* (Boutrif, 1998). Aflatoxin may cause aflatoxicosis in man and some of the symptoms are abdominal pain, nausea, buildup of fluids in the lungs, convulsion, coma and death from accumulation of fluids in the brain (Greenfield, 2013). *Aspergillus* species are indigenous to soils in Ghana and soil is been reported as the primary source of inoculums for Aspergillus sp. (Horn 2003). Spores of the fungi are found everywhere because they are carried by air, but certain environmental factors should be conducive for the fungus to contaminate crops. Specifically, Aspergillus grows when temperature is between 18°C and 33°C and relative humidity is above 50 percent. Conditions suitable for fungal growth prevail during most of the year in Ghana (Florkowski and Kolavalli, 2013). Whenever conditions are favorable for its growth like high moisture content (at least 7%), high humidity and high temperature, the possibility of its occurrence is high. Minimizing growth conditions is the safest way to reduce the prevalence of the toxin (Bao *et al*., 2010; Li *et al*., 2009). Due to the susceptibility of most groundnut accessions to aspergillus, the Crop Research Institute of Ghana has developed the following accessions *Yenyawoso*, *GK* 7, *ICGV* 03331, *ICGV* 99053, *ICGV* 02171, *ICGV* 01279, *ICGV* 01273, *ICGV* 02184, *ICGV* 99017, *ICGV* 99033 in order to minimize the aflatoxins contaminations.

Aflatoxin levels can be reduced effectively on the field by applying *Trichoderma viride* at 1kg (mixed with 50kg farm yard manure) per hectre to the soil at the time of sowing and gypsum at peak flowering, lights but frequent irrigation during pod and seed development stages (Janila and Mula, 2015).

2.2 Accessions of Groundnut

Considerable variation has been recorded for morphological, physiological, and agronomic traits in groundnut crop. Kumazawa and Nishimura (1953) classified groundnut (peanut) varieties into four market types (Spanish, Valencia, Virginia, and Southeast Runner). Valencia and Spanish types belongs to the subspecies *fastigiata* (Krapovickas and Gregory, 1994). Their flowers set on their main axis. They are erect, small seeded, and less branched types. Spanish types have smaller pods that contain two round seeds and Valencia is intermediate in size and shape with long pods that contain three to four seeds. Virginia and Southeast Runner belongs to subspecies *hypogaea* (Krapovickas and Gregory, 1994).

They do not set seeds at their main axis and are highly branched. Southeast Runner and Virginia types have similar morphological characteristics and habitats, but Virginia has larger pods and elongated seeds while Southeast Runner has small pods (Krapovickas and Gregory, 1994).

However, it is very difficult to classify accessions solely according to their morphological traits which can be affected by environmental conditions.

2.3 Nutritional Composition of Groundnut

Knowledge about the nutritional value of indigenous food stuff and dishes is necessary in order to encourage increased production and consumption of food nutritive nut (Achu *et al*., 2005). Groundnut contains on the average 12-15% carbohydrates, 25-30% protein and 45-50 % oil (Kwarteng and Towler, 1994). When pressed for oil, it gives a product referred to as cake which contains largely carbohydrate and protein portions.The cake, a by-product of oil extraction, has been used as an excellent livestock feed because of its high protein content. The cake contains 45-60% protein, 22- 30% carbohydrate, 3.8-7.5% crude fiber and 4-6% minerals (Desai *et al.*, 1999).

The fatty acid composition of the endogenous fats ranges from 20 to 30 % and the average oil content may reach 50 % (Derise *et al*., 1974) which is a good indication of good oil recovery in economic terms. These play an important role in determining the shelf- life, nutritional value and flavor of groundnut (peanut) seeds. Available literature indicates that proximate composition of groundnut varies depending on the origin, variety and or processing method. It has been reported that proximate composition of groundnut is comparable to many known legumes.

Table 2.1 Proximate Composition of raw, sundried and roasted Groundnut

Parameter	**Raw Groundnut**	**Sun dried groundnut**	**Roasted groundnut**
Moisture	7.48	3.4	1.07
Ash	1.48	1.3	1.41
Crude Fiber	2.83	2.43	2.41
Crude Protein	24.7	21.80	18.40
Cabohydrate	17.41	27.19	36.11
Fat	46.10	43.8	40.60

Ayoola and Adeyeye (2010).

Plate 1: Groundnut in Pods

Plate 2: Groundnut Seeds Removed from Pods

2.4 Physicochemical and Functional Properties of Groundnut

A component of food stuff that cannot be overemphasized is starch as it affects greatly the integral properties of many food systems. The development of value-added products from starch depends on a thorough knowledge of its structure and functional properties (Sirivongpaisal, 2008). Groundnuts have high fat content which is important in diets as it promotes fat soluble vitamins absorption. Groundnuts thus have the potential for use in the food and vegetable oil industry due to their high oil content. Groundnuts have been reported to have low carbohydrate content which shows that groundnut is more of a body building food (Atasie *etal* 2009). Groundnuts provide an inexpensive source of high quality dietary protein. The vast food preparations incorporating groundnut to improve the protein has helped in no small way in reducing malnultrition in the developing countries. Groundnuts possess the essential requisite functional properties for successful utilization in various food products. These functional properties are intrinsic physicochemical characteristics which affect the behavior of properties necessary in protein ingredients such as gelation which is an important function of proteins in food

systems. It also includes foam capacity and stability. Other paramount functionalities are protein solubility, organoleptic properties and bulk density.(Aremu *et al* 2007).

Some works have been carried out on defatted or slightly defatted groundnut flour composites (with other substituents) and bambara groundnut flour which is of the same family with ordinary groundnut. Singh and Singh, (1991) worked in the area of Sorghum-Groundnut Composite Flour and concluded that the composite exhibited completely different functional properties from the individual flours but not much was said on the undefatted flour. Work by Sirivongpaisal (2008) only involved the use of bambara groundnut flour. Work also carried out by Fekria *et al*., (2012) was solely centered on the defatted seed cake flour of groundnut of two Sudanese groundnut cultivars. Both cultivars had good functional characteristics with high water absorption capacities. The properties investigated across were; water absorption capacity, bulk density, swelling power, foaming properties, solubility index, and gel concentration. Very little is known about the functional properties of full fat groundnut but some information about full fat mucuna varieties of the same family as groundnuts have been made available in Table 2.

Table 2.2 Functional Properties of Defatted and Undefatted Samples of Some Mucuna Varieties

Mucuna variety	FS		FC		BD		WAC	
	DFD	UFD	DFD	UFD	DFD	UFD	DFD	UFD
M. *veracruz* mottle	94.0±2.7^{c}	60.0±1.7^{b}	84.3±2.4^{d}	15.4±.4^{b}	0.80±0.04	0.51±0.02	2.20±0.06^{d}	2.0±0.60^{c}
M. *rajada*	85.0±2.5^{b}	56.0±1.6ab	66.7±1.9^{a}	9.80±0.3^{a}	0.88±0.05	0.61±0.04	1.70±0.05^{bc}	1.20±0.04^{a}
M. *cochinchinesis*	74.0±2.1^{a}	59.0±1.7^{ab}	73.1±2.1^{c}	15.7±0.5^{b}	0.80±0.04	0.50±0.03	1.60±0.05^{b}	1.2±0.04^{a}
M. *derigeana*	74.0±2.1^{a}	56.0±1.6ab	73.1±2.1c	17.7±0.5^{c}	0.74±0.05	0.42±0.03	1.72±0.05^{bc}	1.60±0.05^{b}
M. *pruriens*	72.0±2.1^{a}	61.0±1.8^{b}	50.0±1.4^{a}	19.2±0.6^{d}	0.72±0.04	0.54±0.04	1.80±0.05c	1.50±0.04^{b}
M. *Veracruz* white	72.0±2.1^{a}	54.0±1.6^{a}	50.0±1.4^{a}	9.60±0.3^{a}	0.84±0.05	0.60±0.02	1.40±0.04^{a}	1.20±0.04^{a}

Note;

DFD – Defatted Sample: UFD – Undefatted Sample: FS- Foaming Stability:

FC- Foaming Capacity: BD- Bulk Density WAC- Water Absorption Capacity

Adebowale *et al*., (2005)

CHAPTER THREE

3.0 METHODOLOGY

3.1 Sample Preparation

The groundnut samples used for the work were obtained from the Crop Research Institute at Fumesua-Ashanti Region (Ghana). These were *Yenyawoso*, *GK* 7, *ICGV* 03331, *ICGV* 99053, *ICGV* 02171, *ICGV* 01279, *ICGV* 01273, *ICGV* 02184, *ICGV* 99017, *ICGV* 99033 accessions. Freshly harvested samples were oven dried in a hot air oven (FS Tupola Plant- Wageningen) at 105 C for 4 hours.This was then followed by milling to obtain powdered samples of the nuts. The powdered form was then accessed for functional properties and proximate composition.

3.2 Physiochemical and Functional Properties

The functional properties carried out were Swelling Power, Water Absorption Capacity, Solubility Index, and Bulk Density, Foaming Capacity and Foaming Stability.

3.2.1 Swelling Power (SP) and Solubility Index (SI)

The SP and SI determinations were carried out based on modifications of the Method of *Leach et al.,* (1995). A gram of powdered sample was weighed into a 40 ml capacity centrifuge tube and distilled water added to the 40 ml mark. This was followed by low speed vortexing using *Thermolyne* 37600 mixer for 1 minute. Samples were then heated in the *Isotherm 205* (Fischer Scientific) water bath at 85 °C for 30 minutes. This was followed by cooling to room temperature before centrifuging at 2200 rpm for 15 minutes using the MSE MISTRAL 300E (SG95/10/256-UK Made) centrifuge. The supernatant obtained was poured into a weighed crucible and evaporated to dryness in a hot air oven (FS Tupola Plant- Wageningen) at 105 °C. The dried supernatant was weighed and values used to calculate for the solubility whilst the sediment paste obtained after

centrifugation was weighed and used to calculate for the swelling power as written below.

- $SwellingPower = \frac{weightofsediment(powderedsample)}{weightofdrysampletaken}$
- $Solubility\ Index = \frac{weight\ of\ dried\ supernatant}{weight\ of\ dry\ sample\ taken}$

3.2.2 Bulk Density

An amount of 50 gram each of the samples was weighed and carefully poured into a 250 mL capacity volumetric flask. This was followed by constant tapping of the measuring cylinder until no change in volume was observed (Maninder *et al*. 2007). The bulk density was calculated as;

- $Bulk\ Density = \frac{weight\ of\ sample(g)}{Volime\ of\ sample\ after\ tapping\ (cm^3)}$

3.2.3 Water Absorption Capacity

This property was determined using the method of Sathe and Salunkhe (1981) as modified by Adebowale *et al.,* (2005). An amount of 1 g powdered sample was weighed into a 10 mL capacity centrifuge tube. A volume of 10 mL distilled water was added. This was followed by mid speed vortexing using *Thermolyne* 7600 mixer for 1 minute and then centrifuged at 3500 rpm for 30 min.The supernatant obtained was measured in a 25 ml capacity measuring cylinder. Water absorption was examined as percent water bound per gram flour.

- $Water\ Absorption\ Capacity(\%\ WAC\ ) = \frac{y-z}{x} \times 100$

Where y = Initial volume of water added;

z= Volume of supernatant collected

x= Initial weight of (dried) sample taken;

y -z = Volume of water retained by the sample after centrifugation

3.2.4 Determination of Foaming Capacity and Stability

A known weight of undefatted groundnut was placed in 100 mL distilled water. The solution was homogenized for 5 min at high speed. The volume of foam separated was noted. The total volume remaining at time intervals was also noted (Jitngarmkusol *et al.* 2008).

- $\%\ Foaming\ Capacity = \frac{(vol\ after\ homogenization) - (vol\ before\ homogenization)}{vol\ before\ homogenization} \times 100$
- $\%\ Foam\ Stability = \frac{foam\ volume\ after\ time\ (t)}{Initial\ foam\ Volume} \times 100$

3.3 Proximate Analysis

3.3.1 Moisture Determination (AOAC, 2005)

Pre- dried moisture cans of known weight were labeled. A mass of 5 g of sample was accurately weighed and transferred into moisture cans. These were oven dried in a hot air oven (FS Tupola Plant- Wageningen) for 6 hours to attain a constant weight. Moisture cans with samples were then cooled in a desiccator before weighing. Moisture content was calculated as;

- $\%\ Moisture = \frac{(Initial\ weight\ of\ can + Sample) - (Final\ weight\ of\ can + Sample)}{weight\ of\ sample\ taken} \times 100$

3.3.2 Crude Ash Determination (AOAC, 2005)

A mass of 5g of each sample was weighed into pre-dried porcelain crucibles of known weight and kept in Muffle furnace for 4 hours at 550 °C. Furnace was allowed to cool below 200^{o}C and maintained for 20 minutes after ashing,and then crucibles were removed from furnace and kept in desiccators. Weights were taken after complete cooling and % Ash calculated as given below.

- $\%\ Crude\ Ash = \frac{(initial\ weight\ of\ crucible + sample) - (Final\ weight\ of\ crucible + Sample)}{weight\ of\ sample}$

3.3.3 Crude Fat Determination (AOAC, 2005)

Crude fat was determined by extracting fat from sample with petroleum ether using Soxhlet extractor. Samples were pre-dried in the oven for 20 minutes at 130 °C and then cooled to room temperature. A mass of 5 g of sample dry groundnut powder was weighed into Whatman No.42 filter paper fold. The extraction flask was weighed in an oven for about 5minutes at 110^{o}C then allowed to cool and weight taken. Extraction was carried out for 3 hours. Extraction flask was dismantled and ether evaporated from the oil extract over water bath until no odour of ether remains. The extraction flask with its extract was re-weighed and weight recorded.

- $\%\ Crude\ Fat = \frac{weight\ of\ extract}{sample\ weight} \times 100$

3.3.4 Crude Fibre Determination (AOAC, 2005)

The residue obtained after crude fat extraction was used in the fibre determination. The residue was transferred into a digestion flask. A volume of 200 mL boiling H_2SO_4 solution was added as well as an anti-foaming agent. The digestion flask was immediately connected with a condenser and heated. At the end of 30 minutes, the flask was removed, filtered immediately through linen and washed with boiling water until washings were no longer acid. A quantity of NaOH solution was heated to boiling point and kept at that temperature under a reflux condenser until used. The residue was washed back into the flask with 200 mL of the boiling NaOH solution. The flask was then connected with a reflux condenser and boiled for exactly 30 minutes. At the end of 30 minutes, the flask was removed and immediately filtered through the Gooch crucible. After thorough washing with boiling H_2O, it was washed with about 15 mL of 95% ethanol. The crucible and its contents were then dried at 110 $^{\circ}$C to a constant weight.

They were afterwards cooled in desiccators and weighed. The contents of the crucible were incinerated in a muffle furnace at 550°C for 30 minutes until the carbonaceous

matter had been consumed. They were again cooled in a desiccator and weighed. The loss in weight was recorded as crude fibre.

- $\%\ Crude\ Fiber = \frac{(A-B)}{C} \times 100$

Where A= weight of dry crucible and sample;

B= weight of incinerated crucible and ash;

C= sample weight

3.3.5 Protein Determination

Protein content was determined using the Kjedahl method. There are three main steps involved in the determination of crude protein as follows; Digestion of sample, Distillation of digest, and Titration of distillate.

Digestion of Sample

A mass of 2 g of the sample was weighed and transferred to a 500/650 mL digestion flask and 10ml volume of distilled water added. A digestion tablet was added to act as a catalyst. Approximately 20 mL of concentrated H_2SO_4 was then added again to the digestion flask. Boiling chips were added to digest the sample till the solution became colorless.

Distillation of Digest

After the digest was cooled, it was diluted with a small quantity of distilled ammonia-free water and made up to 100mL. The Kjeldahl flask was then rinsed with distilled water. A volume of 10 mL out of the 100ml digest was pipetted into the distillation flask and 90 mL distilled water added. Approximately 20 mL of 40% NaOH was added to the contents of the flask. A few drops of mixed indicator (1 part of methyl blue 0.2g/100 mL ethanol+ 2 parts of methyl red 0.2 g/mL ethanol) were added to a conical flask containing 10ml of hitherto added boric acid. The ammonia was distilled and collected into the boric acid. About 100-150 mL of the distillate was collected.

Titration of distillate

The distillate was titrated against the standard 0.1N HCl until the first appearance of pink color, i.e. the end-point. A reagent blank was then run with equal volume of distilled water and the titrated volume subtracted from the sample titration volume. The Protein content of the sample was calculated based on the nitrogen composition as follows;

- $Nitrogen(Total) = \frac{ml\ of\ acid \times normality\ of\ standard\ acid}{weight\ of\ sample} \times 0.014 \times 100$

Therefore,

- $\%\ Crude\ Protein = Total\ Nitrogen(NT) \times 6.25(Protein\ Factor)$

3.3.6 Determination of Total Carbohydrate

The total percentage carbohydrate content of the undefatted groundnut samples was determined by the difference method. This method involved adding the total values of crude protein, lipid, crude fiber, moisture and ash constituents of the sample and subtracting it from 100. The value obtained is the percentage carbohydrate constituent of the sample.

Thus: % carbohydrate = 100 – (%moisture + % crude fiber + % protein + % lipid + % ash)

3.4 Statistical Analysis

Statistical analyses were carried out on a completely randomized design. Data were subjected to analysis of variance and Duncan's multiple range test was used for comparison of means and the significance level at $p \leq 0.05$.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Proximate Composition of Groundnut Accessions

4.1.1 Carbohydrate Content

The results of the proximate composition of the ten improved groundnut (*Arachishypogaea*) accessions investigated are shown in Table 1. The carbohydrate content of the accessions ranged between 21% and 37% of which ICGV 03331 gave the highest carbohydrate content of 36.90% as seen in Table 1.Generally, the carbohydrate content of the individual accessions were within the range of values obtained by Ingale and Shrivastava (2011) and Ayoola and Adeyeye (2010).

In a work conducted by Ayoola and Adeyeye (2010) the carbohydrate contents of groundnut samples investigated varied. Fresh sample gave 17.41% but those that were sun dried and oven dried (at 105°C) gave higher carbohydrate content of 27.19% and 36.11% respectively. This suggests that the four-hour oven drying of the samples could have contributed to the high carbohydrate composition of the groundnut samples. These high amounts of carbohydrates in accessions investigated confer on them, significant roles to human health especially in the supply of energy. With the exception of ICGV 01273 and ICGV99017 there was a significant difference amongst the samples obtained. This could be as a result of the different modes of improvement applications meted out to the various accessions.

Table 4.1 Proximate Composition of Improved Groundnut Accessions

Sample	Moisture Content (%)	Protein Content (%)	Ash Content (%)	Fat Content (%)	Fibre Content (%)	Carbohydrate Content (%)
Yenyawoso	4.90 ± 0.01^{f}	23.13 ± 0.31^{ab}	1.38 ± 0.18^{cd}	34.75 ± 0.35^{e}	3.02 ± 0.03^{b}	32.87 ± 0.18^{b}
ICGV 02171	5.10 ± 0.10^{e}	23.60 ± 0.30^{a}	1.86 ± 0.06^{b}	45.75 ± 0.35a	2.00 ± 0.00^{ef}	21.74 ± 0.21^{fg}
ICGV 01279	5.28 ± 0.06^{e}	25.34 ± 0.32^{a}	2.32 ± 0.11^{a}	42.00 ± 0.70^{d}	2.12 ± 0.06^{ef}	22.95 ± 0.38^{ef}
ICGV 03331	5.30 ± 0.06^{e}	20.71 ± 0.60^{b}	1.85 ± 0.13^{b}	33.25 ± 0.35^{f}	2.00 ± 0.01^{ef}	36.90 ± 1.05^{a}
ICGV 99053	5.79 ± 0.11^{d}	25.12 ± 1.25^{a}	1.83 ± 0.11^{b}	44.00 ± 1.41^{bc}	1.93 ± 0.07^{ef}	21.34 ± 0.32^{g}
ICGV 02184	6.15 ± 0.02^{c}	23.80 ± 0.00^{a}	1.60 ± 0.20^{c}	42.25 ± 0.33^{d}	1.48 ± 0.06^{g}	24.74 ± 0.21^{d}
ICGV 99033	6.25 ± 0.04^{c}	23.37 ± 0.10^{ab}	1.35 ± 0.30^{c}	44.75 ± 0.35^{ab}	2.62 ± 0.10^{c}	23.67 ± 0.64^{de}
GK7	6.47 ± 0.13^{b}	24.01 ± 0.31^{a}	2.20 ± 0.04^{a}	31.50 ± 0.71^{g}	3.85 ± 0.16^{a}	31.98 ± 0.64^{c}
ICGV 01273	6.73 ± 0.13^{a}	23.36 ± 0.63^{ab}	2.12 ± 0.07^{a}	44.00 ± 0.00^{bc}	1.83 ± 0.05^{f}	21.98 ± 0.78^{fg}
ICGV 99017	6.79 ± 0.13^{a}	25.12 ± 0.00^{a}	1.20 ± 0.00^{d}	42.75 ± 0.33^{cd}	2.33 ± 0.16^{d}	21.82 ± 0.06^{fg}

NB: Means in the same column not followed by the same letter (s) are significantly different from each other by Duncan's multiple range tests at the $p \leq 0.05$

4.1.2 Protein Content

The levels of protein in the accessions were relatively high as compared to that of other legumes. The accessions, ICGV03331 had the least protein content of 20.71% whereas ICGV01279 had the highest of 25.34%. Yenyawoso, ICGV 02171, ICGV 99053, ICGV 02184, ICGV 99033, GK7, ICGV 01273, ICGV 99017 gave 23.13%, 23.6%, 25.12%, 23.8%, 23.37%, 24.01%, 23.36, and 25.12% respectively. The higher protein contents of these groundnut accessions, indicate that their intake can contribute to the formation of hormones which controls a variety of body functions such as growth, repair and maintenance (replacement of wear and tear of tissues) of body (Bhattacharjee *et al*., 2013). The high protein content is also desirable as some functional properties have long been associated with the activities of proteins. There was no significant difference amongst ICGV 02171, ICGV 01279, ICGV 99053, ICGV 02184, GK7 and ICGV 99017 samples at $p \leq 0.05$.

4.1.3 Fat

The fat content of most foods are of interest to food processors for numerous reasons. Economically, a high oil yield of groundnut is of great interest to most oil producers. The fat content of the groundnuts ranged from 31% to 46%. The large values obtained shows that the accessions are high in fat. This agrees with works done by Eshun *et al*.(2013); Ingale and Shrivastava (2011); and Ejigui *et al*., (2005). There were significant differences amongst the samples ($p \leq 0.05$).This could be as a result of the variations of agronomic practices within the accessions. Amongst the improved accessions, ICGV 02171 recorded the highest fat value of 45.75%. The least value recorded is 31.50% by GK7 as seen in Table 1. These high fat values present the improved accessions as a highly adequate source of oil, and fat for food formulations requiring high fat content for body. In addition, it is suggestive of a good oil yield from a relatively small mass as

compared to other food sources (Duyff, 2007). Beyond the economic worth of the product, the fat content is important in diet as it promotes fat soluble vitamin (vitamin A, D, E, and K) absorption. The relatively high fat also contributes immensely to the energy value of the groundnuts.

4.1.4 Crude Fibre Content

The crude fibre in this result indicates the ability of groundnut to maintain internal distention for a normal peristaltic movement of the intestinal tract; a physiological role which crude fiber plays (Atasie *et al*., 2009).It is also a measure of the quantity of indigestible cellulose, pentosans, lignin and other components of this type present in food (Aurand *et al*., 1987). These fibres protect the body against colon cancer, diabetes and cardiovascular illnesses (Ponka *et al*., 2005). It provides bulk to food to relieve constipation (Appiah *et al*., 2011). Diet low in crude fiber cause constipation and such diets have been associated with diseases of the colon like piles, appendicitis and cancer (Atasie *et al*., 2009). Crude fibre values expressed ranged from 1.4% to 3.9%. Accession GK 7 recorded the highest crude fiber content, followed by *Yenyawoso* whilst ICGV 02184 recorded the least of 3.85, 3.02, and 1.48 respectively. These results are close to other varieties of groundnut seeds (Atasie *et al*., 2009; Ingale and Shrivastava, 2011) that have crude fibre content of 3.7 . The values of crude fibre obtained indicate that the groundnut varieties have the ability to give bulk to foods. All four groundnut varieties differed significantly ($p \leq 0.05$) from each other in their crude fibre contents.

4.1.5 Ash

Crude Ash measurement represents the portion of mineral composition of the groundnut samples. The mineral content of the cultivars were all significantly different at $p \leq 0.05$ as illustrated in Table 1. The values obtained indicate a very important amount of minerals readily available in the consumption of these accessions. Mineral composition

values recorded are close to values obtained by Atasie *et al*., (2009) as well as Gul and Safdar (2009). In the work conducted by Atasie *etal* (2009), the ash content of the groundnut was 3.8%

4.1.6 Moisture Content

The moisture content of the accessions ranged from 4.9 % to 6.79 %. These values were recorded by *Yenyawoso* and *ICGV* 99017 respectively. All accessions proved to be significantly different from each other at $p \leq 0.05$. The range of moisture values agreed with those reported by Ayoola and Adeyeye (2010). Refer to table 1.0. This low range of moisture is highly important to avoid Aspergillus sp. contamination which can results in aflatoxin and other related groundnut toxin production (Florkowski and Kolavalli, 2013). As indicated by Florkowski and Kolavalli, (2013), the pods of groundnut act well as barriers to protect the seeds from mould attack. Thus in its absence, it is important to control conditions such as moisture, humidity and temperature in order not to encourage the growth of mould.

4.1.7 Energy Value

Calorific value was highest in ICGV 02171 with a value of 592.97 kCal/100 g and lowest in *GK* 7 with a value of 507.46 kCal/100 g. Such values of carbohydrate, protein and fat obtained have been the basis for suggestion by Eshun *et al.,* (2013) that groundnuts could be used to manage protein- energy malnutrition. The highest value is slightly above that which was reported by Eshun *et al.,* (2013) whilst the least equally fell slightly lower than the least amongst the four cultivars investigated by Eshun *et al*., (2013). The energy values obtained by Eshun *et al* ranged from 581.54 Kcal/ 100g – 537.06 Kcal/100g. As seen in Fig. 1.0, energy values are averagely above 500 kCal/100 g which makes the groundnut accession a very good energy store house and be used to manage protein energy malnutrition.

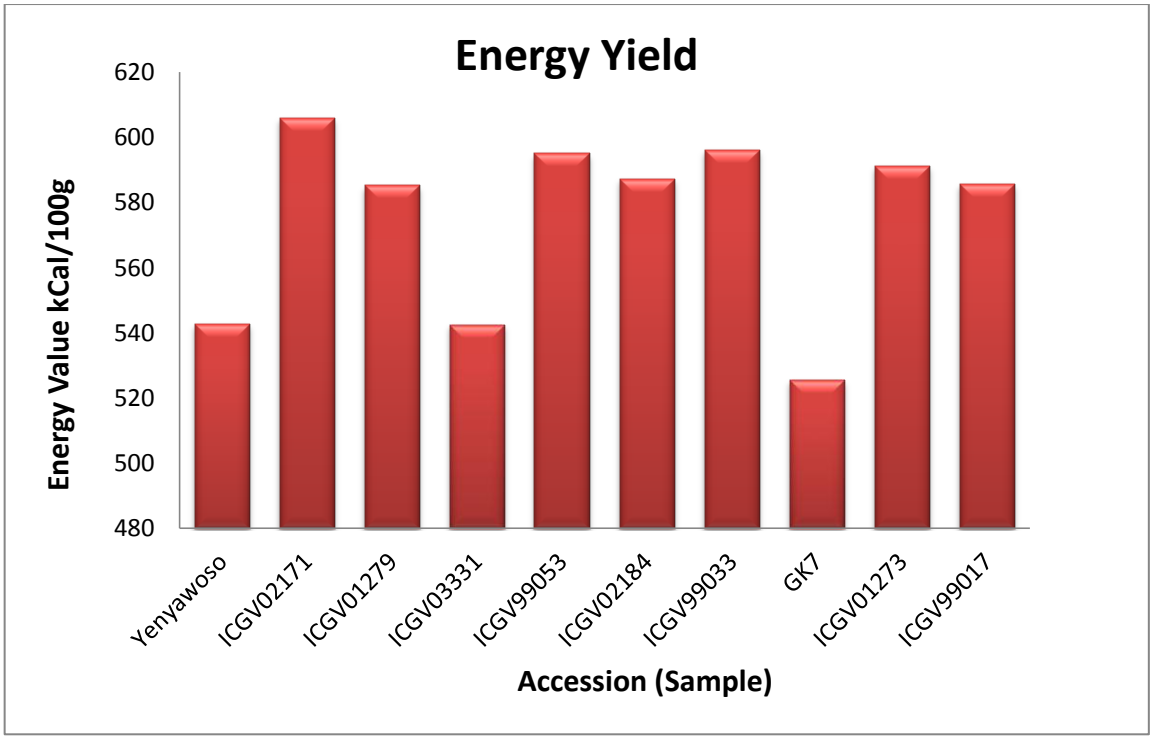

Fig 4.1 Energy Values Obtained for Groundnut Accessions

4.2 Functional Properties

4.2.1 Foaming Stability (FS) and Capacity (FC)

The results of FC and foam FS are shown in Table 2.0. The foaming capacity in full fat groundnut accessions ranged from 4.0 % -16.2 %. It was reported that foamability is related to the rate of decrease of the surface tension of the air/water interface caused by absorption of protein molecules (Sathe *et al.*, 1982). Graham and Phillips (1976) linked good foaming properties to flexible protein molecules, which decreases surface tension. Low foaming properties on the other hand can be related to highly well organised a globular protein, which resists surface denaturation.

The ability of proteins to be classified as excellent foaming agents is dependent on rapid absorptivity at air/water interface while bubbles are being formed, easy rearrangement at surface, film formation through intermolecular forces (Adebowale *et al.*,2005)..

The foaming Stability of the samples was very high as compared to the works mentioned above. Stability values ranged between 94% and 100%. This suggests that viscoelastic

film formed via intermolecular interactions of constituent proteins is so strong that once there's formation of foam it is difficult for the foam to collapse despite the low foaming capacity. As indicated by Adebowale *et al*., (2005), defatting markedly increase the foaming capacity in the flours. Thus a fair balance of fat in the accession could prove to yield high foaming stability cum Capacity. The relationship of Percentage Protein, Fat, Foaming Capacity and Stability can be seen in Fig 2.0.

Table 4.2 Foaming Stability and Capacity of Undefatted Groundnut Samples

Sample	Foaming Stability (%) - 1 hour	Foaming Capacity (%)
Yenyawoso	94.77 ± 0.04^{f}	14.50 ± 0.70^{b}
ICGV02171	98.2 ± 0.05^{c}	16.20 ± 0.28^{a}
ICGV01279	99.16 ± 0.11^{b}	4.00 ± 0.00^{g}
ICGV03331	98.06 ± 0.08^{d}	6.20 ± 0.35^{f}
ICGV99053	99.18 ± 0.11^{b}	8.90 ± 0.14^{d}
ICGV02184	100.00 ± 0.00^{a}	12.50 ± 0.70^{c}
ICGV99033	98.13 ± 0.03^{cd}	8.00 ± 0.00^{e}
GK7	99.21 ± 0.08^{b}	8.10 ± 0.14^{e}
ICGV01273	96.40 ± 0.14^{e}	7.90 ± 0.14^{e}
ICGV 99017	98.28 ± 0.03^{c}	14.20 ± 0.28^{b}

NB: Means in the same column not followed by the same letter (s) are significantly different from each other by
Duncan's multiple range tests at the $p \leq 0.05$.

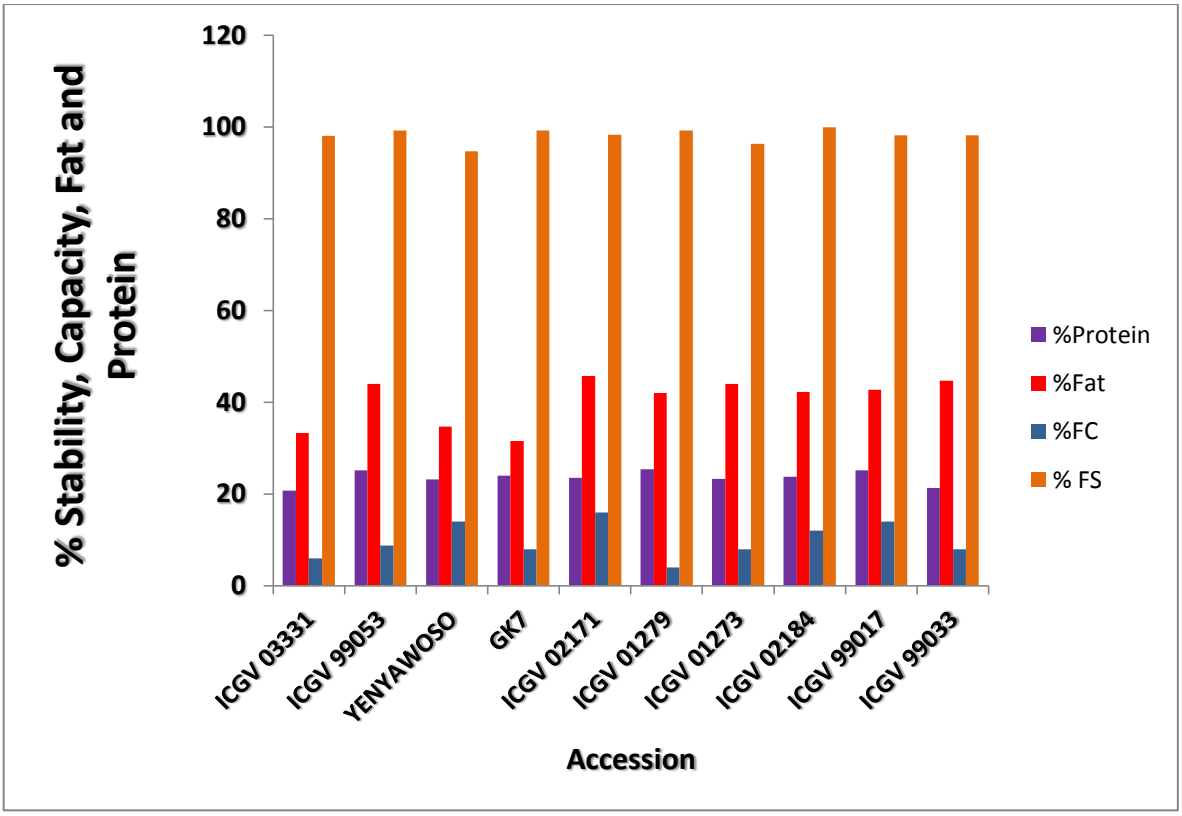

Fig 4.2 Relationship amongst Percentage Protein, Fat, Foaming Capacity and Stability

4.2.2 Water Absorption Capacity (WAC)

According to Fekria *et al*., (2012) hydration is the initial and probably vital procedure in imparting desirable functional properties to proteins in a food system. Relationship between water and flours are very important in food systems because of the bearing it has on flavor and texture of foods. The results obtained for water absorption capacity for the accessions can be found in Table 3.0. The values obtained were low as compared to works by Fekria *et al*., (2012). Values ranged between 20 % and 30 %. This can be attributed to high fat content of the samples. According to Yu *et al*., (2007) and Fekria *et al*., (2012), WAC of defatted samples were higher than those of undefatted samples as the presence of hydrophilic structures in fat restricts water movement. Flours with high WAC have more hydrophilic constituents such as polysaccharides (Fekria *et al*., 2012).

There was no significant difference amongst the samples except for ICGV 99053 and GK 7

Table 4.3 Water Absorption Capacity of Undefatted Groundnut Samples

Sample	Water Absorption Capacity (%)
Yenyawoso	25.0 ± 0.00^{abcd}
ICGV02171	25.0 ± 0.00^{abcd}
ICGV01279	25.0 ± 0.00^{abcd}
ICGV03331	27.5 ± 0.40^{ab}
ICGV99053	20.5 ± 0.40^{d}
ICGV02184	24.0 ± 0.14^{bcd}
ICGV99033	22.0 ± 0.14^{cd}
GK7	29.0 ± 0.14^{a}
ICGV01273	24.0 ± 0.40^{bcd}
ICGV 99017	26.0 ± 0.14^{abc}

NB: Means in the same column not followed by the same letter (s) are significantly different from each other by Duncan's multiple range tests at the $p \leq 0.05$.

4.2.3 Swelling Power and Solubility Index

Several works have underscored the importance of starch portions of a flour in its swelling and solubility abilities of particular flour. Although undefatted samples of the groundnut accessions were investigated, the samples exhibited relatively good swelling and solubility properties. According to Loos et al., (1981), Swelling Power is an indication of the water absorption index of granules during heating. Moorthy and Ramanujam (1986) suggested that the swelling power of granules reflected the extent of the associative forces within the granule. An observation made by Ikegwu et al., (2010) emphasized a correlation between swelling power and starch solubility in pure flours. A similar development is seen though whole undefatted groundnut accessions were investigated. It can be seen from Table 4.0 that, generally as the swelling power increases, solubility also increases across. Dengate (1984) also indicated that with

reference to temperature, this is seen as a result of swelling permitting the exudation of amylose. The accessions ICGV 99017, ICGV 03331, gave swelling power of 4.12 g/g and 3.40 g/g as well as a high corresponding solubility index of and 53.50 %, and 57.00 % respectively. ICGV 99033 gave the least swelling power 2.98 g/g yet produced a higher solubility index of 40.0 % when compared to ICGV01273 of 3.28 g/g swelling power yet gave a solubility index of 26.5 %. This can be due to first of all the amylose content and the extent to which they are exuded as reported by Dengate (1984). There was no significant difference amongst the samples.

Table 4.4 Swelling Power and Solubility Index of Undefatted Groundnut Samples

Sample	Swelling Power (g/g)	Solubility Index (%)
Yenyawoso	3.72 ± 0.45^{abc}	38.50 ± 0.71^{bc}
ICGV02171	4.14 ± 0.08^{a}	38.00 ± 2.83^{abc}
ICGV01279	3.08 ± 0.62^{bc}	35.00 ± 1.41^{bc}
ICGV03331	3.40 ± 0.17^{abc}	57.00 ± 1.41^{a}
ICGV99053	4.18 ± 0.71^{c}	36.00 ± 0.00^{bc}
ICGV02184	3.38 ± 0.71^{c}	34.00 ± 2.83^{bc}
ICGV99033	2.98 ± 0.03^{c}	40.00 ± 0.00^{ab}
GK7	3.80 ± 0.29^{abc}	39.50 ± 2.12^{ab}
ICGV01273	3.28 ± 0.06^{abc}	26.5 ± 2.12^{c}
ICGV 99017	4.12 ± 0.34^{ab}	53.50 ± 2.12^{ab}

NB: Means in the same column not followed by the same letter (s) are significantly different from each other by Duncan's multiple range tests at the $p \leq 0.05$.

4.2.4 Bulk Density

The results of bulk densities of full fat groundnut accessions are presented in Table 5.0. The results obtained were higher than that of some undefatted mucuna bean samples and within the range of values of the defatted ones by Adebowale *et al*., (2005).The values obtained were from 0.625 g/cm^3 to 0.877 g/cm^3.There was significant difference between the values at $p \leq 0.05$. From work conducted by Adebowale *et al*., (2005) values obtained ranged from 0.42 to 0.61 g/cm^3 in full fat flours and 0.72 to 0.88 g/cm^3 in

deffated flours. High bulk density of the groundnut accessions despite high oil content indicates that they would serve as good thickeners in food products.

Table 4.5 Bulk Density of Undefatted Groundnut Samples

Sample	Bulk Density (g/cm^3)
Yenyawoso	0.690 ± 0.003^{c}
ICGV02171	0.625 ± 0.000^{e}
ICGV01279	0.725 ± 0.007^{b}
ICGV03331	0.629 ± 0.005^{e}
ICGV99053	0.877 ± 0.021^{a}
ICGV02184	0.704 ± 0.012^{c}
ICGV99033	0.662 ± 0.005^{d}
GK7	$0.658 \pm 0.000_{d}$
ICGV01273	0.685 ± 0.006^{c}
ICGV 99017	0.694 ± 0.000^{c}

NB: Means in the same column not followed by the same letter (s) are significantly different from each other by Duncan's multiple range tests at the $p \leq 0.05$.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Investigations carried out on the ten undefatted samples revealed that the carbohydrate, fat, protein and fiber content of improved accessions are very high. The high protein content of all accessions shows they could be a valuable protein supplement for cereals based food products. Energy values calculated makes the accessions a very good energy store such that they can be utilized in the development of very rich energy store foods making it a possible means to manage protein-energy malnutrition.

Undefatted groundnut flours showed very good foaming stability. This would be suitable for use in food formulations where foaming is highly desired. The Swelling Power and Solubility index were good indicating how readily the flour constituents would behave under elevated temperature conditions. Despite the above, Foaming Capacity, WAC, and Bulk Density affected by the heavy presence of fat in the sample.

5.2 Recommendation

Future studies are needed to develop a protein concentrate from the groundnut accessions. Also the levels of fat and their direct effect on functional properties and to what extent fat can be reduced should be investigated.

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APPENDICES

APPENDIX A

Homogeneous Subsets

Water Absorption Capacity (WAC)

	SAMPLE	N	Subset for alpha = 0.05			
			1	2	3	4
Duncan[a]	ICGV 99053	2	205.0000			
	ICGV 99033	2	220.0000	220.0000		
	ICGV 01273	2	240.0000	240.0000	240.0000	
	ICGV 02184	2	240.0000	240.0000	240.0000	
	YENYAWOSO	2	250.0000	250.0000	250.0000	250.0000
	ICGV 02171	2	250.0000	250.0000	250.0000	250.0000
	ICGV 01279	2	250.0000	250.0000	250.0000	250.0000
	ICGV 99017	2		260.0000	260.0000	260.0000
	ICGV 03331	2			275.0000	275.0000
	GK7	2				290.0000
	Sig.		.055	.082	.120	.080

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

SWELLING POWER

	SAMPLE	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	ICGV 99033	2	2.9800		
	ICGV 01279	2	3.0800	3.0800	
	ICGV 01273	2	3.2800	3.2800	3.2800
	ICGV 02184	2	3.3800	3.3800	3.3800
	ICGV 03331	2	3.4000	3.4000	3.4000
	YENYAWOSO	2	3.7200	3.7200	3.7200
	GK7	2	3.8000	3.8000	3.8000
	ICGV 99017	2		4.1200	4.1200
	ICGV 02171	2			4.1400
	ICGV 99053	2			4.1800
	Sig.		.112	.053	.087

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

FOAMING STABILITY

	SAMPLE	N	Subset for alpha = 0.05					
			1	2	3	4	5	6
	YENYAWOSO	2	94.7700					
	ICGV 01273	2		96.4000				
	ICGV 03331	2			98.0550			
	ICGV 99033	2			98.1250	98.1250		
	ICGV 02171	2				98.2450		
Duncan[a]	ICGV 99017	2				98.2750		
	ICGV 01279	2					99.1550	
	ICGV 99053	2					99.1800	
	GK7	2					99.2050	
	ICGV 02184	2						100.0000
	Sig.		1.000	1.000	.398	.101	.561	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

FOAMING CAPACITY

	SAMPLE	N	Subset for alpha = 0.05						
			1	2	3	4	5	6	7
	ICGV 01279	2	4.0000						
	ICGV 03331	2		6.2500					
	ICGV 01273	2			7.9000				
	ICGV 99033	2			8.0000				
	GK7	2			8.1000	8.1000			
Duncan[a]	ICGV 99053	2				8.9000			
	ICGV 02184	2					12.5000		
	ICGV 99017	2						14.2000	
	YENYAWOSO	2						14.5000	
	ICGV 02171	2							16.2000
	Sig.		1.000	1.000	.614	.054	1.000	.432	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

BulkDensity

	SAMPLE	N	Subset for alpha = 0.05				
			1	2	3	4	5
Duncan[a]	ICGV 02171	2	.6250				
	ICGV 03331	2	.6290				
	GK7	2		.6580			
	ICGV 99033	2		.6585			
	ICGV 01273	2			.6805		
	ICGV 02184	2			.6850		
	YENYAWOSO	2			.6920		
	ICGV 99017	2			.6940		
	ICGV 01279	2				.7300	
	ICGV 99053	2					.8775
	Sig.		.664	.956	.189	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Solubility Index (SI)

	SAMPLE	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	ICGV 01273	2	24.0000		
	ICGV 01279	2	30.0000	30.0000	
	YENYAWOSO	2	34.0000	34.0000	
	ICGV 02184	2	34.0000	34.0000	
	ICGV 99053	2	36.0000	36.0000	
	ICGV 02171	2	38.0000	38.0000	38.0000
	GK7	2		40.0000	40.0000
	ICGV 99033	2		40.0000	40.0000
	ICGV 99017	2		44.0000	44.0000
	ICGV 03331	2			52.0000
	Sig.		.067	.069	.065

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

APPENDIX B

Homogeneous Subsets

MOISTURE

	SAMPLE	N	Subset for alpha = 0.05					
			1	2	3	4	5	6
Duncan[a]	YENYAWOSO	2	4.8500					
	ICGV 02171	2		5.0900				
	ICGV 01279	2		5.2750				
	ICGV 03331	2		5.2950				
	ICGV 99053	2			5.7900			
	ICGV 02184	2				6.1450		
	ICGV 99033	2				6.2450		
	GK7	2					6.4650	
	ICGV 01273	2						6.7250
	ICGV 99017	2						6.7850
	Sig.		1.000	.062	1.000	.308	1.000	.534

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

ASH

	SAMPLE	N	Subset for alpha = 0.05			
			1	2	3	4
Duncan[a]	ICGV 99017	2	1.2000			
	ICGV 99033	2	1.3450	1.3450		
	YENYAWOSO	2	1.3800	1.3800		
	ICGV 02184	2		1.6000	1.6000	
	ICGV 99053	2			1.8300	
	ICGV 03331	2			1.8500	
	ICGV 02171	2			1.8550	
	ICGV 01273	2				2.1200
	GK7	2				2.1950
	ICGV 01279	2				2.3200
	Sig.		.166	.060	.065	.127

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

PROTEIN

	SAMPLE	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	ICGV 03331	2	20.7100	
	YENYAWOSO	2	23.1300	23.1300
	ICGV 01273	2	23.3550	23.3550
	ICGV 99033	2	23.3700	23.3700
	ICGV 02171	2		23.5700
	ICGV 02184	2		23.7900
	GK7	2		24.0100
	ICGV 99053	2		25.1150
	ICGV 99017	2		25.1200
	ICGV 01279	2		25.3400
	Sig.		.051	.106

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

FAT

	SAMPLE	N	Subset for alpha = 0.05						
			1	2	3	4	5	6	7
Duncan[a]	GK7	2	31.5000						
	ICGV 03331	2		33.2500					
	YENYAWOSO	2			34.7500				
	ICGV 01279	2				42.0000			
	ICGV 02184	2				42.2500			
	ICGV 99017	2				42.7500	42.7500		
	ICGV 99053	2					44.0000	44.0000	
	ICGV 01273	2					44.0000	44.0000	
	ICGV 99033	2						44.7500	44.7500
	ICGV 02171	2							45.7500
	Sig.		1.000	1.000	1.000	.269	.080	.269	.134

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

FIBRE

	SAMPLE	N	Subset for alpha = 0.05						
			1	2	3	4	5	6	7
Duncan[a]	ICGV 02184	2	1.4800						
	ICGV 01273	2		1.8250					
	ICGV 99053	2		1.9300	1.9300				
	ICGV 03331	2		2.0000	2.0000				
	ICGV 02171	2		2.0000	2.0000				
	ICGV 01279	2			2.1150				
	ICGV 99017	2				2.3250			
	ICGV 99033	2					2.6200		
	YENYAWOSO	2						3.0200	
	GK7	2							3.8500
	Sig.		1.000	.091	.076	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

CARBOHYDRATE

	SAMPLE	N	Subset for alpha = 0.05					
			1	2	3	4	5	6
Duncan[a]	ICGV 99053	2	21.3350					
	ICGV 02171	2	21.7350	21.7350				
	ICGV 99017	2	21.8200	21.8200				
	ICGV 01273	2	21.9750	21.9750				
	ICGV 01279	2		22.9500	22.9500			
	ICGV 99033	2			23.6700	23.6700		
	ICGV 02184	2				24.7350		
	GK7	2					31.9800	
	YENYAWOSO	2					32.8700	
	ICGV 03331	2						36.8950
	Sig.		.294	.062	.211	.076	.130	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.