UNIVERSITY OF CAPE COAST

ASSESSMENT OF NUTRITIONAL LEVEL, FUNCTIONAL PROPERTIES AND MINERAL CONTENTS OF NEWLY DEVELOPED GENOTYPES OF COWPEA [*VIGNA UNGUICULATA* (L.) WALP.] IN GHANA

BY

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Thesis submitted to the Department of Chemistry of the School of Physical Sciences, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Chemistry.

JAN 2020

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this University or elsewhere.

Candidate's Signature ………………………… Date: …………………

Name: Ampah James Kwesi

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's signature: ……………………………. Date: …………

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ABSTRACT

The nutritional characteristics, functional properties and mineral elements of twenty-three newly cultivated cowpea genotypes were evaluated using standard methods. The data were subjected to one-way analysis of variance and the means were distinguished by Tukey's multiple range test. The results showed significantly ($p \leq 0.05$) varied and higher protein content ranging from 23.67 % - 33.80 % with fibre, 0.99 % - 4.27 %. The rest of the results were carbohydrates (43.69-58.01 %), moisture (10.80 - 19.03 %), ash (2.48 - 4.03 %) and fat (0.4 - 3.1 %). The study also revealed that the functional properties; OAC, WAC, WHC, OHC, EC, FC, FS, SI and SP were in the range of 1.31-1.81 ml/g, 1.32 -2.94 ml/g, 2.38-3.76 %, 2.83-3.36 %, 43.24-46.61 %, 23.25-50.26 %, 62.32-89.02 %, 0.98-1.25 ml and 4.56-6.55 g/g respectively. The most abundant minerals were K (282.92-346.34 mg/100g) Mg (124.92-145.40 mg/100g), Na (81.30-105.69mg/100g) and Ca (6.74-6.67 mg/100g. The study revealed that the new genotypes (UCC 241, UCC 32, UCC 328, UCC EARLY, UCC 473, UCC 366 and IT10-819-4) exhibited good nutritional and functional properties which can be utilized in food formulations and hence may serve as alternative source of protein-rich food that could aid reduce protein energy malnutrition Ghana.

KEY WORDS

Cowpea

Functional

Mineral

Nutritional

Striga gesnerioides

Vigna unguiculata

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DEDICATION

I dedicate this work to the Ampah and Agbelengor families.

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LIST OF ACRONYMS

ANOVA	Analysis of variance
FAO	Food and Agriculture Organization
FDA	Food and Drugs Association
FND	Food and Nutrition Board
ICRISAT	International Institute for the Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
MoFA	Ministry of Food and Agriculture
NIH	National Institute of Health
PAG	Protein Advisory Group
PEM	Protein Energy Malnutrition
RDA	Recommended Dietary Allowance
SARI	Savannah Agriculture Research Institute
SPSS	Statistical Package for Social Sciences

CHAPTER ONE

INTRODUCTION

Background to the Study

Malnutrition in children and nursing mothers is common and one of the major problems in developing countries due may be caused by insufficient protein in diet. The major nutritional challenge to these children is due to the protein and micronutrient deficiencies (Ochola & Masibo, 2014).

Malnutrition reduces man's capacity for productivity and increases morbidity and mortality. Many children in developing countries often face the risk of malnutrition because of their dependence on others for food, increase in protein and energy requirements as well as their exposure to poor hygienic conditions (Blössner et al., 2005). Malnutrition in children in developing countries can also be based on the constant consumption of cereal based foods which is high in energy (Michaelsen & Friis, 1998).

The increment of protein energy malnutrition (PEM) has now become a major concern for government, agricultural scientists, food scientists and nutritionists (Khalid, Elhardallou, & Elkhalifa, 2012). The rate of malnutrition remains alarming; it persists as the single largest cause of child mortality (UNICEF, 2015). Mostly, the deaths in children under 5 years are attributable to malnutrition.

About 1.2 million Ghanaians were considered to be food insecure and chronic malnutrition affecting one-fourth of children under 5 years (UNICEF, 2015). The 2018 Global Nutrition Report reveals that the global burden of malnutrition is unacceptably high; it now affects every country in the world. Therefore, the inclusion of legumes in the diet of people in developing countries plays a key role in the body's well-being. Legumes are rich sources of protein (18-35%). Legumes are loaded with other variety of nutrients such as fibre, carbohydrates, fats, potassium, iron, zinc, sodium, calcium, phosphorous and selenium (Graham & Vance, 2003; Arya, Salve, & Chauhan, 2015). The leaves of legumes serve as forage for farm animal whiles the oil from some of the seeds serve as medicines.

Legumes such as cowpeas are cultivated in the tropics for a variety of purposes (Ali, Aslam, Hussain, & Shakur, 2004) and they are one of the major contributors in the agricultural sectors in most developing countries in the world. Cowpea is an important annual cash crop and food mainly cultivated in the Sub-Saharan African savanna zone. It is a warm season herbaceous leguminous crop which is often classified into erect, semi-erect, prostrate or climbing in their growth habits. It is also referred to as southern pea, crowder pea, blackeye pea, niebe, lubia or coupe in many different geographical locations (Olalekan & Bosede, 2010). Cowpea originated from Africa but it is also grown in the American and Asian countries.

In the African sub-region alone, cowpea provides about 200 million people with second class protein (IITA, 2009). About 4.3 million tonnes covering over 90 % production of cowpea comes from the West Africa (Antwi, 2011). Cowpea provides good and rich source of protein and energy in human diet. It can therefore be used as major substitute to many staple foods (Antwi, 2011). The functional properties and the nutritional characteristics of cowpea are good enough to be used for several conventional food formulation (Khalid et al., 2012).

Cowpea has a high probability of picking up minerals and other trace elements from the soil thus makes it a great source of livestock feed in the savannah areas. It can actually be used at all stages of growth as a vegetable crop (Davis et al., 1991). Small scale farmers in developing countries normally cultivate cowpea with other different crops because of its ability to grow and cover the ground to prevent erosion. It is able to survive in a variety of soils (IITA, 2009). Cowpea is a drought tolerant crop as compared to other legumes and cereals and it flourishes well in warm seasons with adequate rainfall in sandy or sandy loam soils (IITA, 2009; Dadson et al., 2005; Kuykendall et al., 2000; Martins et al., 2003).

Cowpea seed is rich with a variety of nutrients and minerals like fiber, protein, iron, potassium, calories and with low contents in fat (Carvalho et al., 2012). Its protein is rich in amino acids like tryptophan and lysine, as compared to cereal grain even though it is deficient in methionine and cysteine when compared to animal proteins. Therefore, it is valued as a nutritional supplement to cereals and an extender of animal proteins (Adebowale, Adeyemi, & Oshodi, 2005). According to Obasi, Uchechukwu and Eke-Obia (2012), cowpea is rich with essential minerals, dietary fibre and phytochemicals which has positive effect on man’s health. Cowpea helps to prevent cancer, anemia, supports a healthy metabolism, maintain strong bones and also repairs muscle tissues. The leaves of the cowpea plant are also an important source of food in Africa and other part of the world.

Out of over 5.4 million of cowpea produced in the world, 5.2 million alone are produced in Africa with Nigeria topping the chart with about 61 % production and about 58 % worldwide (Antwi, 2011). Apart from the growing nature of cowpea plant in specific geographical locations in the world over the last 25 years, the United States and other areas have declined from 3/4 million acres to a few thousands over the same period (Davis et al., 1991). According to Kyeremateng (2015), the world will need to feed over 2 billion additional people by 2050. According to FAO (2009), the world's population may rise by 2.3 billion people between 2009 and 2050. Sub-Saharan Africa population may increase tremendously by 114 % which will give rise to market demand for food (FAO, 2009). The rise from 7.3 billion people to 9.7 billion people will cause dietary changes such as eating more protein by 2050, indicating between 59 % to 98 % increment (Maarten & Florian, 2016).

Statement of Problem

West African countries experience rapid changes in the social and economic environment which are associated with changes in food consumption patterns and thus affect the quality of diets and nutritional well-being (Lopriore & Muehlhoff, 2003). Unstable climatic conditions which lead to shifting weather patterns has been making agricultural production much more unpredictable and volatile, making the lives of farmers harder. These stresses can cause complete cowpea loss if not properly managed.

Even though cowpea is rich in protein, the quality of its nutrient and its cultivation are affected by plant parasite (*Striga gesnerioides* and *Alectra vogelii*), drought and climatic change. *Striga gesnerioides* and *Alectra vogelii* are known weed parasites that can cause substantial reduction of cowpea yield in the Sub-Saharan Africa (IITA, 2009). In Ghana, the parasites affect cowpea growth and yield of cowpea in the three northern regions and it makes farmers run at loss. Again, there excessive heat and drought has been another setback to cowpea growth.

Justification

Drought and weed parasite infestations are major constraints that affect the cultivation of the cowpea which also affect it level of nutrients. The University of Cape Coast has produced and released new genotypes of cowpea. Studies were initially done on the cowpes' drought resistance and the resistance to weed parasite infestation by other researchers. The cowpea proved to be to drought resistant and weed parasite (*Striga gesnerioides*) infestations. In spite of the fact that the new genotypes of cowpea have been developed by the University of Cape Coast, the nutritional profile of these cowpeas is unknown. Therefore, it is important that the nutritional profile of the newly developed cowpeas is assessed to facilitate selection of improved and stable genotypes of the crop for farmer cultivation and consumer use.

Significant of the Study

Animal foods are known to be important for their protein content and quality but are very expensive and beyond the economic reach of an average household in a developing nation like Ghana (Adebowale, Adeyemi & Oshodi, 2005). The cowpea plant is not only a cheap source of protein but among the most popular and widely used legumes in the world. Matured dried cowpea contains 20-27 % or more of proteins (IITA, 2018; Carvalho et al., 2012). Although cowpea local varieties such as Vallenga, Bengpla and Marfo-Tuya were released in the 90's to early 2000's and thus are well known and consumed in Ghana (SARI, 2012), the production levels are low and do not meet the demand of consumers. The Department of Molecular Biology and

Biotechnology of the University of Cape Coast, has stored 23 newly developed cowpeas genotypes which require assessment of nutritional potential, their functional properties and mineral constituents to sustain human health. The current work will explore new cowpeas for nutritionally and functionally good quality grains to meet consumer preference and need for balance diet, hence contribute to alleviating extreme PEM and poverty in rural and urban poor communities in Ghana.

The Aim of the Study

The aim of this study was to assess the nutritional characteristics, the functional properties and the mineral elements of twenty-three newly cultivated cowpea genotypes.

The Specific Objectives of the Study

The objectives of the current study were to:

1. evaluate the proximate compositions of the cultivated cowpea genotypes.
2. determine the functional properties of the cowpea genotypes.
3. investigate the nutritional mineral and trace elements in the cowpea grain.

Organization of the Study

This study comprises five chapters. The first chapter contains the background to the study, the statement of the problem, justification, significance of the study, aim and specific objectives of the study. The second chapter covers the literature which is organized under the following sub-headings; the origin and geographical distribution, importance of cowpea, production of cowpea in Ghana, Africa and the world at large, functional properties, nutritional properties, mineral and trace metal determination of food. The third chapter consist of the materials and methods used in the research that include sample collection and preparation, chemical reagents, research instruments and analysis technique. The fourth chapter contains data analysis, its interpretation and discussion. The fifth chapter covers the overview, summary, conclusion and recommendations for further studies.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter reviews related literature relevant to the current study. It discusses the origin and geographical distribution of cowpea, its taxonomy, importance and its production in Ghana, West Africa and the world at large. It also reviews literature on some nutritional characteristics (proximate composition), antinutritional factors, functional properties and mineral properties of cowpea and why they are utilized in the assessment of food.

Classification of Cowpea

The great diversity in wild and cultivated cowpea made considerable uncertainty and confusion about the nomenclature and the classification of the crop. It is now agreed that the botanical name of cowpea is *Vigna unguiculata* (L) Walp (Lush & Evans, 1981; Singh, 2014). Cowpea belongs to the family of Papilionaceae and has 22 number of chromosomes (2n = 22) (Tony & Nixon, 2015). The genus, Vigna which comprises more than 150 varieties was named after Domenico Vigna, a professor of Botany and Director of Botanic Garden of Pisa in 1824 (Singh, 2014). The main groups in African comprises subgenera *Vigna* and *Haydonia*, the America sub-genera *Sibmoidotropis* and *Lasiopron* as well as the Asian sub-genus *Ceratropis* (Timko & Singh, 2008). The sub-specie, *unguiculata*, of *Vigna unguiculata* that are mostly cultivated are *unguiculata, biflora, sesquipedalis* and *textilis* (Ng & Marechal, 1985). The subspecies of *Vigna unguiculata* (*dekindiana*, *stenophylla* and *tenius*) are intermediate wild progenitors of cultivated cowpea and form the main part of the primary gene pool of cowpea.

Origin and Geographic Distribution of Cowpea

The name 'cowpea' might have arisen from the fact that the crop was important source of hay for cows in South-eastern United States of America and other parts of the world (Timko, Ehlers, & Roberts, 2007). Indeed, prior to the Second World War, cowpea was a major forage crop for horses and cattle (hence the name cowpea). In Africa, cowpea has different noble local names; 'ewa', 'niegbe' and 'wake'. In Brazil, it is mostly known as 'caupi'. The United States of America however, also have different important local names for cowpea; 'crowders', 'blackeyed peas', 'pinkeyes', 'southern peas' and 'field peas' (Chandrasekaran, Rajkishore Vijaya & Ramalingam, 2015). Many Ghanaians simply call cowpea as "beans" but have different local names such as 'adua', 'asidua', 'yor', 'bangi', 'ayi', 'benga' and 'sangi'. These local names are mostly dependent on the tribes or ethnic groups in the country.

The center of origin and domestication of cowpea, over many years, have generated considerable discussion and speculations due to the parallel presence of diverse and morphologically different types around the world. Initially, both Africa and India were speculated to be the origin and domestication of cowpea (Singh, 2014). However, records has it that no wild cowpea accessions are found in India but Africa, hence it could possibly be considered that Africa is the originator of the peas. Moreover, aside southeastern Africa which is noted for diverse wild forms of cowpea, a survey of the germplasm accessions from Nigeria, Niger, Burkina Faso and Ghana showed greater diversity than accessions from other areas in Africa, which concludes that West Africa was the primary center of domestication (Nwokolo & Ilechukwu, 1985; Singh, 2014; Tony & Nixon, 2015).

According to Coulibaly, Pasquet, Papa and Gepts (2002), some evidence gathered on amplified fragment length polymorphism analysis suggested that domestication of cowpea occurred in northern eastern Africa. This analysis could have taken place together with the domestication of sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum typhoides*) in the third millennium (Steele, 1976). On the other hand, report from Ba, Pasquet and Gepts (2004), indicates that cowpea was probably domesticated by farmers in West Africa. Carbon dating of cowpea from the Kintampo rock shelter in central Ghana reported by Flight 1976 (as cited in Quin, Singh, Raj Mohan, Dashiell, & Jackai, 1997) is the oldest archeological evidence of cowpea found in Africa.

Additionally, it is believed that cowpea was first domesticated in Africa about 1700 to 1500 BCE and must have been moved to Asia more than 2000 years ago and later to America through Jamaica in 1675 via slave trade (Singh, 2014). Cowpea was introduced to the Indian sub-continent from Africa (Allen, 1983). The crop had reached Europe from Asia and has been cultivated in southern Europe since the 8th century and perhaps since pre-historic times (IITA, 1982). Cowpea was introduced to the West Indies in the 16th century by the Spanish and was taken to the (Purseglove, 1976). The slave trade from West Africa resulted in the crop reaching the southern USA in the early 18th century (Fig 1). However, many United State cultivates appeared more closely related to germplasm from Asia or southern Europe than West Africa (Fang, Chao, Roberts, & Ehlers, 2007). Cowpea is now grown throughout the tropical and sub-tropical regions in the world (Fig 1).

Currently, the collaborators of the International Institute of Tropical Agriculture (IITA) in Nigeria and other countries known to produce cowpea have more than 100 cowpea grown countries. In Africa, Nigeria is the largest producer and consumer of cowpea with 2.9 million tonnes produced annually whiles the Niger Republic produces more than 1.8 tonnes annually. Ghana and other West African countries are no exemption (D'Andrea, Kahlheber, Logan, & Watson, 2007; Lambot, 2002; Lush & Evans, 1981; Singh, 2014).

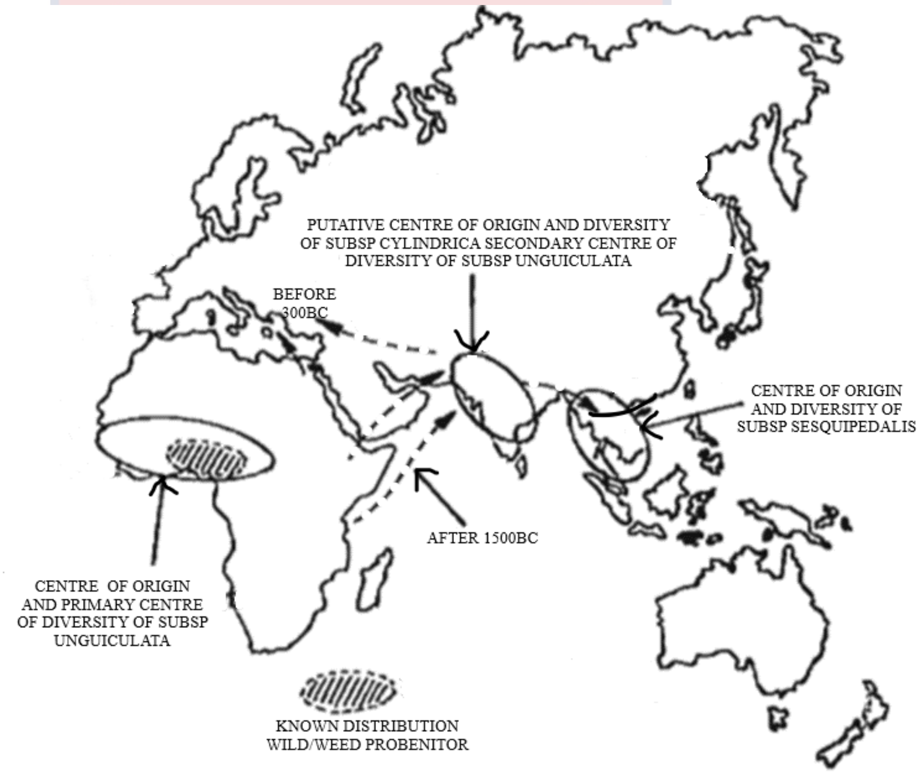

Figure 1: Centers of origin and dispersal routes of cowpea (adapted from Steel & Mehra, 1980)

Importance of Cowpea

The crop is of vital importance to the livelihood of several millions of people in Western and Central Africa especially in rural and some urban families that make up the larger part of the population of these regions. Cowpea is important and therefore used for several purposes; food, animal feed, income generation as well as soil improvement (Langyintuo et al., 2003; FAO, 2004). It is estimated that 52 % of African cowpea production is used as food, 13 % as animal feed, 10 % as seed, 9 % for other uses and 16 % is wasted (IITA, 2018).

Generation of Income

Cowpea is an important annual cash crop which creates the opportunity for millions of people around the globe, both farmer and traders, and hence leads to generation of income (SARI, 2012). This could be the reason to the production of more than 5.4 million tons of dried cowpeas worldwide (IITA, 2018; Langyintuo et al., 2003; Asare, Agbemafle, Adukpo, Diabor & Adamtey, 2013). Trading in freshly produced seeds and processed food and snacks provides farmers, rural and urban women with the opportunity to earning an income (Singh, Ehlers, Sharma & Filho, 2002). In Ghana, cowpea farmers and end users of the crop gains benefit through enhanced food security, crop diversity, cash income, fodder bank, in situ grazing after harvesting when cowpea grain prices peak and when good quality fodder is scarce (Nhamo & Mupangwa, 2003; IITA, 2018). Cowpea therefore, plays an important role in the lives of people in Africa and other parts of the developing world, and so is a valuable and dependable commodity that produces income for farmers and traders (Singh, 2002).

Food and Health Benefits

Cowpea is a food and animal feed crop grown in the semi-arid tropics covering Africa, Asia, Europe, United States and Central and South America (Singh, Chamablis & Sharma, 1997). Cowpea is widely consumed in the developing Sub-Saharan Africa because it is nutritious, tasty, filling, cheaper and easily affordable compared to animal protein. Cowpea is an important crop in Ghana due to its contribution to food and nutrition security besides that of national GDP and farmer incomes; hence demand for the product of the crop is increasing because of high population growth mainly in the urban areas (ICRISAT, 2012). In Ghana, cowpea provides vegetable protein and minerals to over 70 % of its population [Ministry of Food and Agriculture (Quaye et al., 2011]. It is also the second most important grain legume and currently a food security crop in the country (MOFA, 2010). It has a variety of uses as a nutritious component in human diet (Langyintuo et al., 2003). The mature dried seeds, immature seeds and pods and young leaves of cowpea constitute food for human consumption in Africa (IITA, 2018).

Cowpea can be used at all stages of growth as a vegetable crop. The leaves contain significant amount of nutritional value (Ahenkora, Adu-Dapaah & Agyemang, 1998). The tender green leaves are important food sources in Africa and are prepared as a pot herb like spinach. Immature green pods are used in the same way as snap beans, often being mixed with cooked dry cowpeas or with other foods (Aremu, Olaofe & Akintayo, 2006). Nearly mature 'fresh-shelled' cowpea grains are boiled as a fresh vegetable or may be canned or frozen. Dry mature seeds are also suitable for boiling and canning hence used to prepare main dishes, snacks and in the preparation of bakery products.

Cowpea is a major source of dietary protein that nutritionally complement low-protein staple foods (SARI, 2012). Crude proteins of some cowpeas have been reported to be as high as 39 % and hence often referred to as the poor man's meat (Onwuliri & Obu, 2002). This can be a source of protein for vegetarians. Cowpea has also been found to contain essential amino acids (leucine, histidine, thyrosine, alanine, glycine, arginine, threonine, glutamic acid, proline as well as aspartic acid) (Aremu et al., 2006). Amidst the high protein contents, cowpea also contains minerals and vitamins which are recommended in daily diets. It is rich in vitamin A and C and also has appreciable amount of thiamin, riboflavin and niacin. The grain contains about 25 % protein and 64 % carbohydrates (Nawab, Alam & Hasnain, 2014) and therefore has a tremendous potential to contribute to the alleviation of malnutrition among resource-poor farmers. Since the diet of rural and urban poor Africa consists of starchy food made cassava, yam, plantain and banana, millet, sorghum, and maize; the high protein content of cowpea (20 – 25 %) compensate for large proportion of carbohydrates in the diet (Lambot, 2002). Cowpea utilization is critical in many parts of West and Central Africa as a cheap source of protein for those who cannot afford meat or fish (IITA, 2006) and as a traditional staple food (Langyintuo et al., 2003).

The dry grain is the main product consumed by humans. In West and Central Africa, cowpea grain is used for a variety of dishes; the whole grain is mainly eaten with cereals or used as a ingredients of soups or stews, while milled cowpeas are mostly used to make fritters or steamed cakes (Langyintuo et al., 2003). In Ghana, the dry grains can be processed into cowpea flout for preparation of ‘agawu’ and ‘koose’ which are nutritious and popular combination with maize or millet porridge as a meal in addition to the usual popular ‘gari’ and beans, ‘waakye’, ‘apprepransa’. Others include ‘gable’, ‘nyonbeeka’, ‘tubani’, ‘gora’ and ‘nagbechinge’ (maize and beans) popular in Kumbungun district of Ghana (Quaye, Adofo, Madode & Abizari, 2009).

Innovative and appealing processed-food products using dry grass such as cowpea-fortified baked foods, extruded snack foods and weaning foods have been developed (Phillips et al., 2003). Varieties of cowpea with persistent green grain constitute useful product for frozen vegetable application which have been developed through breeding programs in the United States of America (Singh et al., 2002).

The young leaves, green pods, seeds and roots which contain vitamins and mineral elements constitute a source of nutrients for humans (Ehler & Hall, 1997; Nielsen, 1998). Estimated protein content of cowpea leafy parts consumed annually in Africa and Asia is equivalent to five million tons; 30 % of total food legume production in lowland tropics (Singh, 2002). With the ability of cowpea to produce nutritious leaves within 20 days, the National Aeronautics and Space Administration (NASA) is considering sending cowpeas to the international space station to provide food for astronauts (IITA, 2010).

In developed countries, cowpea is expected to become increasingly important as consumers seek interesting and healthy 'new' foods and rediscover 'traditional' foods that is low in fat, high in fibre and that have other benefits (Timko et al., 2007). Fat contents of 100 advanced breeding lines from IITA exhibited a range in fats contents from 1.4 to 2.7 % (Nielsen, Brandt & Singh, 1993) while fibre content is between 4.2 % to 4.8 % (Appiah, Asibuo & Kumah, 2011). Besides being low in fat and high in fibre, the protein grain legumes (cowpea) has been shown to reduce low intensity lipoproteins that are implicated in heart disease (Phillips et al., 2003). In addition, grain legume starch is digested more slowly than starch from cereals and tubers (Phillips et al., 2003). Protein isolates from cowpea grains have good functional properties, including solubility emulsifying and foaming activities (Rangel et al., 2004), and could be a substitute for soy protein isolates for persons, especially infants, with soy protein allergies.

When boiled and eaten as a food, cowpea is considered to have interesting medicinal properties which includes diuretic activity, antioxidant property, antidiabetic activity and antibacterial activity (Chandrasekaran, Rajkishore-Vijaya & Ramalingam, 2015). An infusion of seed can be taken orally to treat amenorrhea whilst powdered roots eaten porridge are believed to treat painful menstruation, epilepsy and chest pain (Van Wyk & Gericke, 2000). The leaves of cowpea are applied on burns and can be used as a snuff to treat headaches. Emetics made from plants are taken to relieve fever (Hutchings, Scott, Lewis & Cunningham, 1996). Traditional healers use it to treat urinary shistomiasis (bilharzias) (Ndamba, Nyazema, Makaza, Anderson & Kaondera, 1994). The seeds are cooked with the roots of other herbs to treat epilepsy, bilharzia, chest pains and constipation (Kritzinger, Lall, Aveling & Van Wyk, 2005).

Furthermore, cowpeas contain bioactive anti-oxidants such as vitamin C, carotenoids and phenolic compounds (Cai, Hettiarachchchy & Jalaluddin, 2003; Dobaldo et al., 2005). It has been reported that some phenolic compounds existing as anti-oxidants represent important group of bioactive compounds in foods which may prevent development of diseases including atherosclerosis and cancer (Formica & Regelson, 1995). Again, the cowpea leaves are known to contain flavonoids (Lattanzio, Cardinalli, Linsalata, Parrino & Ng, 1997) of which some are known to exhibit anti-microbial properties (Aziz, Farag, Monsa & Abo-said, 1998).

Animal Feed

In many areas of the world, cowpea foliage is an important source of high-quality hay for livestock feed (Bationo, Ntare, Tarawali & Tabo, 2002). The above ground parts of cowpea, except pods, are harvested for fodder. Therefore, the leaves are used as leguminous fodder and also as a hay to livestock during the dry season when animal feed becomes scarce (Haruna, Asare, Asare-Bediako & Kusi, 2018; Asare et al., 2013). In the semi-arid regions of Nigeria, cowpea fodder is an important resource for livestock. The take-off of cowpea fodder contributes to feed supplies for large and small ruminants. Cowpea hay is critical in feeding animals during the dry season in many parts of West Africa (Bationo et al., 2002). Cowpea has extra floral nectarines on its petioles and leaflets; these nourish beneficial insects such as honey bees, lady beetles, predatory wasps, ants and soft-winged beetles. Weaver birds and rodents also feed on developing pods or seeds when accessible.

Soil Fertility Improvement

Cowpea is a valuable component of farming systems in many areas because of its ability to restore soil fertility for succeeding non-leguminous crops grown in rotation with it (Carsky, Vanlauwe & Lyasse, 2002) or as an intercrop. Cowpea improves soil nitrogen fertility by fixing atmospheric nitrogen through mutualistic association of the roots nodules with *Bradyrhizobium* bacteria and it further exhibits effective symbiosis with rhizobium symbiont (Asare et al., 2013), thereby making it adaptable to soil with low fertility and tolerant to range of soils pH, as well as considerable drought conditions (Fery, 1990).

The seedlings are used as green manure and the plant residues (shoot and root) remaining after harvest, also form organic manure. The use of cowpea as soil-building cover crop also enhances organic farming for the production of organic food and also help to check erosion (Asare et al., 2013). Animal droppings obtained after feeding on cowpea serve as organic manure to enrich soil fertility.

World Production of Cowpea

It is estimated that the total area under production is about 12.5 million hectare which gives an annual production of over 3 million tons worldwide. This yielded global production of 5.5 million metric tons of dried cowpeas grain in 2010 (FAOSTAT, 2012). Africa alone accounts for 91% of the world production of cowpea. The Central and West Africa alone account for 64 % covering the area of about 8 million hectares (Tony & Nixon, 2015). Nigeria is the largest producer and consumer of cowpea. Nigeria produces about 61 % and 58 % of cowpea in Africa and worldwide respectively. Niger is the second largest producer of cowpea, followed by Brazil, Burkina Faso, Myanmar, Cameroun and Mali (ICRISAT, 2011). A growing number of cowpea readily available in West Africa have been reported to contain the needed nutrients if they are well processed and blended (Fernandez et al., 2002). Cowpea stands out in importance among the 12 primary grain legumes both in Ghana and Nigeria (Broughton, Hernandez, Blair, Beebe & Gepts, 2003). Globally, it is not easy to obtain reliable data on legumes such as different varieties of cowpea cultivated in a particular area because they are mostly involved in mixed-cropping and subsistence cropping (Langyintuo et al., 2003; Tony & Nixon, 2015).

Cowpea Production in Ghana

Cowpea is an annual cash crop in Ghana. According to the 2012 report on legume market analysis of Ghana, on the basis of cultivation and consumption, cowpea stands second to groundnut to be produced all year round. With respect to cultivation alone, cowpea is the most important leguminous crop in Ghana (SARI, 2012). The production of cowpeas in Ghana is much concentrated in the three northern regions (Fig 2). It was estimated that about 143,000 MT covering 156,000 ha of cowpeas were produced in Ghana and this made the country the fifth cowpea producer in the sub-Saharan Africa (Haruna, Asare, Asare-Bediako & Kusi, 2018). Cowpea production increased progressively in 2004 from 142,300 MT to 219,300 in 2010 (Egbadzor, Yeboah, Offei, Ofori & Danquah, 2013). Cowpea production in Ghana has been influenced by exotic ones due to their susceptibility to some diseases and pests. Ghana imports 10, 000 metric tons of cowpea annually; 20 % from Burkina Faso and 70 % from Nigeria. There is a huge production and consumption gap which can be reduced by breeding improved cultivars desired by farmers (Azam, Farhatullah, Nasim & Shal-Igbal, 2013).

Cowpea is economical and nutritional and therefore makes it a good choice crop for serving food security needs in communities (Appiah, Asibu & Kumah, 2011). In view of this, consumption rate of Cowpea increased from 2008 to 2010 at 10.5 %. Recently, much attention of farmers in Ghana have been shifted towards the cultivation of cowpea due to its drought tolerance level (Haruna et al., 2018). Generally, cowpea is prepared as a whole meal or part of a meal in Ghana. It is the main raw material in meals like 'koose' (cowpea fritters) and 'gari' and beans (roasted graded fermented cassava and cooked beans). It is also utilized in soup and in the preparation stews (Asare et al., 2013).

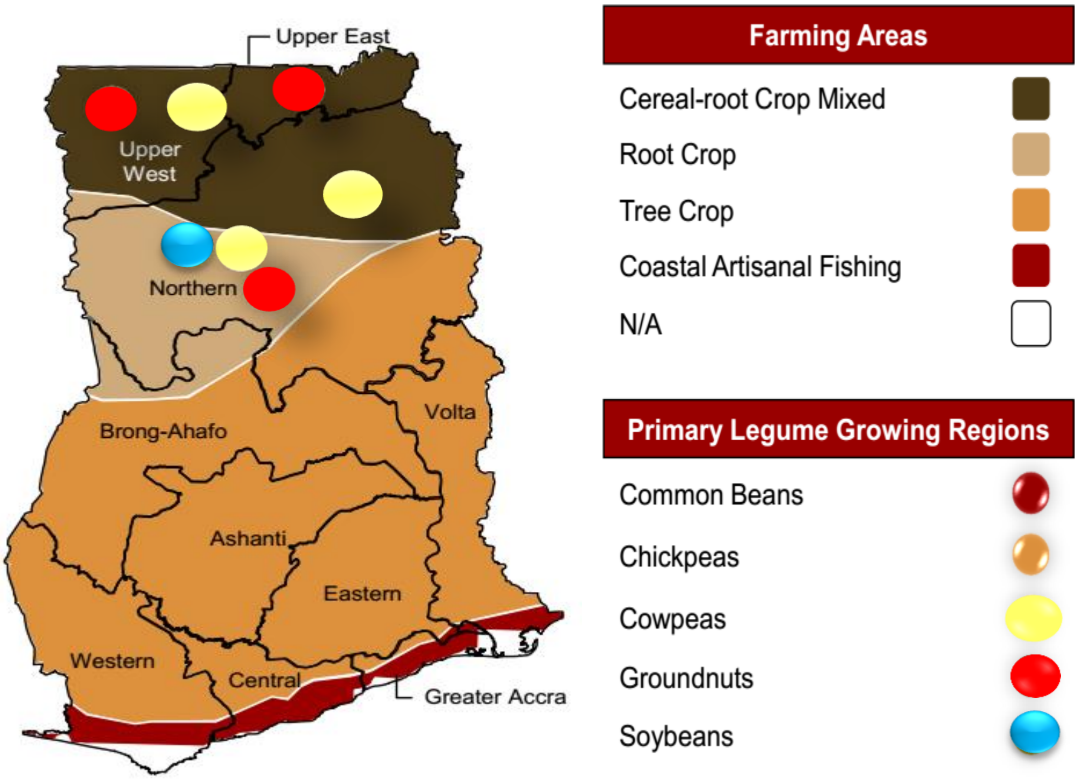

Figure 2: Ghana's primary legume. Source: Legume Market Analysis, Ghana

Constraints to Cowpea Production

Cowpea production in general is often challenged due to abiotic and biotic factors, as well as some cultural practices (Haruna et al., 2018). Tamo, Arodokoun, Zenc and Adeoti (2003) reported that the reasons for low yields are numerous but most of the times it involves a combination of limiting factors such as low plant density, shading by other crops, abiotic factors (drought, flood and poor soil fertility) and biotic factors (Arthropod pests, birds and rodents). However, in most parts of West Africa, insect pests are the most important constraints to cowpea production (Jackai & Doust, 1986; Karungi et al., 2000; Singh & Jackai, 1985). Indeed, all these factors, singly or combined, are responsible for the low grain yield, estimated at approximately 350 kg/ha that farmers in subs-Saharan Africa obtain from their cowpea fields (Mortimore, Singh, Harris & Blade, 1997; Emechebe & Singh, 1997). According to Directorate Plant production (2011) poor cultural practices including inadequate management practices in terms of plant protection, sub-optimal planting dates, low planting populations, poor weed and pest control and mixed cropping affect cowpea production.

Abiotic factors that affect cowpea production include low-pH or high-pH, saline soils, low-fertility soil, poor soil physical properties, excessively high temperature, drought, and excessive moisture (Dugje, Omoigui, Ekeleme & Ajeigbe, 2009; Taffouo, Kouamou, Ngalangue, Ndjeudji & Akoa, 2009). Cowpea is cultivated in a variety of soils but it survives better in well-drained sandy-loam soils (SARI, 2012). Reproductive development, yield potential and seed yield in cowpea are sensitive to changes in weather conditions. A number of studies have shown that most cowpea genotypes respond to photoperiod in a manner typical of short-day plants, however, some genotypes are insensitive (neutral) to a wide range of photoperiod (Timko et al., 2007). Since cowpea is grown mainly in the dry savannah areas with no irrigation facilities, irregular and inadequate rainfall especially early in the season have adverse effects on the growth of the crop although cowpea requires less rainfall and hence can tolerate drought than many other crops (SARI, 2012).

Changes in the morphology, metabolism and physiology of the crop can hinder or increase its yield (Haruna et al., 2018).

Besides, heavy biotic pressure from insects and other pests, fungi, bacterial and viral pathogens and nematodes, also affect the plant throughout its life cycle and the seeds in storage. Many of these biotic factors have influence on cowpea and hence may limit the plant's yield or nutritional level. Although heavy rain encourages early maturity and vegetative growth, pest infestation may arise (SARI, 2012). More importantly, cowpea plants are also attacked by the parasitic flowering plants, *Alectra vogelii* and *Striga gesnorioides* and can cause severe fields losses (Packer & Riches, 1993). Indeed, *Striga gesnorioides*, which is a major bottleneck to cowpea cultivation in sub-Saharan Africa (Ehlers & Hall, 1997) is gradually invading the major growing areas in Ghana. This could become a serious threat to production of the crop in the future if intervention measures are not put in place to avert the spread of the parasite.

Functional Properties

Functional properties describe how ingredients behave during preparation and cooking, how they affect the finished food products in terms of how it looks, tastes and feels. The functional characteristics of food material has been explained as the physicochemical properties that influence the behavior of proteins in food systems during processing and storage (Kyeremateng, 2015). The functional properties is subdivided into hydration properties which is the solubility, wettability, swelling, water binding, gelling and thickening. The surface properties comprises foaming, emulsion, protein-lipid interactions, film formation, lipid and flavor binding. Also, structural properties consist of elasticity, grittiness, cohesiveness, chewiness, aggregation, gelation, stickiness, viscosity, texturization, fiber formation, dough-forming ability, extrudability, and adhesion (Onimawo & Akubor, 2005). Functional properties can be classified according to the mechanism of action on three main groups: properties related with hydration (absorption of water/oil, solubility, thickening, wettability), properties related with the protein structure and rheological characteristics (viscosity, elasticity, adhesiveness, aggregation and gelification), and properties related with the protein surface (emulsifying and foaming activities, formation of protein-lipid films, whippability) (Moure, Parajo, Sineiro & Domı, 2006).

The functional properties of food components make it possible to manufacture products of desirable quality. Thus, pectins contribute to the characteristic texture of ripe apples and make perfect jellies. Other polysaccharides are efficient thickening and gelling agents at different ranges of acidity and concentration of various ions. Alginates in the presence of Ca^{2+} form protective, unfrozen gels on the surface of frozen products. Some starches are resistant to retrogradation, thereby retarding staling of bread (Sikorski, 2007). During the two most recent decades, the term functional has been primarily given to a large group of products and components, also termed designer foods, pharma foods, nutraceuticals, or foods for specific health use, which are regarded as health-enhancing or potentiating the performance of the human organism (Goldberg, 1994).

Functional properties of foods are however distinctively reported in many journal articles. The properties include emulsion capacity, swelling index, swelling power, hydration index, protein solubility, gelation properties, foam capacity, foam stability, water and oil absorption capacity, water and oil holding capacity, emulsion properties among others (Appiah, Asibuo & Kumah, 2011; Asare et al., 2013; Moses, Olawuni & Jo, 2012; Saima, Sabeera, Wani & Farooq, 2015). This is due to the high demand for promising plant sources of functional ingredients to improve food nutritional quality and also to control costs (Clemente, Vioque, Bautista, Milla & Sa, 1999).

Emulsion Capacity and Stability

Emulsification process is of paramount importance in the manufacturing of many formulated foods. Food emulsions are heterogeneous fat globules mixture with a droplet size of 0.2 to 50 µm and they can be of the oil in water (O/W) or water in oil (W/O) type (Zayas, 1997a).

Protein emulsifying activity describes the ability of the protein to be involved in emulsion formation and to stabilize the newly created emulsion. According to Avramenko, Low and Nickerson (2013), emulsions in food systems are dispersions of thermodynamically unstable immiscible liquids in which its phase separates overtime via creaming, flocculation and/or coalescence. Emulsion stability is highly dependent upon liquid droplet size and distribution, emulsion processing conditions (homogenization rates), protein characteristics (size, conformation, surface reactivity, concentration and solubility), solvent conditions (salts and temperature), phase volume ratio and continuous phase viscosity.

The ability of proteins to act as emulsifiers varies with the molecular properties of proteins (Moure et al., 2006). The unfolding of proteins at oil and water interfaces plays a significant role in the formation and stability of emulsions (Kyeremateng, 2015). Emulsion stability is the capacity of emulsion droplets to remain dispersed without separation by creaming, coalescing, and flocculation. EC and ES depend on the properties of proteins and conditions of emulsification and vary with the source of protein, its concentration, pH, ionic strength and viscosity of the system (Zayas, 1997b).

Water Absorption Capacity

Water absorption describes the amount of water absorbed by a composite material when immersed in water for a stipulated period of time or the ratio of the weight of water absorbed by a material to the weight of the dry materials (Antwi, 2011). However, in this contest, water absorption capacity (WAC) is the amount of water that can be held per unit weight of the protein material (Sikorski, 2007).

Water absorption capacity consists of adding water or an aqueous solution to food material, followed by centrifugation and quantification of the water retained by the pelleted material in the centrifuge tube (Damoradan et al., 2010). WAC is economically important for the meat processing industry because the loss of moisture adversely affects the yield and quality of the product (Ordóñez, 2005). High values of water absorption capacity are important to help maintain the moisture content of products. Water binding capacity is very essential in the preparation of baked products, extruded snacks and mash and also in the development of ready to eat foods, hence foods with high water binding capacity will assure product cohesiveness (Houson & Ayenor, 2002). The water absorption capacity of cowpea flour plays an important role in food preparation because it influences texture and sensory properties (Kyeremateng, 2015). The absorption index and solubility of water as functional properties have been reported widely by several authors because their effect on the yield of products, consistency, water retention as well as their applicability (Aziz et al., 2011; Waramboi, Dennien, Gidley & Sopade, 2011).

The protein quality of legume flours also affects their WAC (Kaur & Singh, 2005). The legume flours containing several water-loving components, such as polysaccharides and hydrophilic proteins generally have high water absorption capacity and impart soft texture to cereal-based foods (Wall, 1979; Kaur & Singh, 2005).

Oil Absorption Capacity

The oil absorption capacity shows the rate at which proteins bind to fats in foods and in the formulation of drugs and attributed mainly to the physical entrapment of oils involved (Omimawo & Akubor, 2012). Protein-lipids interaction is very important in food systems. The differences in the oil absorption capacities of food systems may be due to the variation in the presence of non-polar side chains which bind the hydrocarbon side chain of the oil as well as different protein concentration (Seena, Sridhar & Jung, 2005; Moses et al., 2012). Low fat absorption may also be due to the presence of a large proportion of hydrophilic group and polar amino acids on the surface of the protein molecules (Moses et al., 2012). These reports enable cowpea flours that exhibit higher oil absorption capacity to possess a large proportion of non-polar side chain within their protein molecules (Kyerematen g, 2015).

Oil absorption capacity plays an important role in flavor retention, improvement of palatability, increment in the mouth-feel of food and extension of shelf life where fat absorption is desired such as in doughnut and pancake production as well as in baked goods (Seena et al., 2005; Asare et al., 2013).

Foaming Capacity and Foaming Stability

Foaming is a surface active function of a protein which forms an interface that holds air bubbles suspended in a solution and prevent their collapse (Kyeremateng, 2015). A colloidal system which enables the incorporation of gas or air into a soluble surface-active agent is termed as foaming (Kinsella & Melachouris, 1976). Legumes are available in many parts of the world yet legume foam products are scarce. The properties of protein foams are usually measured in three different ways; foam stability, foam capacity and foam expansion (Boye et al., 2010). Saponins play a major role in the formation of foams in food systems. Whipping of food products facilitates partial protein denaturation which leads to foam formation by unfolding of protein molecules. Surface tension existing at the water-air interface which leads to the foaming of products is the results of the presence of some protein and peptide bonds (Kyeremateng, 2015).

According to Kempka & Prestes, (2015), proteins that exhibit low stability, show high foam capacity and vice versa. The stability of foam is affected by pH as it approaches the isoelectric point of protein due to rigidity and thickness of the adsorbed at the interface between air and water (Damodaran, Kirk & Fennema, 2012). Other factors that affect the foaming of properties include protein concentration, mixing time, a method of foaming, Film thickness, mechanical strength, protein-protein interactions and temperature (Zayas, 1997c; Sai-Ut, Ketnawa & Rawdkuen, 2009).

The stability of foam is essential in many food products such as marshmallow, mousses, chantilly and ice cream since the appearance of the food products and their shelf-life should not be denatured when subjected to heating, mixing and cutting (Doucet, Gauthier & Foegeding, 2001). The capacity and stability of foams play an important role in the formulation of shampoos, liquid beverages, toothpaste and detergents. Foaming properties are important in the preparation food and drug products because in the improvement of texture, consistency and appearance (Akubor & Eze, 2012; Chen et al., 2010)

Swelling Power

Swelling power describes the volume and weight increment of protein when freely allowed to swell in water (Balogopalan, Padmaja, Nanda & Moorthy, 1988). Swelling power depends on the nature of the material, treatment types and the process conditions. Bipolymers of flour protein and starch facilitate the development of these characteristics (Gujska, Duszkiewicz-Reinhard & Khan, 1994; Hoover & Manuel, 1995).

The degree of swelling in food systems depends on the availability of water, species of starch, temperature and extent of starch is damaged. This is because of the mechanical and thermal process as well as some protein and carbohydrates such as hemicelluloses, cellulose and pectins (Gujska, Duszkiewicz-Reinhard & Khan, 1994; Hoover & Manuel, 1995). The eating quality of most foods is related to the water retention within swollen protein and starch granules. The water absorption index of starch-based flour has also been reported to have a connection with swelling properties during heating (Iwuoha & Nwakanma, 1998). The swelling volume and cooking quality have been reported to have a possible correlation; the higher the swelling volume the better the cooking quality (Moorthy & Ramanujan, 2001). Swelling properties as a functional property are mostly considered because most foods are water-swollen systems.

Water Holding Capacity and Oil Holding Capacity

The water holding capacity (WHC) of foods can be defined as the ability to hold its own and added water during the application of forces, pressing, centrifugation, or heating (Zayas, 1997d). WHC is a physical property and it is the ability of a food structure to prevent water that could be released from the three-dimensional protein structure (Zayas, 1997d). Water interaction with proteins is expressed interchangeably many other ways; water hydration and holding, water retention, water binding, water imbibing, water adsorption, and others. Oil or water retention is the water or oil adsorbed or retained by a dry mixture of protein or starch. Water and oil protein interaction affect the color, texture and sensory properties of products. The holding capacities are characterized by the amount of water or oil held by a protein powder or solid material in the presence of excess water (Zayas, 1997d). The enhanced hydrophobic character of proteins in the flours indicates high oil holding capacity and this binds to fat via capillary action where the proteins expose more non-polar amino acids to the fat and enhance hydrophobicity (Hussain & Choudhry, 2013).

WHC is important for the formation of food texture especially in meat products and baked doughs. In Plant proteins, it is used as additives in foods to influence quality characteristics of the finished food products. Oil holding capacity plays a major role in the formulation of meat products such as sausage (Akinyede & Amoo, 2009).

Nutritional Properties

The nutritional value of food defines what food is made of and its impact on the body. Because of disease and weight control, it is particularly important to understand the nutritional value of food due to the impact on the body as it relates to cholesterol, fat, salt, and sugar intake (Thompson, 2017). The nutritional value of food which is often referred to as the proximate composition may be categorized into the various analysis; moisture content analysis, ash content analysis, fibre content analysis, fats contents, proteins and carbohydrates contents analysis.

The differences in the composition of cowpea can rely on several factors; type of soil, cultural practices, environmental and genetic factors (Appiah et al., 2011). Chemical composition and nutritional properties of cowpeas vary considerably with respect to the type of variety (Carvalho et al., 2012) therefore, for effective utilization of new varieties of cowpea for human nutrition, the removal or reduction of anti-nutrients and evaluation of their nutritional properties are necessary (Giami, 2005). Although cowpea among other legumes is rich in proteins, minerals, fats and carbohydrates, other nutrients are limited due to the presence of anti-physiological/anti-metabolic substances such as protease inhibitors, lecithins and phenolic substances (Adebowale, Adeyemi & Oshodi, 2005). Heat treatment has been shown to improve the nutritive value of legumes, oilseeds and other edible seeds by decreasing the levels of anti-nutrients and increasing protein digestibility (Giami, 2002; Giami, Adindu & Akusu, 2000).

Moisture Content of Food

The moisture content is an important factor in food preservation, quality and resistance to deterioration. It is one of the most important properties to consider when determining proximate composition of food. Accuracy and precision of moisture contents are however, mostly difficult to come by due to various factors (Bradley, 2010). Its determination is necessary to calculate the content of other food constituents on a dry weight basis. Even though moisture content is not added in the nutritional labelling of the food product, its determination is very necessary for the determination of carbohydrate contents (Nielsen, 2010).

Water exists in food product in three forms; water of hydration, free water and adsorbed water. Free water behaves as an agent of dispersion in colloids and salt solution, adsorbed water is well adsorbed to proteins and water of hydration is mostly bound to acid and basic salts (Bradley, 2010). Moisture sorption properties of food products aids in the determination of the limits at which a food substance may deteriorate. It is therefore important to know the moisture sorption characteristics in order to know the shelf life of dried food products (Al-Muhtaseb, McMinn & Magee, 2002).

Ash Content of Food

Ash content is the inorganic residue remaining after either ignition or complete oxidation of organic matter in a foodstuff (Baraem, 2017). Generally, two types of ashing are employed in food analysis; dry ashing for proximate composition and specific minerals and wet ashing via oxidation for the analysis of certain minerals (Nielsen, 2017). Ashing becomes the primary step for specific elemental analysis because certain foods are high in minerals.

It represents the total amount of minerals in food analysis. Ashing is an index for the quality of feeding materials used for poultry and cattle feeding (Adebowale et al., 2005) aside from its importance in the nutritional evaluation. Ash content is essential for the elemental analysis of animal products and certain plant products.

The ash content of most fresh foods is rarely greater than 5 %. Products such as cured bacon may contain 6 % of ash whiles that of dried beef may be as high as 11.6 %. Fats, oils, and shortenings vary from 0.0 to 4.1 % ash, while dairy products vary from 0.5 to 5.1 %. Fruits, fruit juice and melons contain 0.2–0.6 % ash, while dried fruits are higher (2.4–3.5 %). Flours and meals vary from 0.3 to 1.4 % ash. Pure starch contains 0.3 % and wheat germ 4.3 % ash (Marshall, 2010).

Fats Content

Fatty acids are ubiquitous molecules in biological systems and they occur as components of lipids, notably, phospholipids and glycolipids in membranes and triacylglycerols in seed oils of plants, oily fish, and adipose tissue (fat) in animals (Dobson, 2002). Scientifically, there is no clear definition for lipids (O'Keefe, 1998) mainly because fats are sparingly soluble in water, but show variable solubility in a number of organic solvents such as diethyl ether, petroleum ether, acetone, ethanol, methanol and benzene (Nielsen, 1998). However, The US Food and Drug Administration (FDA) has defined total fat as the sum of fatty acids from C4 to C24, calculated as triglycerides and this gives a clear path for resolution of any nutrition labeling disputes (Min & Ellefson, 2010).

Different methods are employed in the fats analysis of foods. The different solvent system used yield different results depending on the polarity when employing the use of soxhlet, Goldfish and Mojonnier extractions. The non-solvent wet extraction methods, Babcock, Gerber, and instrumental methods, infrared, density and X-ray absorption are also employed depending on the nature of the sample and the purpose of the analysis (Nielsen, 2010; Min & Ellefson, 2010). Lipids occur in foods but usually, less than 2 % but triacylglycerols deposited in animal tissues and organs of some plants can raise the lipid content up to 20 % (Ellen et al., 2003). Some lipids in fats act as building blocks in the formation of biological membranes.

Crude Fibre

Crude fibre has been and remains a common means of evaluating fibrous feeds as its digestibility is associated with plant age or maturity (Pigden, Balch & Graham, 1980). The role of fibre in human nutrition in recent scientific research has led to the development of the establishment that total dietary fibre is the polymeric substance within plant and hence resistant to the digestive enzymes in mammals. The dietary fibre plays a major role in the digestive system of mammals (Pigden et al., 1980). Dietary fibre can be grouped into two based on their water solubility, as insoluble dietary fibre and soluble dietary fibre (Antwi, 2011; Omar, Benito & Carlos, 2010). Fibre contains lignin, cellulose, and hemicelluloses and includes pectins, gums as well as galactans and it may be involved in fermentation process by microorganism and subsequent flatulence production (Rene & Francy, 1988). It is micronutrient whose target of the action, as a nutrient, is the gastrointestinal tract. It acts as a substrate for microflora in the large intestine, regulates nutrient digestion rate and also promotes normal laxation (Schneeman, 2008). The growing interest over the past 25 years of research has shown the important metabolic consequences of fibre inclusion in the human diet; reduction of risk for non-communicable diseases such as cardiovascular diseases, certain types of cancer and diabetes mellitus (Schneeman, 2008; Schneeman, 2002; Anderson et al., 2009).

Cowpea among other legumes contains about 11.2g of fibre per serving cup but other beans can go as high as 50 % of the daily value (Whitbread & MScN, 2018). Beans high in fiber include navy beans, small white beans, adzuki beans, split peas, lentils, pintos, mung, chickpeas, and kidney beans (Whitbread & MScN, 2018).

Protein in Cowpea

Research has shown that cowpea has a significant amount of protein that can satisfy the protein demand of infants. The protein percentage of cowpea flour or seed ranges from 20 % to 40 % of its dry matter (Tiencheu & Tenyang, 2016; Kyeremateng, 2015). According to FAO/WHO a minimum protein of 15 % and a maximum of 25 % are needed for maximum complementation of amino acids in foods and growth. The successful operation of legume protein isolates lies on functional properties characterized by intrinsic factors (composition and conformation of proteins), environmental factors (composition of the model system or food) and methods and conditions of isolation (Fern´, Macarulla, Barrio & Mart, 1997). The protein storage house in legumes, the globulins, alone contains about 70 % of the total proteins whiles the rest is shared between glutelins and albumins. Again, legumin and vicilin are the storage site found within the globulins in leguminous plants such as common beans (Jansman, 1996). Proteins contain different level and variety of amino acids and are important for the building of the body tissues (Antwi, 2011). The percentage protein is obtained by multiplying a calculated nitrogen value by specific Jones' factor or 6.25 depending on the kind of food of which the analysis is being conducted on (Mariotti, Tome & Mirand, 2008).

Minerals and Trace Elements

The knowledge concerning the mineral composition of foods is essential as far the nutritional and the toxicological point of view is concerned (Szefer & Nriagu, 2007). Trace metals are natural components of the environment, but elevated and potentially toxic levels sometimes occur (Kopittke, Blamey, Asher & Menzies, 2010). Minerals and trace metals level largely depend on their concentrations in the soil. The concentration of trace elements in living tissues varies between 0.01 and 100 mg kg^{-1} which generally forms a range of safe and adequate intakes (Szefer & Nriagu, 2007). Trace metals such as copper (Cu), magnesium (Mg) and Zinc (Zn) are important for the growth of plants and animals. The levels of soluble metals such as aluminium (Al) and lead (Pb) may arise in acidic soils. The mining, transport and agricultural activities can also increase the concentration of trace metals such as Cu and Pb in the soil (Kopittke et al., 2010; Batianoff & Singh, 2001). Recent scientific literature reviews indicate the influence of trace metals and minerals on nutritional analysis (Kopittke et al., 2010; Szefer & Nriagu, 2007; Babula et al., 2009). Nutritional elements are grouped into their levels or concentrations and the requirement of the body needs in order to function well. Elements grouped as macronutrients are magnesium (Mg), calcium (Ca), potassium (K) and sodium (Na). Elements grouped as micronutrients are made up of chromium (Cr), cobalt (Co), copper (Cu), molybdenum (Mo), nickel (Ni), and selenium (Se). Element chemically regarded as essential elements are arsenic (As), boron (B) and vanadium (V), whereas the toxic metals include beryllium (Be), cadmium (Cd), lead (Pb) and mercury (Hg) (Szefer & Nriagu, 2007).

Essentiality and Toxicity of some Trace Elements in Food

The concentrations of trace elements in food give important information about dietary habits of a special group, health situation of individuals and the origins of elements (Szefer & Nriagu, 2007). A review of scientific literature of the phytotoxicity levels of trace elements over the past 34 years has been established: (Pb=Hg >Cu >Cd=As >Co=Ni=Zn >Mn (Kopittke et al., 2010).

Copper (Cu) occurs in a form of organic complexes which are involved in a variety of metabolic reactions, such as the use of oxygen during cell respiration and energy utilization (Aras & Ataman, 2006). Studies have shown that the actual Cu intake should be between 1 and 1.5 mg per day for a normal adult. The body contains about 4g of Iron (Fe) for males, 3.5 g for females and 3 g or less for children (Iron Disorders Institute, 2009). About 60 - 70 % is found in haemoglobin and about 20 -39 % is stored in the liver. The recommended daily allowance (RDA) of Fe is 10-12 mg for male and 15 mg for female.

Selenium is one of the important trace, minor, elements found to support life processes. Selenium forms part of the component of the enzyme glutathione peroxidase which works together with vitamin E to catalase dismutase, an antioxidant of the body defense system (Aras & Ataman, 2006). It also contains other antioxidants; iodothyronine deiodinase and thioredoxin reductase which prevent free radicals from damaging the cells in the body (Kieliszek & Bła, 2016). Selenium can, therefore, be a substitute for some of the antioxidant activities in Vitamin E. Selenium shows variable responses to vitamin E yet needed for the growth and fertility of man and animals (Aras & Ataman, 2006). Selenium has been found recently to help the human body to function properly. RDA for selenium for an adult is set at 70 µg day^{-1}, adult women are 55 µg day^{-1} and that of children is 20–30 µg day^{-1}. Selenium intake exceeding 700 µg day^{-1} may pose problems for individuals such as hair loss and diarrhoea (Kieliszek & Bła, 2016). Notwithstanding this limit, selenium yeast content can be as high as 3000 µg/g (Pedrero & Madrid, 2009)

Antinutritional Factors of Cowpea

Even though cowpea, as a legume, serves as an important source of not only protein but fibre, the acceptability and utilization of its nutritional properties is limited due to the presence of the anti-nutrients such as cyanogens, lectins and protein inhibitors (Adebowale et al., 2005). In addition to the beany flavour and long cooking times of some varieties of cowpea, the presence of antinutrients such as polyphenols and phytic acids have been identified as one of the major factors limiting the use of the whole cowpea as food (Giami, 2005). Other anti-nutrients such as saponins, phenolics, tannins and some toxic amino acids present in legumes, have been reported not only to be heat resistance but to inhibit the activities of the digestive system (Jambunathan & Singh, 1981; Linier, 1994). Complexes of tannin-protein is insoluble whiles Protease inhibitors block either trypsin or chymotrypsin to reduce protein digestibility (Carnovale, Lugaro & Marconi, 1991).

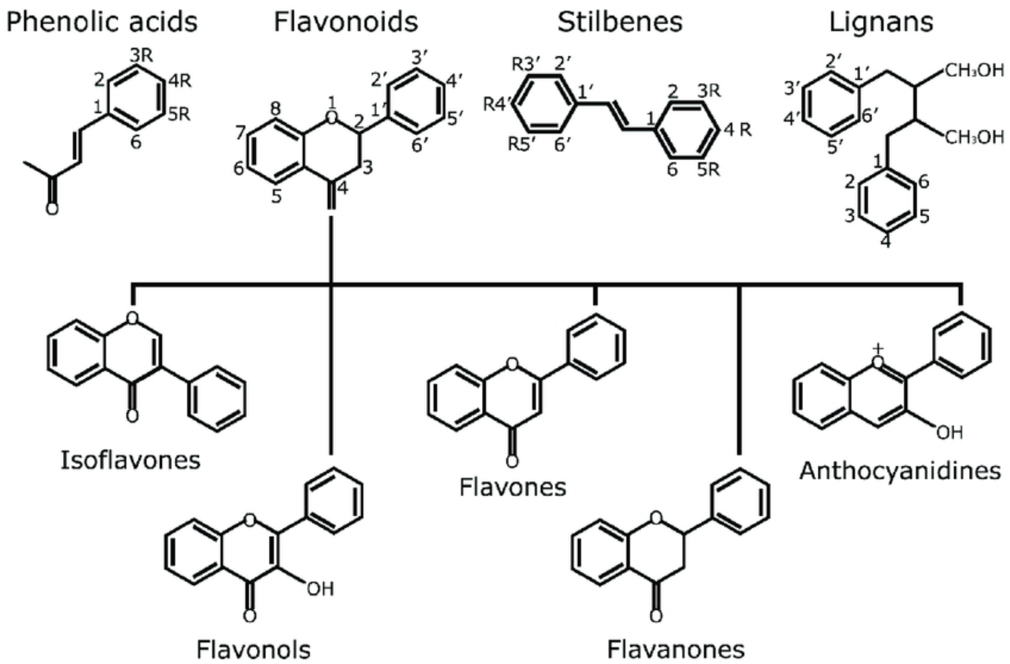

Figure 3: Classification of polyphenols (adapted from Losada Echeberria et al., 2017).

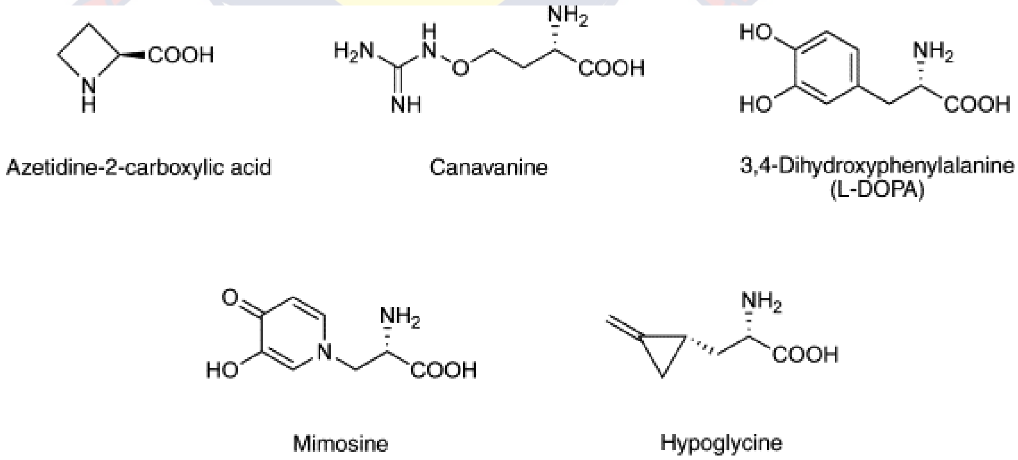

Figure 4: Chemical structure of toxic amino acids (adapted from Hisakazu & Hideaki, 2010).

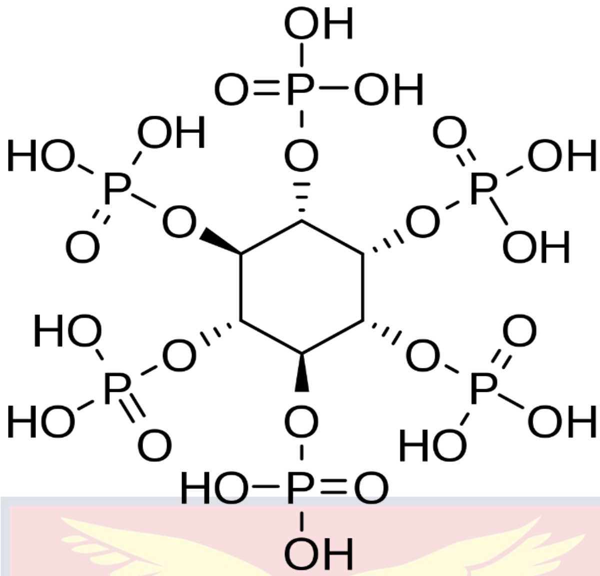

Figure 5: Chemical structure of phytic acid (adapted from Gabriel & Katarzyna, 2014)

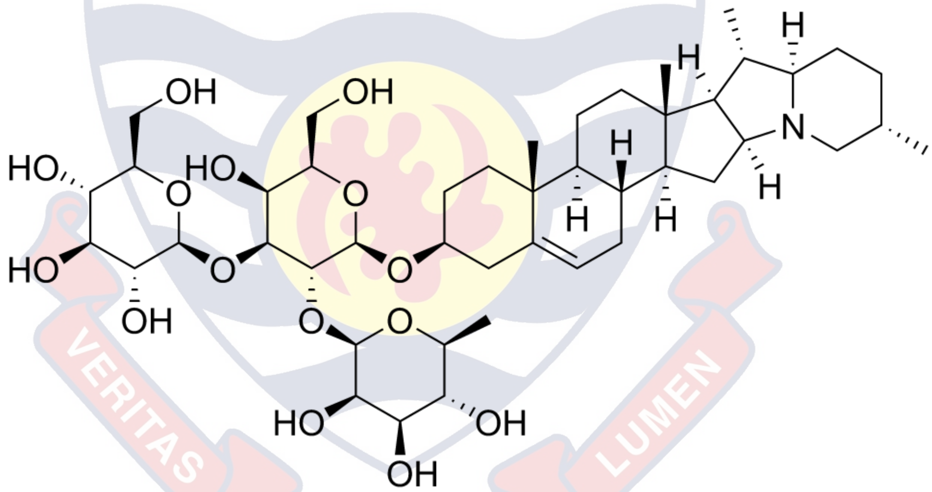

Figure 6: Chemical structure of saponins (adapted from Ozlem & Giuseppe, 2007)

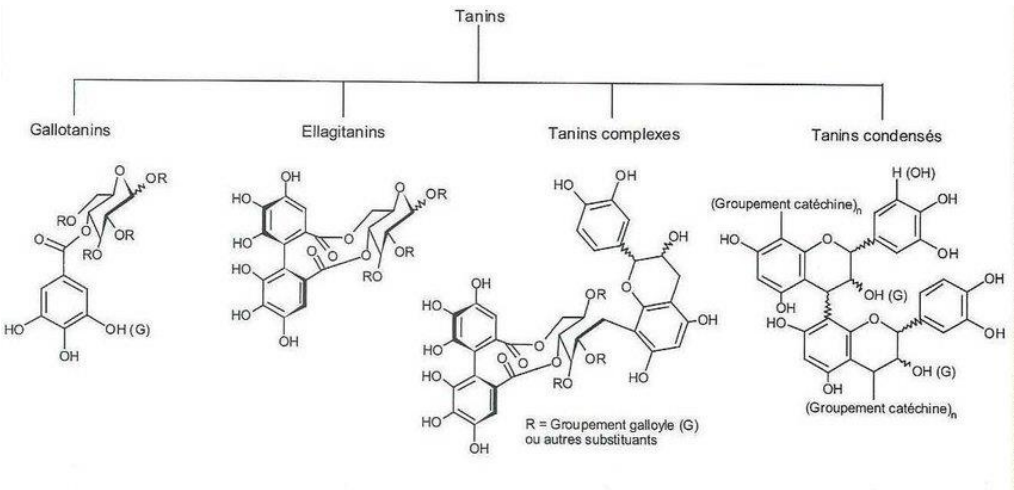

Figure 7: Tannins classification (adapted from Imane, Idrissi, Draoui, & Bouatia, 2016).

Phytates (hexaphosphates of myo-inositol) found in plant seeds chelate di- and trivalent mineral ions, such as $Ca^{2+,}$ $Mg^{2+,}$ $Zn^{2+,}$ and $Fe^{3+,}$ resulting in reduced bioavailability of trace minerals to consumers (Duffus & Duffus, 1991).

Chapter Summary

Just as highlighted in the review of related literature, there are a number of evidence that proves that cowpea originated from Africa since wild accessions were found especially in southeastern Africa. Again, the center of origin and domestication of cowpea were found in West Africa since it showed greater diversity than other accessions in other parts of Africa.

Cowpea is very important to millions of people because; it provides food and health benefits and leads to income generation, it is a source of animal feed, it also helps to improve the fertility of the soil. It was also noted from the reviewed literature that some of the functional properties give details of how food behave during preparation and cooking and the finished products in terms of it taste, feel and looks. Some examples of functional properties are emulsion behavior, holding and absorption capacities for oil and water, as well as foaming behaviors. It was also noted that the nutritional properties which describe about how food is made and its impact on the body includes the carbohydrates, protein and fibre contents. From the literature review studies have shown that minerals and trace metals are essential to the body. However, their concentrations are limited as they may be toxic at a particular amount.

CHAPTER THREE

MATERIALS AND METHODS

Introduction

In this chapter, detailed descriptions of materials used such as equipment, analytical tools, and chemical reagents, samples used for experimental analysis as well as statistical and experimental methods are outlined.

The proximate analysis except fats and protein were carried out at the Organic Research laboratory, Department of Chemistry, School of Physical Sciences, University of Cape Coast. The functional properties were conducted at the Biomedical Research laboratory and Molecular Biology and Biotechnology laboratory, both of the School of Biological Sciences, UCC. Fats and trace elements analyses were done at Radiological and Medical Sciences Research Institute (RAMSRI) laboratory, Ghana Atomic Energy Commission (GAEC). The protein and the mineral analyses were also conducted at the Animal Science Nutrition laboratory of the School of Agricultural Sciences UCC.

Sample Collection and Preparation

The seeds were previously cultivated to multiply the seeds in the Teaching and Research Farm of The School of Agriculture. The seeds of the cultivated cowpea genotypes were obtained from the Department of Molecular Biology and Biotechnology, University of Cape Coast. Twenty-three cowpea genotypes were used in this study and these include; UCC-490, UCC-484, PADI-TUYA, UCC-473, UCC-153, IT10K-817-3, UCC-328, IT10-819-4,

IT08K-193-14-1, UCC-513, IT07-125-107, UCC-EARLY, UCC-11, UCC-241, UCC-24, UCC-466, UCC-32, UCC-445, UCC-366, IT97K-499-35,

UCC-523 and IT10K-832-3 (Table 1). PADI-TUYA and APAGBAALA were already released cowpea varieties under farmer cultivation in Ghana. IT10K-817-3, IT10-819-4, IT08K-193-14-1, IT07-125-107, IT97K-499-35 and IT10K-832-3 were genotypes developed by International Institute of Tropical Agriculture (IITA), Nigeria. However, UCC-490, UCC-484, UCC-473, UCC-

153, UCC-328, UCC-513, UCC-EARLY, UCC-11, UCC-241, UCC-24, UCC-466, UCC-32, UCC-445, UCC-366 and UCC-523 were new cowpea genotypes developed by the Department of Molecular Biology and Biotechnology and were resistant to drought conditions and *Striga gesnorioides* infestation.

Figure 8: Pictures of some of the new cowpea genotypes studied

Table 1: List of Cowpea used for the Research

Samples	Name of Genotype	Colour of seed coat	Source of seed
1	UCC-490	White	UCC
2	UCC-484	White	UCC
3	Padi-Tuya	White	SARI
4	UCC-473	White	UCC
5	UCC-153	White	UCC
6	IT10K-817-3	Red	IITA
7	UCC-328	White	UCC
8	IT10-819-4	Red	IITA
9	IT08K-193-14-1	White	IITA
10	UCC-513	White	UCC
11	IT07-125-107	White	IITA
12	UCC-Early	Red	UCC
13	UCC-11	White	UCC
14	UCC-241	White	UCC
15	UCC-24	White	UCC
16	UCC-466	White	UCC
17	UCC-32	White	UCC
18	UCC-445	White	UCC
19	UCC-366	White	UCC
20	IT97K-499-35	White	IITA
21	Apagbaala	White	SARI
22	UCC-523	White	UCC
23	IT10K-832-3	White	IITA

Source: cowpea project 2015

The cowpea seeds were blended into fine flour (size of mesh, 1.00mm) using IKA–WERK Universal Mill (M 20, Germany). The flour samples were stored in air-tight zip-lock plastic bags, weighed and labelled according to their varietal names.

Proximate Composition

The proximate composition of the flour samples were analysed and the following parameters were measured and expressed as percentage; ash, moisture, fat, crude fibre, crude protein and crude carbohydrates. All the parameters were done in triplicates.

Moisture Content Determination

The moisture content was determined by the method of AOAC No. 945.38 (AOAC, 2005). Two grams of the cowpea flour of each genotype were weighed into a pre-weighed dry crucible. The flour was dried in a hot oven (Nabertherm, Germany) at 105 °C for 6 hours, cooled in a desiccator to room temperature and re-weighed afterwards using an analytical balance (Satorius CP224S-23VAC). The difference between the two weighed masses were calculated and expressed as percentage of the mass of the original sample.

$$\%\ \text{Moisture} = \frac{\text{Mass of Moisture (MM)}}{\text{Mass of Sample (MS)}}$$

MM = MS – (DC - EC)

Where:

MS = mass of sample

DC = mass of dried sample and crucible

EC = mass of empty crucible

Fat Determination

The crude fat was determined using the AOAC No. 2003.05 method (AOAC, 2005). Two grams of each flour sample were transferred into a 22×80 mm paper thimble, capped with glass wool and placed in a Soxhlet extraction chamber which was attached to a pre-weighed 250 mL round bottom flask containing 200 mL hexane (68 °C). It was assembled on Soxhlet extractor.

Contents of the thimble were refluxed for 6 hours after which the solvent was removed using rotary evaporator. The flask and its contents were cooled to room temperature and kept in a desiccator. The weight of the flask and content was determined and difference in the mass of flask was recorded as crude fat from which percentage crude fat was calculated using the expression below:

$$\% \text{ Fats} = \frac{\text{Mass of Fat (MF)}}{\text{Mass of sample}} \times 100$$

MF = FMF – IMF

Where:

MF = mass of fat

FMF = final mass of the flask

IMF = Initial mass of the flask

Ash Content Determination

Ash content was determined by the method of AOAC No. 936.07 (AOAC, 2005). Two grams of the cowpea flour of each genotype were transferred into a dried pre-weighed porcelain crucible and combusted in a muffle furnace (Nabertherm, Germany) at 600 °C for 2 hours until the sample turned white. The porcelain crucible containing the ash was kept in a desiccator and cooled to room temperature. The crucible was re-weighed and the loss in mass was calculated as percentage ash content using the formula below:

$$\% \text{ Ash} = \frac{\text{Mass of Ash}}{\text{Mass of Sample}} \times 100$$

MA = MAC - MEC

Where:

MA = Mass of Ash

MAC = Mass of Ash and Crucible

MEC = Mass of Empty Crucible

Crude Fibre Determination

A modified method of AOAC 920.86 (AOAC, 2005) was employed in the crude fibre determination. Two grams of the cowpea flour of each genotype samples were transferred into fibre bags and carefully placed in a 500 mL distilling flask containing 200 mL of 1.25 % H_2SO_4. The set-up was mounted and the content was refluxed for 45 minutes. The fibre bags were washed with a large volume of hot (100 ^oC) distilled water until the filtrate was no longer acidic. The refluxing was repeated with 1.25 % sodium hydroxide and washed with a large volume of hot (100 ^oC) distilled water to remove all alkali. The fibre bag containing the fibre sample was dried in an oven (MIDO/3/SS/F Model D3S, Genlab Widens, England), at 100 ^oC in a previously weighed porcelain crucible (B1), kept in a desiccator, and re-weighed (B2). The crucible was ignited in the muffle furnace (Nabertherm, Germany) at 600 ^oC for 30 minutes and re-weighed after cooling in a desiccator (B3). The difference in the mass of the crucible following ignition was recorded as crude fibre and expressed as a percentage of the original mass of flour using the formula:

$$\% \text{ Crude Fibre} = \frac{B1-B2}{B3} \times 100$$

B1 = mass of sample before incineration

B2 = mass of sample after incineration

B3 = initial mass of sample

Crude Protein Determination

Protein content was determined using the Kjeldahl method according to AOAC No. 2001.11 (AOAC, 2005). Two grams of the cowpea flour of each genotype were placed in a Kjeldahl flask, and 25 mL of 98 % H_2SO_4 was added with catalyst (3.5 grams potassium sulphate: 0.105 grams copper sulphate: 0.105 grams titanium oxide). The mixture was digested for 2 hours till it turned a clear solution. The solution was transferred into a 100 mL volumetric flask and the volume was made up to the 100 mL mark with distilled water. Ten milliliters of the solution was distilled and titrated against 0.1 M hydrochloric acid against a blank and titre values were recorded. Percentage nitrogen was calculated and converted to percent crude protein by multiplying by a factor of 6.25 according to the formula:

$$\% \text{ Total Nitrogen} = \frac{100\ (T-B) \times 0.007142 \times 14.007}{\text{weight of sample}} \times \frac{100}{20}$$

% Total Protein = % Total Nitrogen × 6.25

Where:

T = Titre value of sample

B = Titre value of blank

Crude Carbohydrate Determination

Carbohydrate content was determined by finding the percentage sum of all the proximate parameters and subtracting from 100 % according to the formula below:

$$100\ \% - (\%\ \text{moisture} + \%\ \text{ash} + \%\ \text{protein} + \%\ \text{fibre} + \%\ \text{fat})$$

Functional Properties

The functional properties employed in this analysis were water absorption capacity, oil absorption capacity, swelling power, emulsion activity, swelling index, foam capacity, foam stability, water holding capacity and oil holding capacity. These describe how food ingredients behave during cooking and how they affect the finished food product in terms of how it looks, tastes and feels. All the parameters were done in triplicates.

Water Absorption Capacity (WAC)

The water absorption capacity was determined using the method by Tiencheu & Tenyang, (2016). One gram of the cowpea flour of each genotype was mixed with 10 mL of distilled water and vortexed (Vortex Genie 2 Mixer, USA) for 30 seconds. The emulsion formed was incubated at a temperature of 20 °C for 30 minutes and then centrifuged at 13,600 x g for 10 minutes at 25 °C. The supernatant was decanted and measured as volume of water absorbed. The volume of water absorbed was divided by the weight of the cowpea flour to obtain the water absorption capacity of the diet and expressed in mL/g.

$$\text{WAC}\left(\frac{\text{mL}}{\text{g}}\right) = \frac{\text{Volume of water absorbed}}{\text{Weight of flour}}$$

Oil Absorption Capacity (OAC)

The oil absorption capacity was determined by the method of Tiencheu and Tenyang, (2016). One gram of the cowpea flour of each genotype was mixed with 10 mL of refined oil (frytol) and vortexed for 30 seconds. The emulsion formed was incubated at a temperature of 20 ^{o}C for 30 minutes and then centrifuged at 13,600 x g for 10 minutes at 25 ^{o}C. The supernatant was decanted and measured as volume of water absorbed. The volume of oil absorbed was divided by the weight of the cowpea flour to obtain the water absorption capacity of the diet and expressed in mL/g according to the formula:

$$\text{OAC}\left(\frac{\text{mL}}{\text{g}}\right) = \frac{\text{volume of oil absorbed}}{\text{weight of flour}}$$

Swelling Power (SP)

The swelling power was determined according to the method described by Appiah, Asibuo and Kumah, (2011). One gram of the cowpea flour of each genotype was mixed with 10 mL distilled water in a centrifuge tube and heated in a hot water bath at 80 °C for 30 minutes while continuously shaking the tube. After heating, the suspension was centrifuged at 1000 x g for 15 minutes. The supernatant was decanted and the weight of the paste was taken using the formula below:

$$\text{SP (g)} = \frac{\text{weight of paste}}{\text{weight of dry flour}}$$

Emulsion Activity (EA)

Emulsifying activity was determined according to the method of Neto, Narain, Silva and Bora, (2001). Five milliliters of flour dispersion in distilled water (10 mg/mL) was be homogenized at 1 minute with 5 mL oil. The emulsions was centrifuged at 1100 x g for 5 minutes. The height of the emulsified layer was measured and recorded whiles the height of the total contents in the tube was also determined using a meter rule. The EA was calculated by using the formula below:

$$\text{EA (\%)} = \frac{\text{Height of emulsified layer in the tube}}{\text{Height of the total contents in the tube}} \times 100$$

Swelling Index (SI)

The swelling index was determined according to a modified method proposed by Kyeremateng, (2015). One gram of the cowpea flour of each genotype was transferred into a 10 mL graduated measuring cylinder and tapped several times to remove air spaces. Five milliliters distilled water was carefully added to the flour sample without agitation and the volume occupied by the sample was recorded. The content in the measuring cylinder allowed to stand undisturbed for 30 minutes. The volume of soaked flour sample was recorded and the change in volume after swelling of the flour sample was then determined as stated below.

$$\text{SI (mL)} = \frac{\text{volume occupied by flour after swelling}}{\text{volume occupied by flour before swelling}}$$

Foam Capacity (FC) and Foam Stability (FS)

The foam Capacity was determined by slightly modified the method proposed by (Hussain & Choudhry, 2013). The seed flour (2 grams) of each genotype was dispersed in 100mL distilled water in a 200 mL beaker and homogenized for 2 minutes in a kitchen stick blender (Kenwood HB510, Japan). The homogenized solution was transferred into a 200 mL measuring cylinder and the volume recorded. The volume of the foam on top of the solution was also recorded and the FC was calculated. The content was allowed to stand for a minimum of 30 minutes and the volume of the foam was measured again and the foam stability was calculated as below:

$$\text{FC (\%)} = \frac{V1}{V2} \times 100$$

$$= \text{FS (\%)} = \frac{Va}{Vi} \times 100$$

Where:

V1 = Volume of foam

V2 = Volume of homogenized mixture

Va = Volume of foam after 30 minutes

Vi = Initial foam volume

Water Holding Capacity (WHC)

The water holding capacity was determined by a modified method of Hussain and Choudhry, (2013). The seed flour of each sample, 1 gram, was vortexed (Vortex Genie 2 Mixer, USA) with 10mL distilled water in pre-weighed centrifuge tube for 10 seconds every 5 minutes for 30 minutes. After standing at room temperature for 30 minutes, the sample was centrifuged for 15 minutes at 1000 x g. The sediments were weighed after complete removal of the supernatant. The WHC was calculated according to the formula below:

$$\text{WHC (g)} = \frac{W2 - W1}{Wo}$$

Where:

W2 = weight of centrifuge tube plus sediments

W1 = weight of centrifuge plus sample (flour)

Wo = weight of the sample

Oil Holding Capacity (OHC)

The oil holding capacity (OHC) was determined by a modified method of Hussain and Choudhry, (2013). One gram the seed flour of each genotype was vortexed (Vortex Genie 2 Mixer, USA) with 10 mL refined oil (frytol) in pre-weighed centrifuge tube for 10 seconds every 5 minutes for 30 minutes. After standing at room temperature for 30 minutes, the sample was centrifuged for 15 minutes at 1000 x g. The sediments were weighed after complete removal of the supernatant. The Oil Holding Capacity was calculated according to the formula below:

$$\text{OHC (g)} = \frac{W2 - W1}{Wo}$$

Where:

W2 = weight of centrifuge tube plus sediments

W1 = weight of centrifuge plus sample (flour)

Wo = weight of the sample

Mineral and Trace Metal Determination

A wet digestion method was done using nitric acid (HNO_3) and peroxide (H_2O_2) according to AOAC No. 999.11 (AOAC, 2000). The digestion was done to remove organic matter from flour to proceed mineral analysis. A mass of 2 g was weighed into 150 mL beaker. An amount of 20 mL of nitric acid and 2 mL peroxide was added to the beaker containing the 2 grams cowpea flour and digested on a hot plate in a fume chamber at 45 ^{o}C for 3 hours. After the digestion, the digest was transferred to a 20 mL beaker and topped up to the 20 mL mark with distilled water. The solution was cooled and transferred into a test-tube for mineral analysis. The calcium (Ca), Potassium (K), and Sodium (Na) contents were determined using Jenway Digital Flame Photometer (PFP 7 model), whiles other minerals analysis; selenium, manganese, magnesium, copper, zinc and iron apart from phosphorus were determined in duplicate using VARIAN Fast Sequential Atomic Absorption Spectrometer (Model AA240FS, USA). The phosphorous in the sample was determined by using ascorbic acid and ammonium molybdate reagents at wavelength of 882 nm using calorimetric method UV spectrophotometer (Spectronic 20D, USA).

Statistical Analysis

The twenty-three genotypes of cowpea obtained from the University of Cape Coast were assessed and evaluated in this study. Their data were obtained in triplicates with the aid of Microsoft® Excel 2010 software for windows 10. Results for analysis were done using the computer software; Statistical Package for Social Sciences version 21.0 software (IBM SPSS Inc., Chicago IL, USA). Significant differences among nutritional values, functional properties and mineral compositions of different varieties were verified by one-way analysis of variance (ANOVA). Tukey's multiple range tests were used to compare means statistically significant difference between samples at a 95 % confidence level. The analyses were done in triplicates and the data were presented as mean ± standard deviation.

Chapter summary

The proximate composition were analysed by using the official method of AOAC (AOAC, 2005). Most of the mineral and trace metals were determined by official method of AOAC (AOAC, 2000). The phosphorous in the cowpea was determined by calorimetric method. The various functional properties outlined in this study were also determined by using current but widely used methods utilized by food scientists.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

Introduction

In this chapter, the experimental results and findings of the study: the nutritional level (proximate composition), functional properties and mineral and trace element is thoroughly analysed and discussed.

Proximate Analysis

Proximate composition is essential in assessing the quality of food which is normally the aim for establishing the nutritional value and the overall acceptance of consumers (Moses et al., 2012). The proximate composition of the twenty-three new cowpea genotypes which are carbohydrates, proteins, moisture, fats, fibre and ash, were determined. The cowpea genotypes exhibited wide variation in fats and fibre while moisture, protein, carbohydrates and ash contents were similar among the genotypes (Table 3). The differences in their composition is dependent on the type of soil, environmental and genetic factors and cultural practices (Appiah et al., 2011). Once the cowpea genotypes were cultivated in the same conditions the changes in proximate compositions may be predominantly due to genetic factors (Asare et al., 2013).

It is very important to evaluate the moisture content in foods in order to ensure the quality. This is because, it affects the physical and chemical aspects of the food which relates with the freshness and stability for the storage of the food for a long period of time. The result of moisture content of the new cowpea sample which ranged from 10.8 % to 19.03 % (Table 3) exhibited significant difference ($p \leq 0.05$). The genotype, UCC-153, recorded the highest value (19.03 %) for the moisture content while UCC-484 recorded the least (10.8 %). The genotypes IT10K-832, UCC-523, UCC-445, UCC-Early, UCC-466, IT10K-817-3, UCC-473 and Apagbaala also recorded equally low moisture contents. Generally, the moisture values were slightly higher than other reported values; (9.15 – 9.83 %: Appiah et al., 2011) for local cowpea cultivars, (5.00 - 15.09 %: Asare et al., 2013) for some cowpea genotypes in Ghana and (9.80 – 13.90 %: Kyeremateng, 2015) for lima bean cultivars. Low moisture content of food is an indication of a longer shelf life and very high moisture content may enhance perishability of food products (Alozie et al., 2009; Temple et al., 1996). On the whole, the moisture contents of the cowpea genotypes were similar to those reported by Aremu et al., (2006) for scarlet runner bean.

Proteins play a key role in the development of the human body. It is needed by the body in large amount for the maintenance and building of body tissues. The results obtained from the protein analysis on all the cowpea samples showed significant ($p \leq 0.05$) amount of protein ranging from 23.80% (UCC-Early) to 33.80 % (Padi-Tuya). Similar results have been reported for cowpea grains (Ologhobo & Fetuga, 1984; Giami, 2005; Onwuliri & Obu, 2002; Vasconcelos et al., 2010; Carvalho et al., 2012). Among the cowpea genotypes which recorded higher crude protein values more than (25 %) were UCC-328 (28.27 %), UCC-32 (26.58 %), UCC-241 (27.42 %), UCC-490 (32.23 %), UCC-153 (26.36 %), IT07-125-107 (26.40 %) and IT08K-193-14-1 (27.87 %). The protein content of the cowpea grains in the current study were quite higher than the crude protein values reported by other researchers (20.70 - 24.00 %: Kyeremateng, 2015) and (26.53 - 29.00 %: Appiah et al., 2011) for lima beans and cowpea respectively, but lower than soybean protein (37.10 %: Iqbal et al., 2006) and other varieties of cowpea (20.10 – 25.80 %: Giami, 2005). Crude proteins of some cowpeas have been reported to be as high as 39 % (Onwuliri & Obu, 2002). The crude protein contents of cowpea grains above 25 %, as observed in this study, are considered quite high for pulses, which are staple foods consumed in many parts of the world (Iqbal et al., 2006). The difference in protein contents may be due to genetic and edaphic factors (Asare et al., 2013). This may serve as an inexpensive source of protein to feed human and livestock. More importantly, the high and moderate protein content of cowpea grains obtained in this study will help improve nutrition, reduce protein energy malnutrition (PEM) and protein deficiency conditions such as Kwashiorkor. This will be a potential alternative rich food source of protein to most people in the rural-poor and urban-poor communities who cannot afford animal based products due to low income. Protein from cowpea has also been found to have good levels of some essential amino acids (Carvalho et al., 2012; Vasconcelos et al., 2010).

The carbohydrates contents of cowpea genotypes varied significantly ($p \leq 0.05$) from each other; ranging from 43.69 % to 58.01 % with standard deviations of ± 0.83 and ± 0.32 respectively (Table 3). On the whole, UCC-Early, recorded the highest carbohydrates content of 58.01% whiles Padi-Tuya recorded the least value of 43.69 %. The genotypes; IT10K-817-3, UCC-484, IT10K-832-3 and UCC-445 also exhibited high values for carbohydrates (Table 2).

Carvalho et al. (2012) reported relatively lower variability in carbohydrate contents for thirty genotypes of cowpea cultivated in Brazil. The reported values were also higher than the carbohydrate contents of soyabean (46.80 %) (Kizito, 2010). The results were however in general agreement with what was reported by Rufina, Ngozi and Mirabel (2016) (49.26-54.09 %).

The determination of the crude fibre content of food is mandatory worldwide. It is a degree of the amount of the non-digestible cellulose, pentosans and many other constituents of this type in present foods. The analysis of the results gave an estimate of crude fiber in the new cowpea genotypes. The crude fibre contents varied significantly ($p \leq 0.05$) among the cowpea genotypes and ranged from 0.99% for UCC-328 to 4.27% for UCC-32. The values recorded for the crude fibre in the current study were higher than some previously reported works; (1.70-1.80 %: Abbey & Ibeh, 1988), (1.50-2.05 %: Mofoluke et al., 2013), (0.10-1.10 %: Olalekan & Bosede, 2010) and (1.02- 4.10 %: Khalid, Elhardallou & Elkhalifa, 2012). Nevertheless, Appiah et al., (2011) reported higher crude fibre content (4.24-4.80 %) for local cowpeas than the current study. The differences in the crude fiber content of the new cowpea genotypes may be due to genetic factors (Asare et al., 2013). The intake of dietary fiber has been reported to prevent diabetes, heart-related disease, digested tract diseases and hypertension (Brownlee, 2011; Oboh & Omofoma, 2008; Adu, 2015).

Determining the ash content is very important for nutritional evaluation (Baraem, 2017). It provides information on presence of the inorganic components (minerals) present within foods, such as calcium, phosphorous, potassium and sodium. These minerals can be essential to a healthy diet whereas others may be toxic (Nielsen, 2017). The ash content of the cowpea seed samples differed significantly ($p \leq 0.05$) from each other with values ranging between 2.48 % (UCC-32) and 4.03 % (UCC-241). UCC-466, UCC-24 and IT97K-499-35 also recorded high ash values. (Table 3). Asare et al., (2013) reported high ash contents of similar recombinant inbred lines of cowpea ranging from 4.26 % to 6.64 %. However, the results obtained in this study were similar to what was reported in literature by Appiah et al., (2011) (2.95-3.22 %) and Chinma, Alomede, & IG, (2008) (2.72-3.73 %). The ash content of complementary foods should rarely exceeds 5 % according to Protein Advisors Group (PAG, 1971) and Nielsen (2009), hence it can be deduced that, the ash content of the cowpea grains observed in the current study were within recommended range. The high ash content is a clear indication that the newly developed cowpea genotypes may be important source of minerals. Similar observations were made by other researchers (Butt & Batool, 2010; Nielsen, 2009). According to Appiah et al. (2011), the difference in the range of ash content could be influenced by the type of soil, genetic and environmental factors as well as some cultural practices.

All the cowpea genotypes exhibited low crude fat contents ranging from 0.43% (UCC-241) to 3.18 % (UCC-153); the differences among them were significant ($p \leq 0.05$) from each other (Table 3). However, the range of crude fat content of cowpea grains (0.43 % - 3.18 %) in the current study were higher than the fats content of lima bean (0.94 % - 1.66 %) (Kyeremateng, 2015) but lower than the values reported for chickpea (3.10 % - 5.50 %) (Kuar & Singh, 2007), jack bean (3.40 - 4.70 %) (Vadivel & Janardhanan, 2001) and soyabean (18.56 - 21.66 %) (Redondo-Cuenca, Villanueva-Suarez, Rodriguez-Sevilla, & Mateos-Aparicio, 2006). The fat level recommended for weaning foods according to Tiencheu and Tenyang (2016), should not exceed 10 %.

Fat contents which are more than 10 % or in excess can affect the stability of foods. This is due to oxidative deterioration which may lead to rancidification and spoilage; hence a food sample with high fat is more liable to spoilage (Tiencheu & Tenyang, 2016).

The cowpea genotypes with moderate carbohydrate values might have recorded higher protein or moisture content. Starch is the most abundant bean carbohydrate (30 % to 58 %) and therefore, the high carbohydrate content is a good indication that the cowpea genotypes could be good sources of energy (Leonardo & Francy, 1988; Appiah et al., 2011).

Functional Properties

The results of the functional properties for the 23 cowpea genotypes are exhibited in Table 4. The functional properties analysed in the current study were swelling index, water absorption capacity, oil absorption capacity, emulsion capacity, foam capacity, foam stability, water holding capacity, oil holding capacity and swelling power.

Water Absorption Capacity (WAC)

The water absorption capacity (WAC) presented in Table 3 for the 23 cowpea genotypes ranged from 1.32 ml/g for UCC-Early to 2.94 ml/g for IT97K-499-35. The cowpea genotypes, UCC-523, UCC-325, UCC-513, UCC-490, UCC-153 as well as IT07-25-107 obtained high WAC of 2.90 ml/g, 2.67 ml/g, 2.66 ml/g, 2.59 ml/g, 2.57 ml/g and 2.81 ml/g respectively. Although

WAC in this study exhibited significant difference ($p \leq 0.05$) among the cowpea genotypes, the results were higher than 1.60 g/g and 1.94 g/g reported for some cowpea varieties (Chinma et al., (2008), 1.12 g/g to 1.89 g/g for lima bean (Kyeremateng, 2015) and 1.68 g/g for soybean flour

Table 2: Proximate composition [percentage (%) dry weight basis][x] of 23 cowpeas

Sample ID.	Moisture	Ash	Fibre	Fats	Protein[y]	Carbohydrates[z]
UCC-490	13.98 ± 1.02^{abcde}	3.28 ± 0.10^{abcd}	3.47 ± 1.25^{ab}	2.31 ± 0.27^{cde}	32.23 ± 0.50^{de}	44.70 ± 1.79^{ab}
UCC-484	10.80 ± 0.04^{a}	3.25 ± 0.10^{abcd}	3.32 ± 1.18^{ab}	1.55 ± 0.44^{abcd}	25.87 ± 0.39^{ab}	55.19 ± 0.83^{fghi}
PADI-TUYA	15.00 ± 0.88^{bcdef}	3.21 ± 0.65^{abcd}	2.02 ± 0.49^{ab}	2.23 ± 0.49^{cde}	33.82 ± 0.46^{e}	43.69 ± 0.97^{a}
UCC-473	12.54 ± 0.20abc	3.03 ± 0.17^{ab}	2.91 ± 1.61^{ab}	2.63 ± 0.36^{de}	25.86 ± 0.12^{ab}	53.00 ± 1.46^{defghi}
UCC-153	19.03 ± 0.23^{g}	2.50 ± 0.20^{a}	2.17 ± 0.67^{ab}	3.18 ± 0.80^{e}	26.36 ± 1.36^{abc}	46.74 ± 2.32^{abc}
IT10K-817-3	12.69 ± 0.16^{abc}	3.61 ± 0.12^{bcd}	1.04 ± 0.15^{a}	1.71 ± 0.66^{cde}	25.82 ± 1.65^{ab}	55.11 ± 2.61^{fghi}
UCC-328	14.51 ± 2.51^{abcdef}	3.51 ± 0.07^{bcd}	0.99 ± 0.25^{a}	0.77 ± 0.14^{ab}	28.27 ± 1.14^{bcd}	51.92 ± 3.66^{cdefghi}
IT10-819-4	14.75 ± 0.13^{abcdef}	3.50 ± 0.08^{bcd}	1.97 ± 0.18^{ab}	0.84 ± 0.19^{ab}	31.92 ± 0.59^{de}	46.99 ± 0.34^{abcd}
IT08K-193-14-1	14.75 ± 0.75^{abcdef}	2.91 ± 0.63^{ab}	3.29 ± 0.83^{ab}	2.27 ± 0.41^{cde}	27.37 ± 0.75^{abc}	49.40 ± 0.90^{abcdefg}
UCC-513	15.08 ± 4.19^{bcdefg}	3.18 ± 0.23^{abcd}	3.36 ± 1.34^{ab}	0.87 ± 0.24^{ab}	24.95 ± 1.11^{ab}	52.53 ± 2.32^{cdefghi}
IT07-125-107	16.03 ± 0.33^{cdefg}	3.38 ± 0.07^{bcd}	3.47 ± 1.40^{ab}	2.49 ± 0.31^{cde}	26.40 ± 0.61^{abc}	48.20 ± 1.89^{abcde}
UCC-EARLY	11.70 ± 0.35^{ab}	3.30 ± 0.05^{abcd}	1.87 ± 0.47^{ab}	1.43 ± 0.43^{abc}	23.67 ± 0.59^{a}	58.01 ± 0.32^{i}
UCC-11	17.38 ± 1.25^{efg}	3.50 ± 0.08^{bcd}	1.62 ± 0.65^{ab}	0.97 ± 0.20^{ab}	26.61 ± 1.65^{abc}	49.89 ± 1.30^{bcdefgh}
UCC-241	15.63 ± 0.36^{bcdefg}	4.03 ± 0.45^{d}	2.84 ± 1.66^{ab}	0.43 ± 0.20^{a}	27.46 ± 2.89^{abc}	49.59 ± 4.56^{abcdefg}
UCC-24	15.20 ± 1.26^{bcdefg}	3.73 ± 0.05^{bcd}	1.44 ± 0.48^{ab}	0.87 ± 0.26^{ab}	24.42 ± 0.47^{ab}	54.32 ± 2.22^{efghi}
UCC-466	13.31 ± 0.284^{abcd}	3.95 ± 0.50^{cd}	4.11 ± 0.93^{b}	0.59 ± 0.19^{ac}	24.13 ± 0.22^{a}	53.89 ± 0.65^{efghi}
UCC-32	18.34 ± 1.55^{fg}	2.48 ± 0.22^{a}	4.27 ± 0.70^{b}	1.04 ± 0.44^{ab}	26.58 ± 1.24^{abc}	47.27 ± 1.44^{abcd}
UCC-445	13.35 ± 1.03^{abcd}	3.28 ± 0.27^{abcd}	3.34 ± 1.02^{ab}	0.73 ± 0.22^{ab}	23.79 ± 1.18^{a}	55.48 ± 0.76^{ghi}
UCC 366	14.05 ± 0.52^{abcde}	3.40 ± 0.10^{bcd}	3.12 ± 0.71^{ab}	0.45 ± 0.10^{a}	24.85 ± 0.57^{ab}	54.11 ± 1.24^{efghi}
IT97K-499-35	17.25 ± 0.22^{defg}	3.70 ± 0.22^{bcd}	3.91 ± 0.62^{ab}	0.63 ± 0.35^{ab}	25.39 ± 1.60^{ab}	49.10 ± 0.45^{abcdef}
APAGBAALA	12.96 ± 0.48^{abc}	3.08 ± 0.47^{abc}	3.17 ± 0.95^{ab}	0.98 ± 0.17^{ab}	25.13 ± 1.01^{ab}	54.65 ± 1.55^{fghi}
UCC-523	12.21 ± 0.75^{abc}	3.45 ± 0.05^{bcd}	2.52 ± 0.34^{ab}	0.97 ± 0.75^{ab}	30.25 ± 2.96^{cde}	50.58 ± 3.38^{bcdefgh}
IT10K-832-3	13.05 ± 0.18^{abc}	3.35 ± 0.35^{abcd}	2.91 ± 0.88^{ab}	0.75 ± 0.27^{ab}	24.04 ± 1.15^{a}	55.89 ± 0.52^{hi}

[x]All values in dry weight basis are means ± standard deviation (n = 3). Mean values followed by different letters in the same column are significantly different ($p \leq 0.05$). [y]Protein = N × 6.25. [z]The available carbohydrates contents was determined by calculating the percentile difference from all other constituents according to the formula: 100 % - (% moisture + % ash + % protein + % fibre + % fat)

(Edema, Sanni & Sanni, 2013). The water absorption capacity of food is greatly influenced by its carbohydrate contents. In addition, since protein has both hydrophilic and hydrophobic properties, it has the ability to bind water together in food which is an indication of WAC (McWatters et al., 2003). Therefore, the high protein content could be a factor to the high WAC. High WAC influences the textural and sensory properties during food preparations. Also, most legume seed flours containing polysaccharides and hydrophilic proteins impart soft texture to cereal based foods due to their high water absorption capacity (Kuar & Singh, 2007). The high WAC in this study indicate that the cowpeas would be useful in bulking and consistency of food products as well as their baking properties (Tiencheu & Tenyang, 2016). The differences observed in water absorption properties among the cowpea flours could be attributed to the their conformational behaviours, differences in protein concentration and the extent of their reaction with water (Butt & Batool, 2010).

Oil Absorption Capacity (OAC)

The OAC values reported in this study ranged from 1.31 ml/g for UCC-11 and 1.81 ml/g for Padi-Tuya. There were no significant differences ($p > 0.05$) in the OAC among the cowpea varieties. The OAC of the cowpea genotypes reported in this study were higher than reports for some ten cowpea varieties (0.39 - 0.54 g/g) (Chinma et al., 2008) and for lima bean which also ranged from 1.01 g/g to 1.55 g/g (Kyeremateng, 2015). Retention of oil absorbed in foods is aided by capillary action during oil absorption mechanism. This mechanism particularly involves the size of the particles, starch granules, the nature and content of protein available. Proteins that are hydrophobic in nature would prefer to bind to lipid. It can therefore be deduced that, legumes with higher OACs may also contain a higher number of amino acid residues that are hydrophobic in nature (Kyeremateng, 2015). Based on this explanation, UCC-484, UCC-490, UCC-153, UCC-328 and UCC-241 which recorded high OAC are likely to contain higher hydrophobic amino acid residues. The ability of the proteins of these cowpea genotypes to bind oil makes them useful in food systems where oil imbibition is anticipated (Appiah et al., 2011). The high OAC of the cowpea genotypes makes this functional property fit for enabling the enhancement in flavour and mouth feel when used in foods such as sausage.

Emulsion Capacity (EC)

The emulsion capacity describes the ability of a protein to be absorbed at the interfacial area of oil and water to form an emulsion (Kyeremateng, 2015). The cowpea genotypes exhibited high emulsion capacities between 43.24 % (UCC-445) and 46.61 % (UCC-Early) (Table 3) as compared to 23.30 % reported by Odedeji and Oyekele, (2011). Other cowpea genotypes in this study also recorded high EC were UCC-32 (44.84 %), IT10K-832-3 (44.84 %), IT10-819-4 (44.83 %) and UCC 328 (44.59 %) even though there were no significant difference ($p \geq 0.05$) among them. The EC values reported were lower than what was reported for lima bean (49.02-78.08 %) (Kyeremateng, 2015) and soyabean (81.70 %) (Ali, Tinay, Elkhalifa, Mallasy & Babiker, 2012). The good emulsion property of the cowpea genotypes indicates that it can be excellent binders of fat and water as good adhesive agents (Tariq et al., 2015). Therefore, the EC of the cowpea genotypes suggest they can be used as an emulsifier in many natural and processed emulsion-type products such as sausage and cakes. These differences in starch, fat, sterol and protein contents of the cowpea flours might have given rise to the variations in emulsion activities observed in the current study.

Foam Capacity (FC) and Foam Stability (FS)

Foaming ability as a functional property in food, is determined by the composition of carbohydrates and protein; It enables proteins to form a flexible cohesive film to trap air bubbles (Tariq et al., 2015; Sreerama, Sashikala, Pratape & Singh, 2012). The foam capacity in this current study for the twenty three cowpea genotypes ranged from a minimum of 23.25 % to 50.26 % for IT10-819-4 and UCC-241 respectively. There were significant differences ($p \leq 0.05$) in foaming capacities among the cowpea genotypes. Among the new cowpea genotypes that exhibited high foam capacities were UCC-490 (43.15 %), UCC-484 (40.09 %), UCC-Early (41.70 %), UCC-466 (43.52 %), UCC-445 (41.54 %), UCC-366 (46.92 %) and UCC-523 (49.02 %). These values were higher than the values reported by Tiencheu and Tenyang, (2016) for formulated weaning foods and for lima beans (Kyeremateng, 2015).

The foaming stability, also exhibited significant differences ($p \leq 0.05$), showed values ranging from 62.32 % (IT10-819-4) to 89.02 % (UCC-24) among the twenty three cowpea genotypes (Table 3).

High foamability is seen when protein is adsorbed and unfolded rapidly at air/liquid interface during bubbling. The high foam stability seen in this study could be attributed to the denaturing of the structures of protein that promoted greater electrostatic repulsion (Toews & Wang, 2013). The unstable foams formed for some of the cowpea genotypes could be due to the disproportionate bubbles formed, the concentration of protein or the pH (Makeri et al., 2017).

Good foaming stability and capacity of protein could be useful for the making of cakes, ice creams and whipped desserts (De-Wit, 1998).

Swelling Behaviours

Swelling power for the cowpea genotypes ranged from UCC-366 (4.55 g) to UCC-490 (6.55 g). There were no significant differences ($p > 0.05$) in the swelling power among the cowpea genotypes. The swelling powers of the 23 genotypes of cowpea in this study were higher than 2.77 – 5.67 g/g for some cowpea varieties reported by Asare et al., (2013), 2.65 – 2.68 g/g by Appiah et al., (2011) and 2.94 – 3.21 by Adebayo-oyetoro, Olalekan, Olatidoye, Ogundipe & Eniola, (2017). On the contrast, the swelling power results were lower than some cowpea starch, (12.6 g/g) (Nawab, Alam & Hasnain, 2014) and wheat flour and starch in relation to amylose, (7.70-11.6) (Blazek & Copeland, 2008). The differences in the swelling power may be attributed to varietal factors Asare et al., (2013). The result for swelling power for the current study is high and therefore would be useful in food preparations where swelling would be needed (Appiah et al., 2011: Asare et al., 2013). The swelling index (SI) values ranged from 0.99 ml to 1.25 ml for UCC-484 and IT10K-832-3 respectively. The results among the cowpea genotypes were significant ($p \leq 0.05$). The SI results in this study were higher than other reported values for brown cowpea composite flour, (0.45) (Iwe, Onyeukwu & Agiriga, 2016) and two cowpea cultivars in the temperate Indian climate, (0.84-1.15) (Hamid, Muzaffar, Wani, Masoodi & Bhat, 2016) but lower than other results for cowpea, (2.12-9.39) (Abu, Muller, Gyebi & Minnaar, 2005). Swelling properties is highly considered as a criteria in food quality in terms of baking (Iwe, Onyeukwu & Agiriga, 2016)

Table 3: Functional properties of Grains of 23 Cowpea Genotypes

Cowpea genotype	WAC (ml/g)	FC (%)	F.S (%)	OAC (ml/g)	S.P (g)	S.I(ml)	E.C (%)	O.H.C (g)	W.H.C(g)
UCC-490	2.59 ± 0.42^{ab}	43.15 ± 0.62^{ijk}	82.68 ± 0.28^{fghij}	1.75 ± 0.19	6.55 ± 0.43	1.22 ± 0.11^{b}	44.14 ± 0.78	2.84 ± 0.01^{a}	3.11 ± 0.01^{l}
UCC-484	1.47 ± 0.25^{ab}	40.09 ± 0.64^{ghi}	80.84 ± 0.35^{efgh}	1.60 ± 0.33	5.77 ± 0.24	0.91 ± 0.37^{a}	43.30 ± 1.11	3.36 ± 0.00^{j}	3.23 ± 0.12^{m}
PADI-TUYA	2.66 ± 0.42^{ab}	36.81 ± 0.33^{efgh}	87.60 ± 0.36^{hijk}	1.81 ± 0.16	6.23 ± 0.48	1.20 ± 0.28^{b}	43.49 ± 0.43	3.14 ± 0.04^{i}	2.94 ± 0.00^{jk}
UCC-473	1.61 ± 0.44^{ab}	42.74 ± 0.35^{ijk}	76.87 ± 0.77^{cdef}	1.55 ± 0.10	5.23 ± 0.32	1.10 ± 0.06^{ab}	43.94 ±0.67	3.05 ± 0.01^{efgh}	2.81 ± 0.01^{ghi}
UCC-153	2.57 ± 0.55^{ab}	32.40 ± 1.42^{bcde}	65.51 ± 1.56^{ab}	1.70 ± 0.19	6.10 ± 0.59	1.11 ± 0.02^{ab}	43.94 ± 0.67	3.33 ± 0.03^{j}	3.34 ± 0.04^{m}
IT10K-817-3	1.50 ± 0.44^{ab}	34.03 ± 1.29^{cdef}	73.49 ± 1.85^{cd}	1.42 ± 0.38	5.57 ± 0.14	1.22 ± 0.08^{b}	44.44 ± 0.76	2.83 ± 0.01^{a}	2.51 ± 0.00^{bc}
UCC-328	2.67 ± 0.39^{ab}	28.02 ± 0.82^{ab}	70.70 ± 2.69^{b}	1.80 ± 0.05	6.30 ± 0.61	1.19 ± 0.051	44.59 ± 1.35	3.11 ± 0.01^{ghi}	2.79 ± 0.03^{gh}
IT10-819-4	2.72 ± 0.20^{ab}	23.25 ± 1.04^{a}	62.32 ± 2.01^{a}	1.61 ± 0.27	5.88 ± 1.55	1.22 ± 0.02^{b}	44.83 ± 1.72	3.04 ± 0.00^{defgh}	2.96 ± 0.13^{k}
IT08K-193-14-1	2.26 ± 0.62^{ab}	29.81 ± 1.16^{bc}	88.68 ± 1.57^{jk}	1.56 ± 0.03	5.65 ± 1.21	1.06 ± 0.00^{ab}	43.30 ± 1.11	3.14 ± 0.01^{i}	3.76 ± 0.00^{o}
UCC-513	2.66 ± 0.39^{ab}	23.27 ± 1.11^{a}	63.88 ± 2.40^{ab}	1.64 ± 0.04	5.79 ± 1.16	1.24 ±0.12^{b}	43.75 ± 0.98	3.00 ± 0.00^{cdef}	3.14 ± 0.01^{lm}
IT07-125-107	2.82 ± 0.82^{ab}	46.29 ± 0.72^{jkl}	87.90 ± 0.36^{ijk}	1.59 ± 0.07	4.88 ± 1.22	1.24 ± 01^{b}	44.14 ± 0.78	3.01 ± 0.00^{cdef}	2.90 ± 0.19ijk
UCC-EARLY	1.32 ± 0.32^{a}	41.70 ± 0.40^{hij}	78.01 ± 1.41^{def}	1.56 ± 0.08	4.70 ± 1.52	1.13 ± 0.01^{ab}	46.61 ± 3.75	3.03 ± 0.01^{defgh}	2.41 ± 0.02^{a}
UCC-11	2.73 ± 0.41^{ab}	31.36 ± 0.84^{bcd}	79.52 ± 0.59^{defg}	1.31 ± 0.34	6.37 ± 1.09	1.23 ± 0.02^{b}	44.59 ± 1.35	3.11 ± 0.01^{hi}	2.90 ± 0.01^{ijk}
UCC-241	2.62 ± 0.35^{ab}	50.26 ± 0.36^{l}	88.64 ± 0.25^{jk}	1.73 ± 0.20	6.54 ± 1.21	1.20 ± 0.04^{b}	44.19 ± 0.34	2.98 ± 0.00^{bcde}	2.77 ± 0.12^{fgh}
UCC-24	2.36 ± 0.75^{ab}	38.66 ± 1.33^{fghi}	89.64 ± 0.36^{k}	1.60 ± 0.24	5.10 ± 1.56	1.15 ± 0.02^{ab}	43.94 ± 0.67	3.02 ± 0.01^{cdefg}	2.65 ± 0.03^{e}
UCC-466	1.62 ± 0.49^{ab}	43.52 ± 4.65^{ijk}	74.83 ± 7.77^{cde}	1.52 ± 0.25	5.24 ± 0.39	1.25 ± 0.01^{b}	43.30 ± 1.11	2.90 ± 0.01^{ab}	2.38 ± 0.02^{a}
UCC-32	2.70 ± 0.30^{ab}	35.83 ± 0.34^{defg}	81.33 ± 2.30^{efghi}	1.56 ± 0.19	6.08 ± 1.20	1.17 ± 0.01^{ab}	44.84 ± 0.42	2.95 ± 0.03^{bc}	2.84 ± 0.03^{hi}
UCC-445	2.33 ± 0.58^{ab}	41.54 ± 2.77^{hij}	85.13 ± 0.50^{ghijk}	1.60 ± 0.25	5.08 ± 1.36	1.17 ± 0.01^{ab}	43.24 ± 00	2.95 ± 0.06^{bc}	2.85 ± 0.02^{hi}
UCC-366	1.87 ± 0.59^{ab}	46.92 ± 0.37^{kl}	84.98 ± 0.53^{ghijk}	1.65 ± 0.24	4.56 ± 1.32	1.17 ± 0.00^{ab}	44.14 ± 0.78	3.15 ± 0.02^{i}	2.62 ± 0.01^{de}
IT97K-499-35	2.94 ± 0.61^{b}	46.52 ± 2.08^{jkl}	86.86 ± 2.05^{hijk}	1.63 ± 0.25	4.94 ± 2.42	1.15 ± 0.02^{ab}	43.69 ± 0.78	3.40 ± 0.00^{j}	2.53 ± 0.01^{cd}
APAGBAALA	1.70 ± 0.36^{ab}	41.09 ± 0.94^{hi}	89.02 ± 0.54^{jk}	1.53 ± 0.21	4.74 ± 1.28	1.17 ± 0.01^{ab}	43.74 ± 0.43	3.03 ± 0.02^{defgh}	2.51 ± 0.01^{bc}
UCC-523	2.90 ± 0.26^{b}	49.02 ± 1.21^{l}	87.31 ± 1.10	1.67 ± 0.62	5.26 ± 1.16	1.18 ± 0.01^{ab}	43.94 ± 0.67	3.07 ± 0.01^{fghi}	2.71 ± 0.01^{efg}
IT10K-832-3	1.81 ± 0.42^{ab}	43.55 ± 3.38^{ijk}	86.10 ± 2.77	1.52 ± 0.34	4.98 ± 1.711	1.25 ± 0.01^{b}	44.84 ± 0.99	2.96 ± 0.06^{bcd}	2.68 ± 0.03^{ef}

All values in dry weight basis are means ± standard deviation (n = 3). Mean values followed by different letters in the same column are significantly different ($p \leq 0.05$)

Oil and Water Holding Capacities

The water holding capacity, WHC, enables us to know how food system are able to sustain added water during food processing; in heating, centrifuging or during pressing (Zayas, 1997). The WHC in the current study varied significantly ($p \leq 0.05$) and ranged between 2.38 g for UCC-466 and 3.76 g for IT08K-193-1 as shown in Table 4. This result for WHC was found to be greater than the result (2.20 g/g) examined by Ragab, Babiker and Eltinay (2004) for similar pulse but less than 4.06 g/g reported by Olivos-Lugo, Valdivia-Lopez and Tecante (2010) for WHC of chia seed. The differences in the WHC results could be influenced by the presence of soluble fibre (Olivos-Lugo et al., 2010).

The oil holding capacity, OHC, is an important functional property which exhibits how non-polar protein chains are bound to one another in food systems through capillary action (Olivos-Lugo et al., 2010: Hussain & Choudhry, 2013). The result for OHC in this study significantly ($p \leq 0.05$) increased from 2.83 g/g to 3.40 g/g for IT10K-817-3 and IT97K-499-35 respectively. This range of values has been found to be higher than results of some cowpea, (1.10 g/g) (Ragab et al., 2004). Olivos-Lugo et al. (2010) also found the OHC of chia seed to be 4.04 g/g which was higher than the values in the current study. The results for OHC and WHC and the emulsion of food facilitate the formulation of bakery products and sausage production (Hussain & Choudhry, 2013: Olivos-Lugo et al., 2010).

Mineral Composition

The mineral composition of the grain among the cowpea genotypes analysed in the current study comprises the major or macro mineral elements and the minor or micro mineral elements (trace metal elements). The main difference between the two is much dependent on their requirement in the body. However, the cowpea genotypes were found to be a potential source of variable minerals elements such as potassium, magnesium, phosphorus, calcium, sodium, manganese, copper, iron, zinc, copper and selenium when the analysis were carried out.

Major Mineral Elements

The major mineral elements determined in this study were magnesium (Mg), potassium (K), sodium (Na), phosphorus (P) and calcium (Ca) and they exhibited remarkable variations as observed in Table 4. Among the major minerals determined, potassium contents were found to be the most abundant element and it varied from a minimum of 282.92 mg/100 g to a maximum of 346.34 mg/100 g. The highest potassium content of the cowpea genotypes was observed in UCC-490 (346.34 mg/100) whiles the genotypes; UCC-11, UCC-241, UCC-523 and IT10K-832-3 exhibited the least value of 282.92 mg/100 g. There were significant differences ($p \leq 0.05$) in the amount of potassium of the grains among the cowpea genotypes.

This results seems to be higher than earlier reports on three Nigerian peas (Olalekan & Bosede, 2010; Adebowale, Adeyemi, & Oshodi, 2005). Even though the results for the current study were lower than other reports on similar legumes (Arinathan, Mohan & Britto, 2003), they were within the Recommended Dietary Allowances (RDA) range of US Food and Nutrition Board (FNB, 2017).

According to Siddhuraju, Becker and Makkar (2002), high potassium

Table 4: Composition of Mineral Elements of the Grain Flour of 23 Cowpea Genotypes

Genotypes	Mg (mg/100g)	K (mg/100g)	Na (mg/100g)	P (mg/100g)	Ca (mg/100g)
UCC-490	145.4 ± 0.47l	346.34 ± 19.5c	105.69 ± 7.04	6.28 ± 0.10ab	10.44 ± 1.41abc
UCC -484	144.60 ± 0.41l	312.19 ± 8.44abc	105.69 ± 7.04	5.11 ± 0.25ab	9.70 ± 0.83ab
PADI-TUYA	143.58 ± 0.33k	318.69 ± 2.81abc	97.56 ± 12.19	5.86 ± 0.20ab	10.35 ± 1.14abc
UCC-473	142.49 ± 0.25ij	330.08 ± 20.3bc	101.62 ± 7.04	5.08 ± 0.20a	10.88 ± 0.27abc
UCC-153	141.54 ± 0.35gh	304.06 ± 18.4ab	101.62 ± 7.04	5.12 ± 0.15ab	10.13 ± 0.96abc
IT10K-817-3	141.48 ± 0.35gh	317.07 ± 9.75abc	81.30 ± 7.04	5.07 ± 0.35a	9.40 ± 0.80ab
UCC-328	138.66 ± 0.25b	317.07 ± 21.2abc	85.36 ± 0.00	5.01 ± 0.11a	9.91 ± 0.54abc
IT10-819-4	141.54 ± 0.40gh	300.81 ± 19.7ab	93.49 ± 7.04	5.43 ± 0.16ab	10.48 ± 0.30abc
IT08K-193-14-1	141.58 ± 0.25ghi	284.55 ± 5.63a	89.43 ± 7.04	5.35 ± 0.36ab	11.48 ± 1.23bcd
UCC-513	141.84 ± 0.14ghi	300.81 ± 2.81ab	85.36 ± 0.00	4.95 ± 0.39a	10.70 ± 1.77abc
IT07-125-107	141.52 ± 0.38gh	295.93 ± 7.45ab	105.69 ± 18.6	6.67 ± 1.37b	10.50 ± 1.83abc
UCC-EARLY	143.37 ± 0.17jk	305.69 ± 10.1ab	97.56 ± 0.00	6.20 ± 0.29ab	10.71 ± 1.62abc
UCC-11	139.48 ± 0.23bc	282.92 ± 8.44a	101.62 ± 7.04	5.63 ± 0.18ab	20.17 ± 2.33f
UCC-241	141.33 ± 0.20fg	282.92 ± 8.44a	97.56 ± 12.19	5.77 ± 0.50ab	14.09 ± 1.93cde
UCC-24	140.41 ± 0.20de	317.07 ± 9.75abc	97.56 ± 21.12	5.29 ± 0.86ab	8.06 ± 1.61ab
UCC-466	139.74 ± 0.11cd	317.07 ± 21.2abc	97.56 ± 0.00	5.45 ± 0.25ab	6.84 ± 0.40a
UCC-32	139.59 ± 0.27cd	300.81 ± 19.7ab	101.62 ± 14.0	5.31 ± 0.09ab	6.74 ± 1.91a
UCC-445	142.31 ± 0.36hi	284.55 ± 5.63a	85.36 ± 0.00	4.92 ± 0.23a	8.11 ± 1.08ab
UCC-366	140.52 ± 0.23ef	300.81 ± 2.81ab	85.36 ± 12.1	5.35 ± 0.21ab	7.94 ± 0.55ab
IT97K-499-35	140.42 ± 0.34de	295.93 ± 8.44ab	89.43 ± 7.04	5.33 ± 0.65ab	7.94 ± 1.80ab
APAGBAALA	124.92 ± 0.00a	297.56 ± 4.87ab	85.36 ± 0.00	5.17 ± 0.10ab	15.37 ± 1.26de
UCC-523	139.35 ± 0.28bc	282.92 ± 8.44a	97.56 ± 21.12	5.85 ± 1.20ab	20.19 ± 1.39f
IT10K-832-3	141.69 ± 0.17ghi	282.92 ± 8.44abc	89.43 ± 7.04	5.72 ± 0.65ab	16.93 ± 1.80ef

All values in dry weight are means ± standard deviation (n = 3) Mean values followed by different letters in the same column represents significantly different at ($p \leq 0.05$)

content can be of much benefit in the diets of people who take diuretics to control hypertension and suffer from excessive excretion of potassium through the body fluid.

The second most abundant mineral in the current study was found to be magnesium. It ranged from 124.92 mg/100 g for Apagbaala to 145.40 mg/100 g for UCC-490. This range of values varied significantly ($p \leq 0.05$) among the twenty three cowpea genotypes. The magnesium contents of cowpea grains observed in this study were generally in agreement with values reported for 30 Brazilian cowpea (Carvalho et al., 2012) but higher than the magnesium content reported for mucuna species (Adebowale et al., 2005) and some leguminous tribal pulses in South India (Arinathan et al., 2003). Although the results were lower than sorghum-pigeon pea, it falls within the standard national requirements (FNB, 2017). The results for magnesium were within the range which could be beneficial to children as well as pregnant mothers. According to the US National Institutes of Health (NIH, 2018), magnesium in diet supports a healthy immune system, keeps the heart beat steady, and helps bones remain strong. It helps to regulate blood glucose levels and also aids in the production of energy and protein.

The sodium content for the current study ranged from 81.30 mg/100 g to 105.69 mg/100 g. The cowpea genotypes; UCC-484, UCC-490 and IT07-125-107 recorded the highest value whiles IT10K-817-3 recorded the lowest value for the sodium content. There were no significant differences ($p > 0.05$) among the cowpea genotypes for the sodium contents. More importantly, the twenty three cowpea genotypes were found to contain adequate level of sodium for infants (FNB, 2017). The results for the sodium content were lower when compared to what was reported for similar species (Tiencheu & Tenyang, 2016). The results were higher than the results of sodium content reported for 30 new varieties of Brazilian cowpea (Carvalho et al., 2012). Sodium in diet keeps body fluids in a normal balance hence plays a key role in normal nerve and muscle function.

The calcium content of the cowpea genotypes differed significantly ($p \leq 0.05$) from each other with values ranging between 6.74 mg/100 g and 20.19 mg/100 g. The cowpea genotypes, UCC-32 and UCC-523, exhibited the lowest and the highest contents respectively. The range of calcium content for this current study was deficient when compared to that of US Food and Nutrition Board (FNB, 2017). The calcium contents were lower than report of 30 new varieties of Brazilian cowpea (Carvalho et al., 2012) and report of other legumes (Tiencheu & Tenyang, 2016; Kyeremateng, 2015). Calcium is important in blood clotting, muscle contraction and in some enzymes in metabolic processes (Aremu et al., 2006).

The least abundant major mineral element found among the cowpea varieties was phosphorous and it ranged from 4.92 mg/100 g for UCC-445 to 6.67 mg/100 g for IT07-127-107. These results for the phosphorous content were significantly different ($p \leq 0.05$) among the cowpeas. However, the phosphorous contents of currently studied cowpea genotypes were low according to US (FNB, 2017) good requirements for infants. The results were also lower than what was observed in other reports of similar species (Rufina et al., 2016; Tiencheu &

Tenyang, 2016; Adebowale et al., 2005). The main function of phosphorous in diet is to aid in the formation of bones and teeth as well as constitutes the structural components of nucleic acids.

Minor Mineral Elements (trace elements)

The trace metal elements analyzed in this work were zinc (Zn), manganese (Mn), copper (Cu), iron (Fe) and selenium (Se). These metals are very essential but needed in human diet in very small quantity since high levels could be toxic to the body. Selenium (Se) is an essential trace metal. It was the most abundant in the twenty three cowpea genotypes analysed. The amount of selenium in cowpea grains ranged from 11.57 mg/100 g for Apagbaala to 101.32 mg/100 g for UCC-484 (Table 6). These selenium contents of cowpea genotypes were significantly different ($p \leq 0.05$) among the cowpea grains. Selenium enables the human body to produce antioxidant enzymes which play a role in preventing cell damage. According to US National Library of Medicine (NIH, 2018), Se prevents certain cancers and protects the body from the poisonous effects of heavy metals and other harmful materials. Recently, Se in diet was found to aid in the regulation of the body's defense system, as well as the reproductive system. It has also been found to detoxify the body against high concentration of heavy metals and excess peroxides in the body (Kieliszek & Bła, 2016). Unfortunately, Se is not much considered when analysis is being conducted for trace metals in diet. This could be the first time selenium has been reported among mineral elements in different genotypes of cowpea. Therefore, instead of taking selenium supplements, the consumption of these genotypes of cowpea could be considered as a substitute.

Manganese was the second most abundant trace metal element observed among the cowpea genotypes. It ranged from 4.48 mg/100 g to 24.4 mg/100 g. The highest and lowest Mn contents were recorded in UCC-484 and IT10-819-4 respectively (Table 6). The Mn content of the cowpea grains differed significantly ($p \leq 0.05$) among the cowpeas. The results for this analysis were quite higher than the US RDA values and what others reported for similar species (Arinathan et al., 2003; Carvalho et al., 2012). Mn is needed in human diet because it aids in the formation of bones, formation of connective tissue and sex hormones.

The values for the iron (Fe) contents which ranged from 1.13 mg/100 g to 67.17 mg/100 g showed significant difference ($p \leq 0.05$) among the cowpea genotypes (Table 6). The highest and lowest results were exhibited in UCC-484 and UCC-523 respectively (Table 5). With the exception of UCC-484 which was quite higher than the recommended dietary allowance, the rest of the cowpea genotypes had Fe content within the required range for children and lactating mother (FNB, 2017). The results for this current study were in general agreement with what was reported for mucuna species (Adebowale et al., 2005) (8.62 mg/100 g – 19.60 mg/100 g) as well as for similar tribal pulses (Arinathan et al., 2003) (6.42 mg/100 g – 45.20 mg/100 g). However the results were higher than the results for two local cowpeas (Rufina et al., 2016) (6.49 mg/100 g – 8.62 mg/100 g), thirty Brazilian cowpeas (Carvalho et al., 2012) (6.00 mg/100g – 8.10 mg/100 g) and other legumes (Pugalenthi et al., 2004) (6.57 mg/100 g – 7.42 mg/100 g).

The result was indeed remarkable since Fe plays an important role in the

Table 5: Mineral composition of Trace Element of the Grain Flour of 23 Cowpea Genotypes

Genotypes	Zn (mg/100g)	Mn (mg/100g)	Cu (mg/100g)	Se (mg/100g)	Fe (mg/100g)
UCC-490	18.43 ± 0.40[ij]	23.63 ± 0.05[o]	9.63 ± 0.28[f]	83.00 ± 0.00[q]	ND
UCC -484	17.37 ± 0.46[g]	24.40 ± 0.10[p]	8.55 ± 0.37[e]	101.32 ± 0.24[r]	67.17 ± 0.04[n]
PADI-TUYA	19.60 ± 0.34[j]	18.57 ± 0.06[l]	7.46 ± 0.35[d]	67.20 ± 0.35[p]	ND
UCC-473	16.50 ± 0.25[f]	18.16 ± 0.06[k]	8.29 ± 0.42[e]	67.21 ± 0.27[p]	ND
UCC-153	15.53 ± 0.29[de]	19.42 ± 0.03[m]	8.57 ± 0.37[e]	64.70 ± 0.16[o]	5.60 ± 0.00[c]
IT10K-817-3	19.53 ± 0.20[j]	21.75 ± 0.13[n]	10.20 ± 0.21[gh]	44.23 ± 0.26[f]	15.90 ± 0.00[j]
UCC-328	17.46 ± 0.11[gh]	16.83 ± 0.11[i]	10.40 ± 0.00[h]	48.00 ± 0.00[h]	10.10 ± 0.00[f]
IT10-819-4	20.50 ± 0.00[k]	4.48 ± 0.02[g]	6.01 ± 0.02[b]	55.00 ± 0.01[k]	11.13 ± 0.06[g]
IT08K-193-14-1	17.40 ± 0.00g	19.24 ± 0.05m	9.50 ± 0.00f	64.00 ± 0.00n	27.61 ± 0.12[m]
UCC-513	16.50 ± 0.00[f]	17.59 ± 0.10[j]	6.70 ± 0.00[c]	63.01 ± 0.01[m]	20.54 ± 0.09[l]
IT07-125-107	16.10 ± 0.00[ef]	14.73 ± 0.11[g]	14.60 ± 0.00[k]	58.50 ± 0.00[l]	12.39 ± 0.08[h]
UCC-EARLY	21.55 ± 0.08[l]	17.58 ± 0.14[j]	16.72 ± 0.02[l]	42.20 ± 0.00[e]	6.06 ± 0.06[d]
UCC-11	15.20 ± 0.00[cd]	15.63 ± 0.04[h]	10.51 ± 0.01[h]	50.70 ± 0.00[i]	16.38 ± 0.03[k]
UCC-241	18.80 ± 0.00[j]	18.00 ± 0.01[k]	9.40 ± 0.00[f]	39.00 ± 0.01[d]	ND
UCC-24	14.80 ± 0.00[c]	18.20 ± 0.00[k]	11.30 ± 0.00[i]	53.00 ± 0.00[j]	ND
UCC-466	15.10 ± 0.00[c]	13.20 ± 0.01[e]	23.10 ± 0.00[m]	50.34 ± 0.07[i]	ND
UCC-32	15.60d ± 0.01[e]	11.44 ± 0.28[b]	12.71 ± 0.02[j]	21.13 ± 0.06[b]	10.20 ± 0.17[f]
UCC-445	15.10 ± 0.00[cd]	12.17 ± 0.11[c]	11.51 ± 0.01[i]	21.59 ± 0.35[b]	ND
UCC-366	13.67 ± 0.23[b]	11.40 ± 0.16[b]	9.70 ± 0.00[fg]	22.23 ± 0.26[c]	12.58 ± 0.02[i]
IT97K-499-35	20.30 ± 0.00[k]	13.14 ± 0.05[e]	12.50 ± 0.00[j]	21.23 ± 0.10[b]	6.38 ± 0.03[e]
APAGBAALA	3.58 ± 0.38[a]	ND	4.04 ± 0.06[a]	11.57 ± 0.38[a]	ND
UCC-523	18.11 ± 0.01[hi]	12.74 ± 0.10[d]	9.30 ± 0.00[f]	21.10 ± 0.00[b]	1.13 ± 0.06[b]
IT10K-832-3	20.52 ± 0.30[j]	13.91 ± 0.01[f]	10.20 ± 0.01[gh]	46.71 ± 0.01[g]	ND

All values in dry weight basis are means ± standard deviation (n = 3). Mean values followed by different letters in the same column are significantly different at ($p \leq 0.05$)

body by forming part of the haemoglobin which aid the red blood cells to transport oxygen to all parts of the body.

The zinc (Zn) content presented in Table 5 for the 23 cowpea genotypes ranged from 3.58 mg/100 g to 21.55 mg/100 g. The highest value regarding Zn contents were recorded in UCC-Early whiles the lowest was recorded in Apagbaala. The amount of Zn in the cowpea grains differed significantly ($p \leq 0.05$) among the cowpea genotypes. The cowpea genotypes exhibited values which were within the range of the recommended dietary allowance which were between 15 mg to 25 mg per day (FNB, 2017).

The results for zinc in this study appears to be higher than report on similar legumes; (1.20 mg/100 g – 4.12 mg/100 g) by Arinathan et al. (2003), (2.70 mg/100 g – 4.40 mg/100 g) by Carvalho et al. (2012) and (2.11 mg/100 g – 6.08 mg/100 g) by Adebowale et al. (2005). Zn is needed for the body's defensive system to properly work (Merk & Dohme, 2018).

The grain content of copper (Cu), varied significantly ($p \leq 0.05$) from 4.04 mg/100 g to 23.10 mg/100 g. The varieties UCC-466 recorded the highest value and Apagbaala exhibited the lowest. The values obtained were quite higher than the recommended dietary allowance of 2 mg to 10 mg per day (Merk & Dohme, 2018).

Cu is very essential in the body. It works together with Fe to maintain healthy bones, blood vessels, nerves and absorption. Sufficient Cu in diet may aid in the prevention of cardiovascular disease and osteoporosis (Merk & Dohme, 2018).

Summary of Key Findings

The protein content of the cowpea genotypes was found to be between 23.6% (UCC-Early) and 33.8% (Padi-Tuya), fibre was between UCC-328 (0.9%) and UCC-32 (4.2%). Among the major mineral elements, potassium was the most abundant which recorded values from a minimum of 282.92 mg/100 g to a maximum of 346.34 mg/100 g. The least abundant was phosphorous ranged from 4.92 mg/100 g to 6.67 mg/100 g. Among the trace metal elements, selenium was the most abundant whiles copper was the least abundant observed in the analyses. Notwithstanding, iron (Fe) contents which ranged from 1.13 mg/100 g to 67.17 mg/100 g whiles calcium contents ranged from 6.74 mg/100 g to 20.19 mg/100 g. For the functional properties, OAC and WHC recorded values from 1.31 ml/g to 1.81 ml/g and from 1.32 ml/g to 2.94 ml/g respectively. The swelling power, foaming capacity and stability recorded remarkable values which make it useful in the formulation of variety of food products.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Overview

This chapter present the summary of the entire study. The conclusion stated in this chapter is based on the findings and recommendations for further studies.

Summary

The analysis for the proximate composition revealed Padi-Tuya as the genotype with the highest protein content of 33.80 % while the genotype, UCC-Early, emerged the lowest with the protein content of 23.67 %. This remarkable range for the protein analysis proves that the genotypes of cowpea can be a potential alternative rich food source of protein to most people. The crude fibre content ranged from 0.99 % for UCC-328 to 4.27 % for UCC-32 whiles low crude fats content ranging from 0.43 % to 3.18 % was obtained. Generally, the cowpea genotypes in study exhibited low moisture values, which is an indication of a longer shelf life. The ash content also exhibited values ranging between 2.48 % and 4.03 %. This makes the cowpea genotypes be potential sources of minerals. Carbohydrates content exhibited a range from 43.69 % to 58.01 % for Padi-Tuya and UCC-Early respectively.

The mineral contents were between 282.92 mg/100 g and 346.34 mg/100 g for potassium. UCC-490 exhibited the highest content whiles UCC-11, UCC-24 and UCC-523 exhibited the lowest values for the potassium contents. The magnesium contents ranged from 124.92 mg/100 g (Apaagbala) to 145.4 mg/100 g (UCC-490). The sodium content also was found to be between 81.30 mg/100 g and 105.69 mg/100 g. The highest value was observed in UCC-484, UCC-490 and IT07-125-107 whiles the least was IT10K-817-3. The calcium contents exhibited values ranging from 6.74 mg/100 g and 20.19 mg/100 g for UCC-32 and UCC-523 respectively. The phosphorous contents also ranged from 4.92 mg/100 g for UCC-445 to 6.67 mg/100 g for IT07-127-107.

The trace metal elements analysed in this study were zinc (Zn), manganese (Mn), copper (Cu), iron (Fe) and selenium (Se). Selenium were found to be from 11.57 mg/100 g for Apagbaala to 101.32 mg/100 g for UCC-484. Manganese ranged from 4.48 mg/100 g to 24.4 mg/100 g for IT10-819-4 and UCC-484 respectively. UCC-484 and UCC-523 exhibited highest and lowest results for the iron contents with values of 1.13 mg/100 g to 67.17 mg/100 g respectively. The zinc content also ranged from 3.58 mg/100 g to 21.55 mg/100 g for UCC-Early and Apagbaala. The copper contents ranged from 4.04 mg/100 g to 23.10 mg/100 g for Apagbaala and UCC-466 respectively.

The results for the functional properties were (1.32 ml/g - 2.94 ml/g) for water absorption capacity, (1.31 - 1.81 ml/g) for oil absorption capacity, (43.24 - 46.61 %) for emulsion capacity, (23.25 - 50.26 %) for foam capacity, (62.32-89.02 %) for foam stability, (2.38 -3.76 g) for water holding capacity, (2.83 - 3.36 g) for oil holding capacity, (0.98 - 1.25 mL) for swelling index and (4.56 - 6.55 g) for swelling power. The good functional properties in this study will make them useful in foods such as sauces, sausage, ‘koose’, ‘waakye’, soup and stews where they could play functional roles. Out of the general assessment, UCC-Early, IT10-

819-4, IT08K-193-14, UCC-466, UCC-241, UCC-490 and UCC-4328 were more promising.

Conclusion

The proximate composition; protein, fibre, fat, moisture, ash and carbohydrates were assessed. The results exhibited by all the parameters of the proximate composition were significantly different ($p \leq 0.05$) among each other. The cowpea genotypes exhibited wide variation in fats and fibre while moisture, protein, carbohydrates and ash contents were quite closer among the genotypes. Due to the sufficient amount of calories and protein, PEM could be reduced if the cowpeas are consumed daily.

The mineral compositions; the micro and macro elements were also determined. All the minerals analysed for the macro nutrients exhibited values that were significantly different ($p \leq 0.05$) from each other with the exception of sodium. The most abundant element among the macro nutrient was K (282.92 mg/100 g – 346.34 mg/100 g) and the second most abundant element was Mg (124.94 mg/100 g – 145.40 mg/100 g). Their values were however within the RDA range.

The micro elements; Zn, Mn, Cu, Fe and Se were also determined. Their values showed significant differences ($p \leq 0.05$) among themselves. Selenium was the most abundant among the micro nutrients and manganese was the second most abundant. Apart from Apagbaala, all the other genotypes were within the RDA range. The presence of selenium in the cowpea genotypes would prevent certain cancerous interactions and also protect the body against poisoning effects of heavy metal when consumed.

The functional properties; WAC, OAC, EC, FC, FS, SP, SI, WHC and OHC were determined. All except SP and OAC exhibited significant differences ($p \leq 0.05$) among their values. After the analysis, the new genotypes; UCC 241, UCC 32, UCC 328, UCC EARLY, UCC 473, UCC 366 and IT10K-819-4 exhibited good nutritional and functional properties which can be utilized in food formulations and hence may serve as alternative source of protein-rich food that could aid reduce protein energy malnutrition in Ghana

Recommendations

The successful nutritional analysis of the cowpea genotypes and their classification has made it possible for their exploitation for food legumes in Ghana. It is therefore recommended that increased efforts should be made to encourage the cultivation and consumption of cowpea genotypes especially in areas where malnutrition is high. The differences observed among the cowpea genotypes gives the opportunity to broaden the gene pool which may be used in hybridization and more breeding programmes to give rise in their nutritional and functional properties.

Again, effort should be made to assess the antinutritional components such as the oxalates, phytates, tannins, polyphenols, saponins, flavonoids, trypsin inhibitors and alkaloids by way of phytochemical screening and quantification. Since the cowpea genotypes are rich in protein, the assessment of the levels of amino acids can also be considered. Linoleic acids, linolenic acids and lauric acids have been found to be essential fatty acids required for growth, physiological functions and maintenance. Therefore, assessment of the fatty acid composition of the cowpea genotypes would be necessary.

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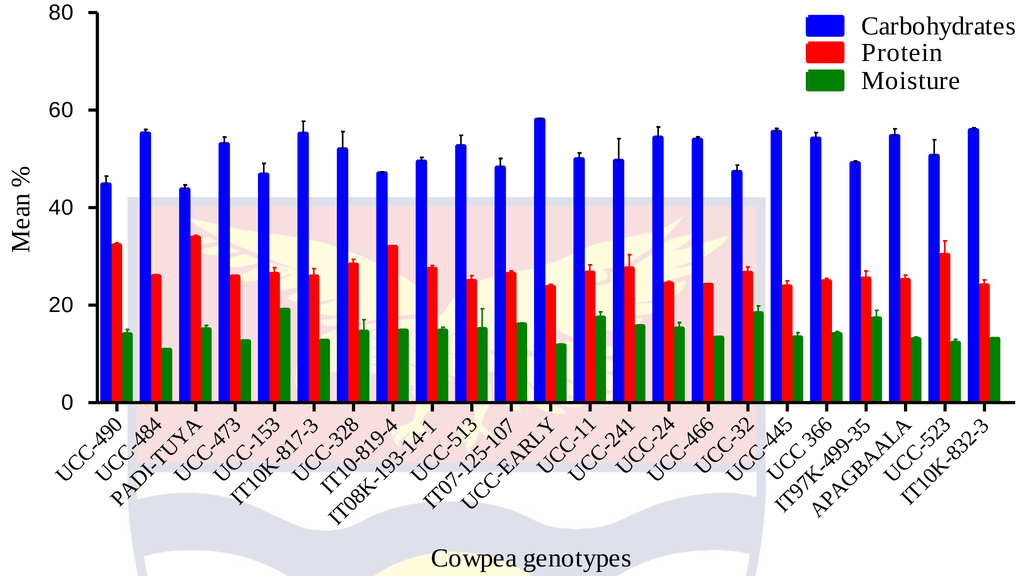
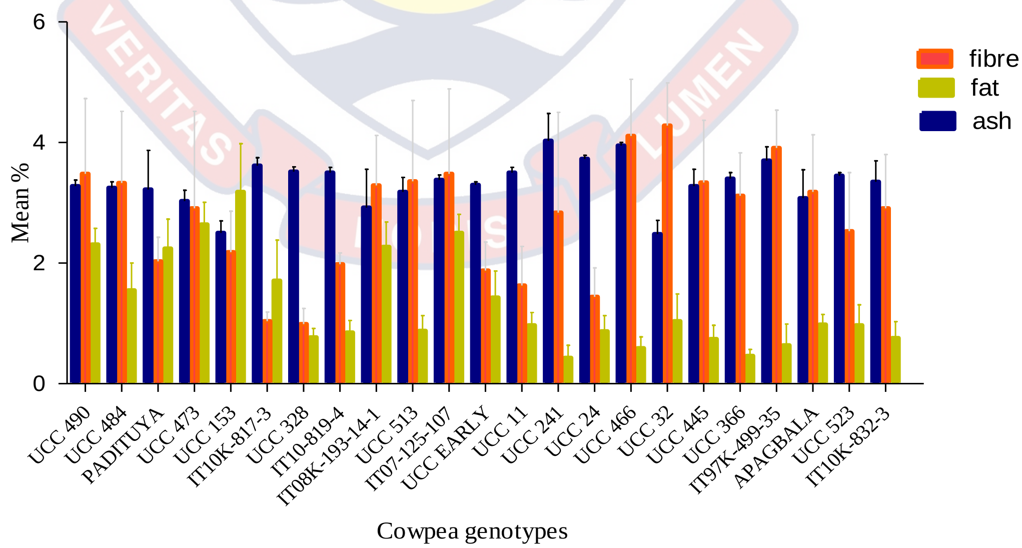
APPENDICES

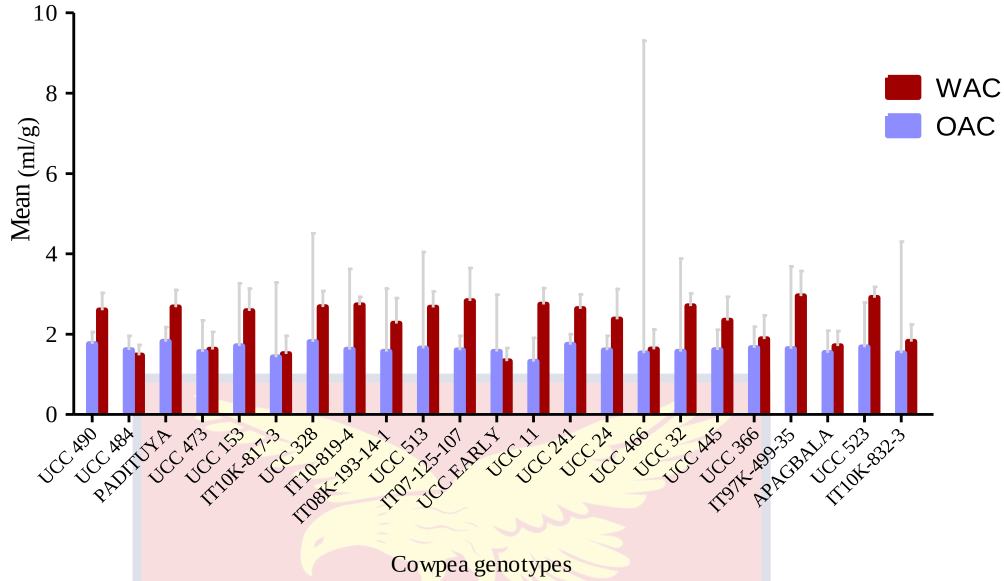
Appendix A: Proximate composition of cowpea grain (protein, moisture and carbohydrates)



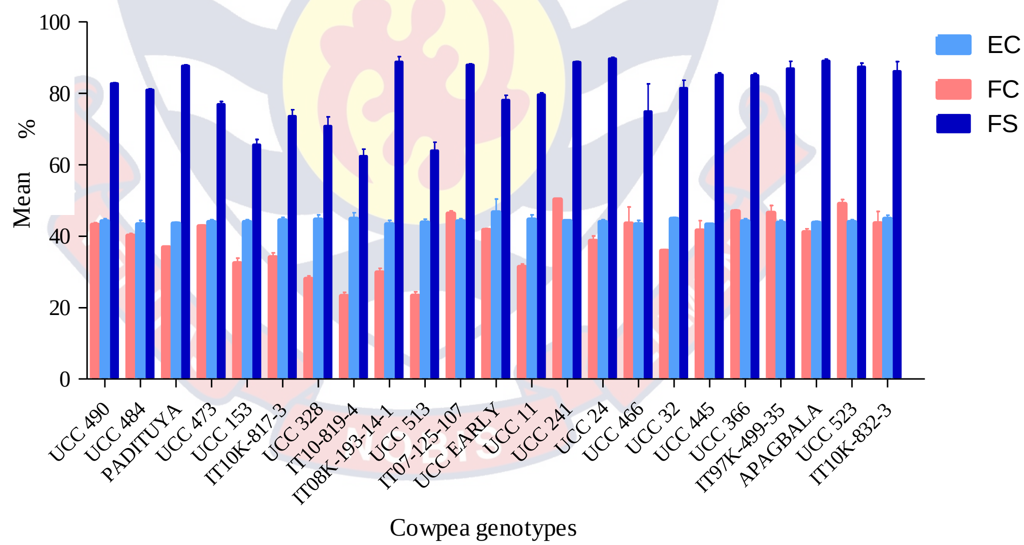
Appendix B: Proximate composition of cowpea grain (ash, fat and moisture)



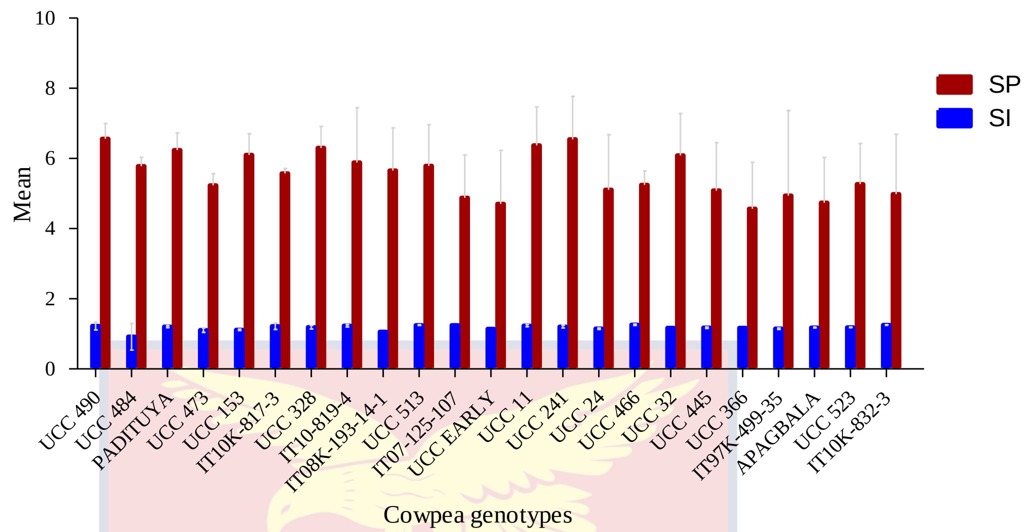
Appendix C: Functional properties of cowpea grain (WAC and OAC)



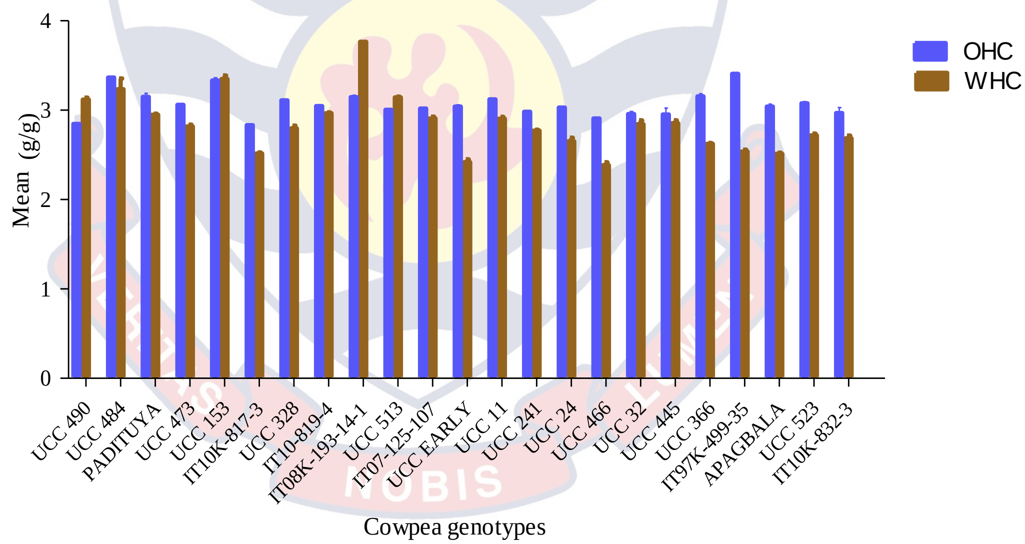
Appendix D: Functional Properties of cowpea grain (FS, FC and EC)



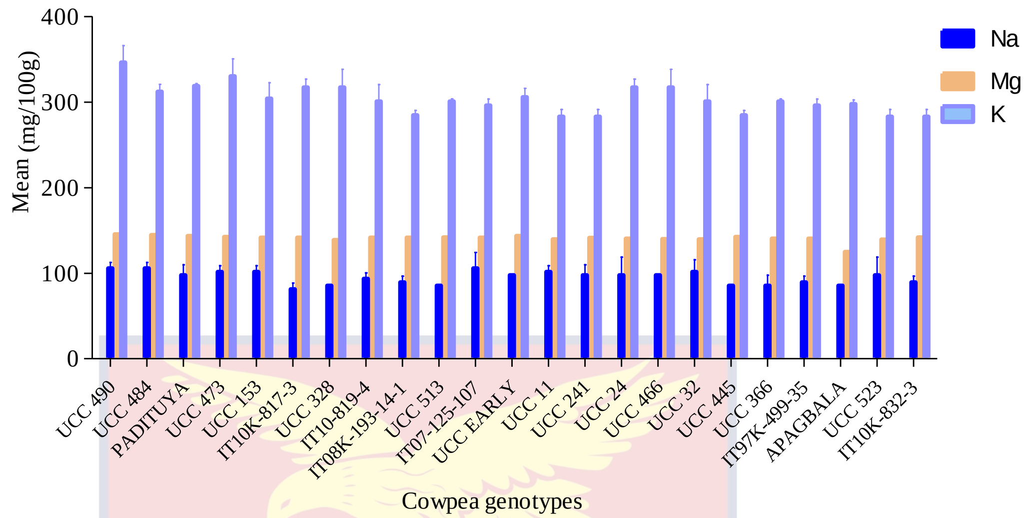
Appendix E: Functional properties (SP and SI)



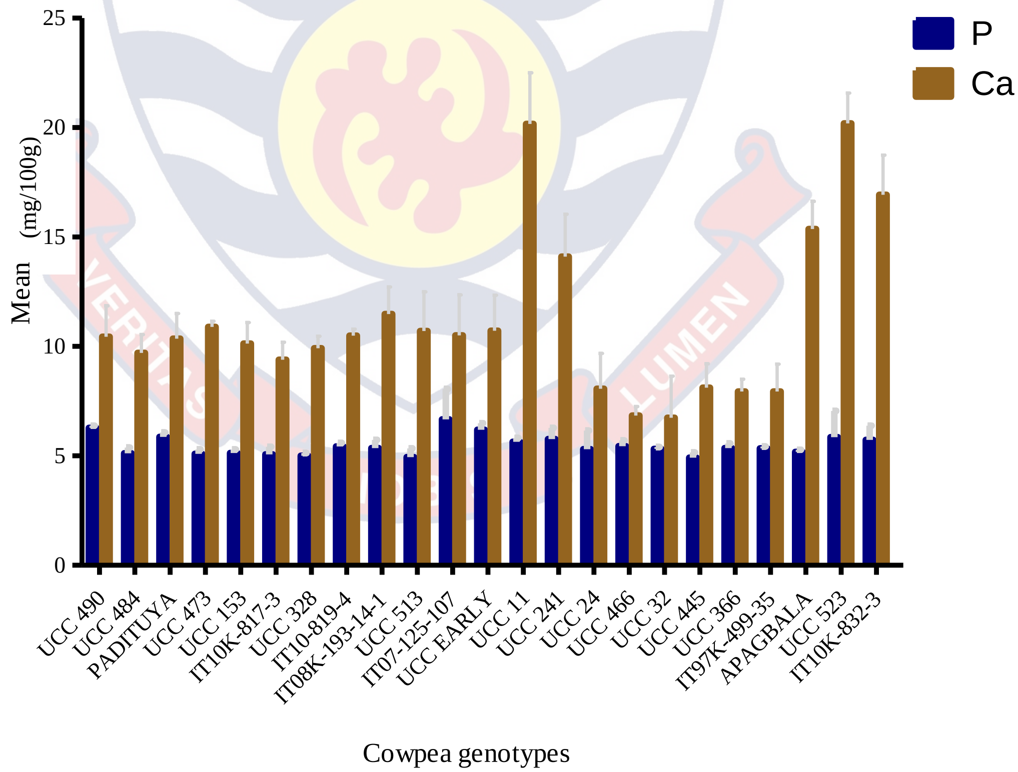
Appendix F: Functional properties of cowpea (OHC and WHC)



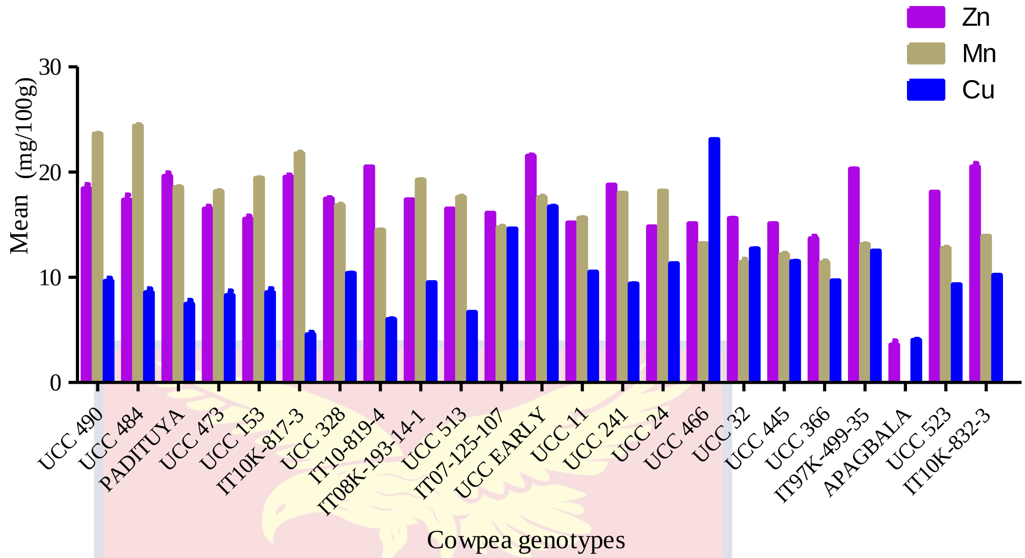
Appendix G: Mineral Analysis (NA, Mg and K)



Appendix H: Mineral analysis (P and Ca)



Appendix I: Trace element composition of cowpea grain (Zn, Mn and Cu)



Appendix J: Trace element composition of cowpea grain