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PLANT SEED CHEMICALS: RENEWABLE RAW MATERIALS FOR INDUSTRIAL APPLICATIONS.

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PLANT SEED CHEMICALS: RENEWABLE RAW MATERIALS FOR INDUSTRIAL APPLICATIONS.

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Great FUTArians

1.0 INTRODUCTION

I seek refuge in Almighty Allah against the evil deeds of shaitan. In the name of Allah the most Beneficent and the most Merciful. May the peace and blessing of Allah be upon the noble Prophet Mohammed (SAW), his companions, his family and all his followers.

I appreciate the favour of Almighty God for making today a reality. Man proposes but God Disposes. I proposed today for my inaugural lecture and God approved my proposal, I really thank Him.

I give thanks to God the Almighty for His grace; sparing my life and keeping me in good and steady health to this day. I acknowledge His unseen hands in all areas and aspects of my life. Glory be to God! I am grateful to you all for finding time to be at this lecture today. I feel greatly honoured by your distinguished presence.

This is the third inaugural lecture to be delivered by a Muslim Professor and the 6th in the Federal University of Technology, Akure inaugural lecture series to be given by Chemistry Department: Professor A.A. Oshodi delivered the first lecture in 1997 titled "Chemistry, Food and Industry". In 1999 Professor K.O. Ipinmoroti gave the second inaugural lecture titled" Chemistry, Metals and Man". This classical masterpiece was followed in 2001 by Professor A.V. Popoola's lecture – "Textile: Then and Now". Professor L.A. Lajide delivered the fourth inaugural lecture –"Plants: God's Own Giant Chemical Factories" in 2002, while in 2014 Professor O.O. Ajayi delivered the 5th inaugural lecture titled "Effective Utilization of Raw Materials: A Catalyst for Industrialization"**.** It is therefore, with humility and deep sense of gratitude that I follow today in the footsteps of my mentors to deliver this lecture tittled: **PLANT SEED CHEMICALS: RENEWABLE RAW MATERIALS FOR INDUSTRIAL APPLICATIONS** in the 82nd Inaugural Lecture Series of The Federal University of Technology, Akure. Ondo State, Nigeria.

1.1 Plants

Plants belong to one of the two groups which all living things were traditionally divided; the other is animals. The division goes back as far as Aristotle (384 BC – 322 BC), who distinguished between plants, which generally do not move, and animals, which often are mobile to catch their food. Much later, Linnaeus (1707–1778) created the basis of the modern system of scientific classification, and both groups became the kingdoms Vegetabilia (later Metaphyta or Plantae) and Animalia (also called Metazoa). Since then, it has become clear that the plant kingdom as originally defined included several unrelated groups, and the fungi and several groups of algae were removed to new kingdoms. However, these organisms are still often considered plants, particularly in popular contexts. Outside of formal scientific contexts, the term "plant" implies an association with certain traits, such as being multicellular, possessing cellulose, and having the ability to carry out photosynthesis (Encyclopedia Britannica, 2016).

Current definitions of Plantae

When the name Plantae or plant is applied to a specific group of organisms or taxon, it usually refers to one of four concepts. From least to most inclusive, these four groupings are:

Name(s)	**Scope**	**Description**
Land plants, also known as Embryophyta	Plantae *sensu strictissimo*	This group includes the liverworts, hornworts, mosses, and vascular plants, as well as fossil plants similar to these surviving groups (e.g., Metaphyta Whittaker, 1969; Plantae Margulis, 1971.
Green plants, also known as Viridiplantae, Viridiphyta or Chlorobionta	Plantae *sensu stricto*	This group includes the green algae, and land plants that emerged within them, including stoneworts. The names given to these groups vary considerably as at July 2011. Viridiplantae encompass a group of organisms that have cellulose in their cell walls, possess chlorophylls a and b and have plastids that are bound by only two membranes that are capable of storing starch. It is this clade that is mainly the subject of this article (e.g., Plantae Copeland, 1956).
Archaeplastida, Plastida or Primoplantae	Plantae *sensu lato*	This group comprises the green plants listed above plus Rhodophyta (red algae) and Glaucophyta (glaucophyte algae). This clade includes the organisms that eons ago acquired their chloroplasts directly by engulfing cyanobacteria (e.g., Plantae Cavalier-Smith, 1981).
Old definitions of plant	Plantae *sensu amplo*	Old classifications placed diverse algae, fungi or bacteria in Plantae (e.g., Plantae or Vegetabilia Linnaeus, Plantae Haeckel 1866, Metaphyta Haeckel, 1894; Plantae Whittaker, 1969).

1.2 Seeds

A seed is an embryonic plant enclosed in a protective outer covering. The formation of the seed is part of the process of reproduction in seed plants, the spermatophytes, including the gymnosperm and angiosperm plants. Seeds are the product of the ripened ovule, after fertilization by pollen and some growth within the mother plant. The embryo is developed from the zygote and the seed coat from the integuments of the ovule. Seeds have been an important development in the reproduction and success of gymnosperms and angiosperms plants, relative to more primitive plants such as ferns, mosses and liverworts, which do not have seeds and use other means to propagate themselves. Seed plants now dominate biological niches on land, from forests to grasslands both in hot and cold climates. The term "seed" also has a general meaning that antedates the above—anything that can be sown, e.g. "seed" potatoes, "seeds" of corn or sunflower "seeds". In the case of sunflower and corn "seeds", what is sown is the seed enclosed in a shell or husk, whereas the potato is a tuber. Many structures commonly referred to as "seeds" are actually dry fruits. Sunflower seeds are sometimes sold commercially while still enclosed within the hard wall of the fruit, which must be split open to reach the seed. Different groups of plants have other modifications, the so-called stone fruits (such as the peach) have a hardened fruit layer (the endocarp) fused to and surrounding the actual seed. Nuts are the one-seeded, hard-shelled fruit of some plants with an indehiscent seed, such as an acorn or hazelnut.

1.2.1 Production of seeds

Seeds are produced in several related groups of plants, and their manner of production distinguishes the angiosperms ("enclosed seeds") from the gymnosperms ("naked seeds"). Angiosperm seeds are produced in a hard or fleshy structure called a fruit that encloses the seeds, hence the name. (Some fruits have layers of both hard and fleshy materials). In gymnosperms, no special structure develops to enclose the seeds, which begin their development "naked" on the bracts of cones. However, the seeds do become covered by the cone scales as they develop in some species of conifers. Seed production in natural plant populations varies widely from year-to-year in response to weather variables, insects and diseases, and internal cycles within the plants themselves. Over a 20-year period, for example, forests composed of loblolly pine and shortleaf pine produced from 0 to nearly 5 million sound pine seeds per hectare (Cain *et al.*, 2001). Over this period, there were six bumper, five poor, and nine good seed crops, when evaluated in regard to producing adequate seedlings for natural forest reproduction.

1.2.2 Economic importance of edible seeds

Many seeds are edible and the majority of human calories comes from seeds (Sabelli *et al.*, 2009) especially from cereals, legumes and nuts. Seeds also provide most cooking oils, many beverages and spices and some important food additives. In different seeds the seed embryo or the endosperm dominates and provides most of the nutrients. The storage proteins of the embryo and endosperm differ in their amino acid content and physical properties. For example, the gluten of wheat, important in providing the elastic property to bread dough is strictly an endosperm protein. Seeds are used to propagate many crops such as cereals, legumes, forest trees, turf grasses and pasture grasses. Particularly in developing countries, a major constraint faced is the inadequacy of the marketing channels to get the seed to resource poor farmers (Mumby, 2016). Thus the use of farmer-retained seed remains quite common. Seeds are also eaten by animals, and are fed to livestock. Many seeds are used as birdseed.

1.2.3 Poison and food safety

While some seeds are edible, others are harmful, poisonous or deadly (Chia, 2006). Plants and seeds often contain chemical compounds to discourage herbivores and seed predators. In some cases, these compounds simply taste bad (such as in mustard), but other compounds are toxic or break down into toxic compounds within the digestive system. Children, being younger than adults, are more susceptible to poisoning by plants and seeds (Clelland, 2016).

A deadly poison, ricin, comes from seeds of the castor bean. Reported lethal doses are anywhere from two to eight seeds, (Wedin 1986) though only a few deaths have been reported when castor beans have been ingested by animals (Albretsen, 2000)

The seeds of many legumes, including the common cowpea (*Phaseolus vulgaris*), contain proteins called lectins which cause gastric distress when the beans are eaten without cooking. The common bean and many others, including the soybean, also contain trypsin inhibitors which interfere with the action of the digestive enzyme trypsin. Normal cooking processes degrade lectins and trypsin inhibitors to harmless forms (Dhurandhar and Chang, 1998).

1.2.4 Seeds in religion

The Book of Genesis (Old Testament) begins with an explanation of how all plant forms began:

And God said, Let the earth bring forth grass, the herb yielding seeds, and the fruit tree yielding fruit after his kind, whose seed is in itself, upon the earth: and it was so. And the earth brought forth grass, and herb yielding seed after its kind, and the tree yielding fruit, whose seed was in itself, after its kind: and God saw that it was good. And the evening and the morning were the third day (Genesis 1: 11-13).

The Quran speaks about seed germination:

It is Allah Who causeth the seed-grain and the date-stone to split and sprout. He causeth the living to issue from the dead, and He is the one to cause the dead to issue from the living. That is Allah: then how are ye deluded away from the truth? (Quran, 95:6)

2. PLANT SEED CHEMICALS

2.1 LIPIDS (FATS AND OILS)

The term "Lipid" refers to heterogeneous collection of biochemical substances which have in common the property of being soluble in organic polar solvent and insoluble or sparingly soluble in water. Lipids contain variable amounts of the chemical elements carbon, hydrogen and oxygen; there is higher carbon content in lipids compared to carbohydrates. The term lipid covers edible oils, fats and waxes of plant or animal origin, and certain related compounds, which include sterols and phospholipids (Kilgour, 1986). The main physical differences between lipid oils and fats is that oils are liquid at room temperature and fats remain solid at this temperature. The exception is coconut oil which is normally solid at room temperature (Mustakas, 1971).

Lipids belongs to a class of compounds that contains long chain aliphatic hydrocarbons (cyclic or acyclic) and their derivatives, such as acids (fatty acids), alcohols, amines, amino, and aldehydes. The presence of the long aliphatic chain as the characteristic component of lipids confers distinct solubility properties on the simpler members of this naturally occurring compounds (Encyclopedia of Science & Technology, 1997).

Fat and oils are naturally occurring esters of glycerol and fatty acids that have commercial uses. The esters are called trimesters or triglycerides.

$$\begin{array}{llll} R_1COOH & + & HOCH_2 & R_1COOCH_2 \\ & & \vert & \vert \\ R_2COOH & + & HOCH & R_2COOCH \\ & & \vert \longrightarrow & \vert \\ R_3COOH & + & HOCH_2 & R_3COOCH_2 \end{array}$$

3 molecules of fatty acids glycerol Fat or oil

The three kinds of fatty acids (alkanoic acids) found in plant and animal lipids are saturated (no double bond), mono-unsaturated (one double bond), and poly-unsaturated (two or more double bonds). Plant lipids with the exception of coconut and palm oils are liquid oils and have a high content of poly-unsaturated fatty acids (Gunstone and Norris, 1983).

Fats and oils provide energy and also help in carrying fat soluble vitamins (A, D, E, K) into the body and also in their absorption. Lipids play a distinctive role in natural flavour of a wide variety of food commodities and degradation products of lipids are the causes of many major off - flavour in foods (Leshile *et al*., 1989).

The sterols, including cholesterol are related to fats and oils which are important in many hormones. Cholesterol is essential in making bile, a digestive fluid and some sex hormones. However, cholesterol is associated with arteriosclerosis, a disease in which the arteries gradually harden as fatty substances are deposited in their walls. A high level of fat in the body may be a risk factor of cardiovascular diseases and are also associated with the condition as high blood pressure, heart attack, stroke, kidney failures, diabetes, certain kinds of cancer and obesity. As a result of the above problem, people having too much fat, in their body tend to be unhealthy and die earlier than those whose weight is normal or slightly below normal (Savage *et al*., 1998).

2.1.1 Classification of lipids

Lipids are generally classified into the following groups:

(a) Simple Lipids: These are sub-divided into three:

(i) Triglycerides or fats and oils are fatty acids esters of glycerol. Examples are lard, corn oil, palm kernel oil, soybean oil, butter etc.

(ii) Waxes are fatty acid esters of long chain alcohol, Examples are bee wax, spermaceti and carnauba wax.

(iii) Steroids are lipids derived from partially or completely hydrogenated phenanthrene. Examples are cholesterol and ergosterol.

(b) Complex Lipids: These are also sub-divided into three groups.

(iv) Phosphatides or phospholipids are lipids which contain phosphorus and in many instances nitrogen. Examples are lecithin, cephalin, and phosphatidyl inositol.

(v) Glycolipids are lipids which contain carbohydrate residues. Examples are sterol glycosides, cerebrosides and plant phytoglycolipids.

(vi) Sphingolipids are lipids containing the long-chain amino alcohol sphingosine and its derivative. Examples are sphingomyelins, ceramides and cerebrosides.

This classification scheme is not rigid since sphingolipids are found which contain phosphorus and carbohydrate and glycolipids which contain phosphorus. Those lipids not included in the above groupings are of the chemically simpler type and include the fatty acids, alcohols, ethers such as batyl and chimyl alcohols, and hydrocarbons such as the terpenes and carotenes. (Gunstone, 1986; Mead *et al.,* 1986).

The fatty acids found in lipids may be saturated or unsaturated, cyclic or acyclic and contain substitutes such as hydroxyl or keto groups. They are combined in ester or amide linkages. The alcohols likewise, may be saturated or unsaturated and are combined in ester or ether linkages in the case of unsaturated ethers; these are best considered as aldehyde derivatives. The amino alcohols found in lipids are linked as amides, glycosides or phosphates esters. Sphingosine is the predominant amino alcohol found in animal tissue lipids, and phytosplongesine is its equivalent in the plant kingdom (Harwood and Russell, 1984).

2.2 CARBOHYDRATES

Carbohydrates are the most abundant and widely distributed food component. Carbohydrates may be defined as substances containing carbon, hydrogen and oxygen. The hydrogen and oxygen usually being present in the same ratio as in water (Garard, 1976).

Carbohydrates include:

(a) i. *Monosaccharides* (polyhydroxy aldehydes or ketones) among which are 5- carbon compounds, such as xylose or arabinose and 6-carbon compounds, such as glucose and fructose ($C_6H_{12}0_6$).

ii. *Oligosaccharides* in which a hydroxyl group of one *monosaccharide* is condensed with the reducing group of another *monosaccharide* (if two sugar units are joined in this manner, a disaccharide results: a linear array of three to eight *monosaccharides* joined by glycosidic linkages gives *oligosaccharides*) and

iii. *Polysacharides* that may be separated roughly into two broad groups. The structural polysaccharides (i.e. cellulose, hemicellulose, lignin) that constitute or are part of rigid, mechanical structures in plants, and nutrient polysaccharides (i.e. starch, glycogen) that are metabolic reserves in plants and animals (Yeshajahu and Clifton, 1987).

(b) In addition to their nutritional and metabolic function, carbohydrates are important as natural sweeteners, raw materials for various fermentation products including alcoholic beverages, and the main ingredient of cereals. Carbohydrates govern the rheological properties of most foods of plant origin. The involvement of carbohydrates in the browning reaction improves or impair consumer acceptance and the nutritional value of many foods. (Yeshajahu and Clifton, 1987).

In food composition tables, the carbohydrate content is usually given as total carbohydrates by difference i.e. the percentage of water, protein, fat, fibre and ash subtracted from 100. Another widely used term is nitrogen-free extract, calculated as components other than water, nitrogeneous compounds, crude fibre, crude fat, and minerals.

The increasing awareness that specific carbohydrates play significant metabolic and functional roles and the availability of analytical tools to determine individual components has stimulated investigations on their distribution in many foods.

2.2.1 Classification of Carbohydrates according to their nutritive value:

Southgate (1969) and Pritchard *et al.,* (1973) grouped carbohydrates into available carbohydrate and unavailable carbohydrates based on the nutritional availability of such carbohydrate fractions.

(a) **Available Carbohydrates**: are the carbohydrates that human digestive system can hydrolyse, such as sugars (glucose, fructose, galactose, maltose, sucrose, lactose) all of them are termed reducing except sucrose. Starch and glycogen are also available carbohydrates.

(b) **Unavailable carbohydrates**: are the carbohydrates that are not easily broken down by human digestive system. This has been used as an index of nutritive and energy value, example, cellulose is only made use of by the ruminants that harbour cellulose decomposing microbes in their digestive tracts. The carbohydrates found here are lignin cellulose, hemicellulose and water soluble polysaccharides, and pectin. They are termed roughages and analytical chemists call cellulose, crude substances.

Table 2 Classification of carbohydrates

Carbohydrate substances	Structural Carbohydrate	Fibre Polysaccharides,	Cellulose
		Matrix Polysaccharides	Hemicellulose
			Pectic
	Non -structural Carbohydrate	Storage Carbohydrates	Starches
			Fructosans
			Saccharose
		Metabolic Intermediates	Free sugars

Source: Tamminga (1981)

2.3 MINERAL ELEMENTS AND THEIR USES

The term mineral elements refers to elements other than carbon, hydrogen, oxygen and nitrogen. That is, those elements which normally form salts (Fox and Cameron, 1977). The minerals supply no energy but can perform the other two functions of a nutrient; they supply structural material and perform physiological functions.

Mineral elements contain the main element such as sodium, magnesium, phosphorus, sulphur, chlorine, potassium, calcium and iron and trace elements found in very much smaller amounts which include copper, manganese, zinc, cobalt, iodine, fluorine etc. Though trace elements are present in only minute quantities, they are just as essential to human life as macro elements. Those elements tend to form soluble salts, which can readily be taken up from the soil, those elements, which form simple soluble compounds, exist in solution as free ions and as such are readily absorbed (Garard, 1976).

Mineral elements are used by the body in a variety of ways. Some constitute organic compounds such as proteins, blood cells and other soft tissue of the body, while also play vital and important roles in enzyme and part in the control of body pH; phosphorus in adenosine phosphate and minerals containing enzymes and hormones. The uses in the body may be considered under three main areas, namely as part of the rigid body structure, as part of soft body tissue and as part of body fluids (Fox and Cameron, 1977).

Mineral elements in body fluids are present as ions and it is important that their concentration is controlled in order to preserve the electrolyte balance in the body. For example, if large amounts of salt is consumed in the diet there is a natural tendency for the concentration of these ions in the blood to increase. In these circumstances, the body restores the concentration of chloride and sodium ions to their original level by withdrawing them to the kidneys hence they pass out of the body in the urine. (Fox and Cameron, 1977).

CLASSIFICATION OF MINERALS BASED ON AMOUNT

Based on the amount needed by the body, minerals can be classified into two namely-

1. Macro-minerals
2. Micro-minerals (or trace elements)

Macro minerals are the elements that are required in amount greater than 100 mg/day (Stanstead, 1995). Examples of macro-minerals are Ca, Mg, K and Na. Micro - elements refer to the inorganic elements, which may be present in foods in amounts usually well below 50 ppm and have some toxicological or nutritional significance (Pearson, 1976). These include, Fe, Cu, Mn, Cr, Co and Zn. A major factor that influences the uptake of both micro and macro-minerals in plants is the composition of soils on which they are grown (Olaofe *et a1.*,1987).

Calcium: **-** Calcium accounts for about 75% in bones and teeth mainly as $Ca_3(PO_4)_2$. It is estimated that a newborn infant contains 28gm of calcium and a fully grown man 120 gm. The blood and soft tissue contain low concentration; the normal concentration in the blood is l0mg in 100 ml of blood (Garard, 1976).

Calcium gives rigidity to the bones and so it's importance in pregnant and lactating women and growing children is obvious. Calcification requires the presence of calcium, phosphorus and vitamin D and a deficiency of anyone or all of these results in badly formed teeth and bones, poor growth and in extreme cases development of rickets. It is also needed in the body fluid for successful functioning of nerves and muscles. Milk is the best source of calcium (Garard, 1976).

Phospborus: - Calcium and phosphorus are usually considered together because both bones and teeth are forms of calcium phosphate. It occurs in the soft tissue and in the blood cells and fluids of the body. Phosphoric acid salt forms buffer mixtures in the blood and thereby preserve its pH at 7.4. Phosphorus forms in the form of phosphate groups in adenosine trio-phosphate, plays a vital part in the complex process whereby energy is obtained from the oxidation of nutrients (Fox and Cameron, 1977). It is abundant in animal products (meat, milk, egg etc.) and in seeds.

Iron: - Iron is very important in the body. It is the prime oxygen carrier i.e. essential for formation of haemoglobin of the red blood cells, which carry oxygen through the body. Nearly 90% of iron is in the red blood cells and the remainder is distributed among the soft tissue. Lack of iron causes anaemia.

Magnesium: - Magnesium is a constituent of the chlorophyll molecule and is therefore a plant nutrient. It is involved in the regulation of cellular pH and cation-anion balance, for effective nerve and muscle functioning. The average adult (man) contains about 35g of magnesium, of which 70% is in the bones. The remainder is, distributed among the soft tissue. Magnesium combines with calcium, to work as a natural tranquillizer and help to prevent calcium deposition, kidney stones and gall stone (Garard, 1976).

Manganese: - Manganese is one of the rare elements; it is needed in normal bone - structure and also helps in hormone of the thyroid gland. It is needed for proper digestion of food and activates enzymes needed for the body's proper use of biotin and vitamin C i.e. it is a component of enzymes and glucose utilization. (Davidson and Passmore, 1975).

Sodium: - This is the cation in the extra cellular fluid. It maintains osmotic pressure of body fluids, which protects the body from excessive fluid loss. It is involved in the contraction of muscle cells and impulse condition along nerve fibres, it regulates the acid-base balance in the body fluid. About 1.8g weight is present in the body. Symptoms of sodium deficiency are those of heart fatigue, muscular weakness, drowsiness, and mental confusion. Most foods naturally contain sodium, however, sodium is added during cooking or at table (Shakuntala and Shadaksharaswamy, 1987).

Potassium: - Potassium has properties similar to that of sodium. It is the principal cation in the intracellular fluid. It influences osmotic pressure and contributes to normal pH equilibrium of the body. The human body contains approximately 2.6 g of potassium per kg of free-fat body weight. Potassium is a nearly constant component of lean tissue and adequate supply of potassium is essential. Potassium is lost whenever the muscle is broken down (Shakuntala and Shadaksharaswamy, 1987). Symptoms of deficiency are mental apathy, muscular weakness, which are associated with attacks of paralysis lasting for 24 h or more. Most common foods such as naturally contain moderate amount of potassium (Olaofe and Sanni, 1980).

Zinc: - Zinc is a constituent of enzymes involved in protein and carbohydrate metabolism and RNA synthesis. It is a vital component of insulin and enzyme in wound healing. Zinc is vital for growth and development. Zinc deficiency in infants may affect the growth (in severe deficiency, dwarfism may result) loss of appetite, testicular atrophy and skin lesion (Fleck, 1976).

Copper: - The concentration of copper in the body is about 150 - 175mg. Copper is needed with iron in haemoglobin formation, also copper forms part of the constituents of enzymes, The concentration of copper in the blood is highest in the liver, kidney, heart and brain, There is little concern that adults may have deficiency of copper since it is widely distributed in food and generally there is an adequate supply. Other evidence of deficiencies are diminished strength of elastin and collagen and degeneration of the nervous system. The richest sources of copper in food are shell fish, Oysters, liver, nuts and seeds, dry beans, kidney, bitter and sweet chocolate etc (Fleck, 1975).

TABLE 3: REQUIREMENT, AMOUNT IN BODY, SOURCES, FUNCTION, DEFICIENCY AND TOXICITY OF SOME MINERAL ELEMENTS

AMOUNT IN BODY	HEALTHY ADULT MALE (mg)	DIETARY SOURCES	BODY FUNCTIONS	DEFICIENCY	EXCESS
1,500	800	Milk,Cheese,Dark-green Vegetable,dried legumes	Bone and tooth formation,blood clothing Nerve transmission	Stunted growth, rickets Osteoporosis, convulsion	Not reported in Man
860	800	Milk,Cheese,Meat, Poultry Grains	Bone and tooth formation, Acid base balance	weakness, demineralization of bone, loss of calcium	Erosion of jaw(fossy jaw)
300	Provided Excess sulfur by amino acid	Sulfur amino acids (Methionine and Cystine) in dietary proteins	Consitutent of active tissue compounds cartilage and tendon	Related to intake and intake deficiency of Sulfur amino acids	leads to poor growth
180	2,500	Meats, Milk, many fruits	Acid-base balance, body water balance Nerve function	Muscular weakness Paralysis	Muscular weakness death
74	2,000	Common salt	Formation of gastric juice Acid-base balance	Muscle cramps, Mental apathy reduced appetite	Vomiting
64	2,500	Common salt	Acid-base balance	Muscle cramps, Mental apathy reduced appetite	High blood
25	350	Whole grains,	Activates	Growth failure,	Diarrhea

		green leafy-vegetables	enzymes involved in protein synthesis	behavioral disturbances, weakness, spasms	
4.5	10	Eggs,Lean meats,legumes,whole grains, green leafy- vegetables	Consitituent of hemoglobins and enzymes involved in energy metabolism	Iron-deficiency anemia(weakness,reduced- resistance to infection)	Siclerosis(cirrhosis of liver) Nothing of teeth silicated ,bone density,Neurol ogical disturbance
2.6	2	Drinking water.tea, seafood	May be important in maintenance of bone structure	Higher frequency of tooth decay	
2	15	Widely distributed in foods	constituent of enzymes involved in digestion	Growth failure, Small sex glands	Fever, nausea, vomiting dia Rare metabolic condition (Wilson's disease)
0.1	2	Meats, drinking water	constituent of enzymes associated with iron metabolism	Anaemia, bone changes (rare in Man)	Industrial exposures. Silicon- Silicosis Vanadium- lung irritation, Tin=Vornitin g, Nickel acute
.024	Not established	Widely distributed in foods	Unknown	Not reported in Man	Pneumonitis

.018 .017 .010					
0.013	Not established (Diet Gastro provides .05-1 per day)	Seafood, Meat, grains	function in close association with Vitamin E	Anemia (rare)	Gastro intestinal disorders, lung irritation
0.012	Not established (Diet Gastro provides 6-8 per day)	Widely distributed in foods	constituent of enzymes	In animals: poor growth disturbance of nerves system, reproductive abnormalities.	Poisoning in Management Mines: generalized disease of nervous system very high intakes high depress thyroid activity.
0.011	0.14	Marine fish and shell-fish, dairy products, many vegetables	constituent of thyroid hormones	Goiter(enlarged thyroid)	
0.009	Not established (Diet Gastro provides 4 per day)	Legumes, cereals, organ meats.	constituent of some enzymes	Not reported in Man	Inhibition of enzymes
0.006	Not established (Diet Gastro provides 4 per day)	Fats, Vegetables oils, meat	Involved in glucose and energy metabolism	Impaired ability to metabolize glucose	Occupational exposures, skin and Kidney damage.

0.0015	(Required as Vitamin B-12)	Organ and muscle Meats, milk	Constituent of Vitamin B-12	Not reported in Man.	Industrial exposures damatius and disease of red blood cell
40,000 (60 percent of body weigth per day)	1.5	Liters Solid foods, liquids, drinking water.	Transport of nutrients temperature regulation participates in metabolic reaction	Thirst, dehydration	Headaches, nausea, edema, High blood-pressure.

Sources: Scrimshaw (1976)

2.4 PROTEIN

Proteins are nitrogenous compounds that are formed by the condensation of large amount of amino acids. Proteins are found in the muscles and tissues as the main organic constituents that are vital components of enzymes that regulate and carry out metabolism and functional processes of living things. Since proteins are nitrogen-containing compounds, nitrogen is used as an index of the protein termed crude protein as distinct from protein (Osborne and Voogt, 1978). The nitrogen content of protein is between 15-18 % and an average of 16 % is assumed (Oyeleke, 1984). Crude protein is estimated as nitrogen multiplied by 6.25 (FAO, 1970) informed that the right nitrogen protein factor should be used. This is because there are different forms of nitrogen - protein factor for different food classes, for example, meat has a factor of (6.25), milk, and diary products (6.38), flour (5.7), gelatin (5.55) while egg (6.68).

There are two major sources of proteins; namely animals and plants. The animal proteins are more complete since they contain almost all the essential amino acids needed by the human body for physiological activities. It was reported that about 87 % of the total protein consumed in Nigeria comes from plant sources (Oyenuga, 1972), while the remaining 13 % consumption comes from animal products. Plants proteins are lower in quality than the animal proteins due to lower content of essential amino acids (Uzogara *et al.*, 1988). In a country with predominantly vegetable diets, a combination of cereals e.g. maize, guinea corn and legumes such as cowpea and soybean can be formulated which will be physiologically satisfactory (Akinrele and Edward, 1971; Oshodi, 1985). Roman *et al.*, (1987) reported that protein nutritional disease results whenever there is shortage of any essential amino acid in the diet. The deficiency of protein manifest in the various forms of protein malnutrition diseases such as kwashiorkor and marasmus (Autret and Behar, 1953). In view of protein malnutrition diseases, some countries that have shortage of proteins have developed various mixtures of proteins that are supplemented by amino acids.

2.5 FUNCTIONAL-PROPERTIES OF PROTEIN

Proteins have no parallel in their structural and textural versatilities, although nature has designed proteins to perform specific roles within the body system, they can display multi -functional properties by appropriate manipulation and processing treatments in different food systems. However, to be exploited successfully, these proteins must be presented to the consumer in forms that are attractive and possesses the flavour, texture, and quality desired by the consumer (Altchul and Wilcke, 1985).

Functional properties denote those physicochemical properties of food proteins that determine their behaviour in food during processing, storage, preparation and consumption. It depends on such intrinsic physicochemical characteristics of protein as amino acid composition and sequence, molecular weight conformation and charge distribution on the molecules. The nature and charge density facilitate interactions with other food components such as water, ions, lipids, carbohydrates, vitamins, colour and flavour constituents, depending upon the environment (pH, ionic strength, temperature during preparation, processing and storage). These properties and the manner in which proteins interact with other components, directly and indirectly affect processing application, food quality, and ultimately acceptance.

The type of functional property required in a protein or a protein mix varies with the particular food system in question. Thus, for example, water binding, solubility, swelling, viscosity, gelatin and surface activity are important properties determining usefulness and final product quality in a meat system. (Altchul and Wilcke, 1985).

TABLE 4: FUNCTIONAL PROPERTIES OF PROTEIN IN FOOD SYSTEMS

FUNCTIONAL PROPERTY	**MODE OF ACTION**	**FOOD SYSTEM**
Solubility	Protein solvation	Beverages
Water absorption and binding	Hydrogen bonding of water, entrapment of water (no drop)	Bread, cakes, meat, sausage$_1$,
Viscosity	Thickening, water binding	Soup, gravies
Gelation	Protein acts as adhesive material	Meat, sausages baked goods, pasta products
Elasticity	Hydrophobic bonding in gluten, disulfide links in gels	Meats, bakery products
Emulsification	Formation and stabilization of fat emulsions	Sausages, bologna, soup, cakes
Fat absorption	Binding of free fat	Meats, sausages, doughnuts
Flavour-binding	Absorption, entrapment, release	Simulated meats, bakery products, etc
Foaming	Forms stable film to entrap gas	Whipped toppings, chiffon, deserts, angle cakes

Source: Kinsella, 1982.

These properties vary with protein source, protein concentration, protein fraction prior to treatment, pH, temperature, ionic strength and dielectric constant of the medium .They are also affected by other treatments, interactions with other molecules in the medium, processing treatments, and physical or chemical modification (Kinsella, 1979).

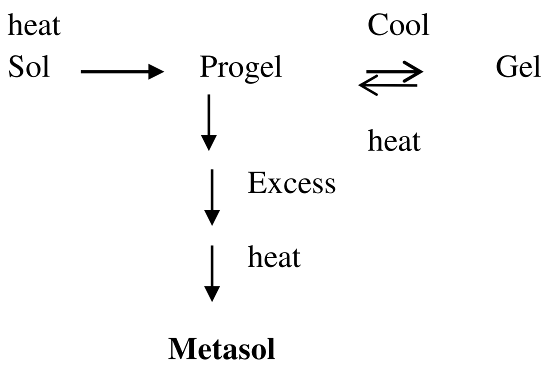
Gelation Properties

Gelation leads to the transformation of the sol into a gel-like structure by heating or other agents in which the individual particles interact with each other to form a three dimensional network. During the transformation, the sol is converted to a gel-like structure. The sol-to-progel transformation may reflect some initial dissociation or the quaternary proteins conformational alterations and possibly unfolding of the subunits. The transformation of a progel to a gel state upon cooling represents the ordered reassociation and aggregation of the unfolded polypeptides via hydrogen bonding and hydrophobic and electrostatic interactions the result is the formation of a three-dimensional network that is capable of trapping a large amount of water. (Altchul and Wilcke, 1985).

The formation of the three-dimensional network depends on the method of preparation of protein, concentration of the protein, rate of heating and cooling, pH, and presence of salts and reducing agents. At highly acidic and alkaline pH, the polypeptides possess high positive and negative charges respectively and under these conditions the electrostatic repulsive forces may destabilize older favourable protein - protein interactions required for the formation' of the gel network, and thus decrease the gel strength, whereas at neutral pH intermolecular electrostatic interaction between positively charged groups may provide additional energy for the gel strength. However, electrostatic shielding of these charges in the presence of NaCl results in decrease in gel strength (Altchul and Wilcke, 1985).

During conversion from sol to progel, viscosity increases as temperature is raised until a maximum is reached. At higher temperatures, the viscosity as a result of irreversible conversions to a metasol state that does not gel on cooling (Circle *et al.,* 1964).

These are shown below,



Gels are characterized by relatively high viscosity, plasticity and elasticity. The ability of protein lo form gels and provide a structural matrix for holding water, flavours sugar and food ingredients is useful in food applications and in new product development and provides an added dimension to protein functionality. Commercial table jellies are made from syrups of glucose and sucrose. Gelation is also responsible for the setting of stews and of broth prepared by boiling bones. Gelation is also used as a stabilizing agent for emulsion, for example in the production of ice - cream. (Circle *et al.*, 1964).

Foaming Properties

The capacity of proteins to form stable foams with gas by forming impervious protein films, is an important property in cakes, and confectioneries, for example, angel and sponge cakes, fudges, frozen desserts etc.

Foams are composed of gas bubbles encapsulated by a thin film of hydrated, surface-active agent. This lowers interfacial tension between gas and water, facilitating deformation of the liquid and expansion against its surface tension. Once formed, foam bubbles move towards each other until nearly touching (Altchul and Wilcke, 1985).

Protein foams consist of gas droplets encapsulated by a flexible protein film, for foam formation. Proteins should be soluble in the aqueous phase and be capable of rapid unfolding to form a cohesive layer of protein around, gas air droplets as they are formed. These films should possess sufficient mechanical strength and viscosity to prevent subsequent rupture and coalescence during continued whipping. The protein films should be flexible but stable, and the component polypeptides must exhibit a balance between their ability to engage intermolecular cohesion required to form membrane and the tendency to self-associate excessively, which would result in foam stability. The ability of protein to rapidly form film during whipping is important. Most proteins spontaneously diffuse to the air, water interface, adsorbs, reorient, and unfold to some extent because of the gain in conformational and hydration energy. The energy of interaction between the molecules in the film and between the film and the adjacent bulk phases is indicated by various rheological measurement, which include dilational modules, surface elasticity, surface viscosity, and surface yield value. These reflect the physical properties and interactions of the molecules in the film. The theoretical properties of the protein film are important in determining the stability of foams. The ability to diffuse rapidly to the interface, reorient, and form a viscous film without excessive aggregation or coagulation is critical for the formation of protein based foams, but to ensure foam stability, the film should possess intermolecular cohesiveness and a certain degree of elasticity to permit localized contact deformation (Altchul and Wilcke, 1985).

Surface viscosity is a major factor contributing to the stability of foam lamellae. In addition to reducing drainage, the viscosity of the surface and bulk liquid minimizes the destructive effects of shocks. High surface viscosity and high film yield values are correlated with strong foams because they reflect strong cohesion between the film foaming molecules.

Films possessing high viscoelasticity form more stable foams than highly viscous but rigid films, which tend to be brittle. Proteins differ in their .ability to stabilize foams, and ironically, some of the properties desired for facile foam formation, namely, solubility and molecular flexibility do not ensure stability while molecular characteristics that impart foam stability, such intermolecular interactions are not compatible with facile formation. For foam stabilization, protein molecules should associate strongly to form continuous intermolecular polymers enveloping the air bubbles.

Several factors affect the foaming properties of proteins, namely protein concentration, pH, temperature, salt, sugars and lipids. The volume and stability of foams tend to increase with protein concentrations. The maximum values for viscosity, rigidity, and foam stability occur near the isoelectric point of proteins including soy where interpeptide interactions are near maximum (Altchul and Wilcke, 1985).

Ionic strength of the medium affects foaming properties because ions may reduce the columbic forces between polypeptide chains and modify stability. Sodium chloride (NaCl) reduces surface viscosity and rigidity of protein films but increases spreading rate, that is, it weakens interpeptide attractions and, for certain proteins, increases foam volume.

Ageing improves foam stability, and this phenomenon probably reflects the gradual increase in intermolecular interactions. Sodium chloride at appropriate concentrations aids foaming, presumably by aiding diffusion and spreading at the interface, however, this is concentration dependent because high levels of salt depress foaming (Altchul and Wilcke, 1985). A range of soy protein preparations containing variable amounts of sucrose and salts is available for frozen desserts, yoghurt, chiffon pies, mousses etc. However, the stability of some of these hydrolysate is highly variable and in some cases, unacceptable for commercial applications (Puski, 1975).

Water Absorption Capacity

Water - holding or absorption capacity is an index of the amount of water retained within a protein matrix under certain conditions. It usually refers to entrapped water but includes bound water and hydrodynamic water and depends on conditions of determination (Kinsella, 1976). The capacity of protein to entrap water is important in meat systems where it affects juiciness, tenderness, and taste. The extent of protein hydration correlates strongly with the content of polar residues and charge residues. Interaction between water molecules and hydrophilic groups (hydroxyl, amino, carboxyl, amide groups, etc) occurs via hydrogen bonding (Chou and Morr, 1979).

The water absorption capacity of different proteins, must be known to facilitate adjournment in food formulation when interchanging protein sources. Some proteins with high water absorption capacities when added to a formular may imbibe a disproportionate amount in food systems or vice-versa. Hence adjustment in water ratio may be necessary to obtain required viscosity. The ability to imbibe and absorb water is desirable during preparation of comminuted meals and baked goods. The capacity to retain moisture during cooking is required in meat while in baking products, moisture released during baking is important (Altchul and Wilcke, 1985).

Several factors aid water binding by proteins, water binding is affected by pH, ionized amino acid groups (Kuntz, 1985). The pH also affects the magnitude of net charge on the protein, which directly affects ionic interactions. At isoelectric pH net charge is zero, eletrostatic interaction is maximum, and water binding is minimum.

At high salt concentrations a reduction in hydration may occur (Altchul and Wilcke, 1985). Cationic species have different effects, for example, when dispersed in chloride salts (2M) of cesium, rubidium, potassium, sodium and lithium, egg albumin bound 0.2, 0.16, 0.15, 0.08g water per gram protein compared with 0.3g in water (Bull and Breese, 1976).

The effect of the ions is related to the size of their hydrated radius, that is, the larger the hydrated radius the greater is the "dehydration" of the protein by Li > Na > K > Cs > Ca. With anions, the larger the hydrated radius the less is its capacity to reduce water binding (CrO_4^- >N03 $^-$>I^- >Br^- >Cl^-). The relative effects of cations and anions are markedly influenced by the intensity of their surface charge, which is influenced by their atomic radii. At high salt concentrations, electrostatic interactions are apparently of little importance with regard to the amount of water bound to proteins because competition of the ions and proteins for water becomes predominant.

This general behaviour may not consistently hold for all proteins, thus in certain oligomeric proteins (e.g. soy) low salt concentrations may facilitate hydrophobic association and reduce hydration by masking electrostatic repulsive charges. Ogunsola (1982) and Fleming *et al.*, (1979) reported that salt (5%) enhanced the water holding capacity of soy flour but reduced that of soy isolate Also salt enhanced the water holding capacity of soy protein in chopped-meat systems (Altchul and Wilcke 1985). Swelling is an important functional property in such foods as processed meats, dough, and custards, in which the proteins should imbibe and hold water without dissolving and, concurrently, impart body thickening and viscosity.

Solubility

Protein solubility is the measure of the solubility of food protein in solution or in suspension. The data obtained are useful in predicting those formulations in which the properties that depend upon the protein being in solution may be optimized. This functional property is pH dependent and is important as it gives the least solubility pH value (isoelectric point) of a given food sample and indicates the soluble protein at physiological pH (Akobundu *et al.*, 1982).

Colloidal stability is often used as measure of protein solubility. Relative methods are used when the amount of nitrogen in the supernatant is measured after centrifugation. Soluble protein preparations are also easier to incorporate into foods. Most functional properties are determined by the balanced between forces underlying protein-protein and protein-solvent interactions. This balance is affected by changes in pH, concentrations, temperature, nature of solvent and presence of other components. Most of these parameters have an influence on the solubility of the proteins (Akobundu *et al.,* 1982).

The manner in which a protein interacts with an aqueous solvent is a manifestation of the protein physicochemical properties under the given conditions, a variety of protein-solvent interactions are involved. Many of the important functional properties of food protein including solubi1ity can be related to these interactions. The extent of protein insolubilization is reflected by the protein solubility index (PSI) or the protein dispersibility index (PDI), an important criterion of functional applications. The extent of reduced solubility depends on the intensity and duration of the process treatment. Such insolubilization decreases yield during the isolation of protein from oilseeds, to obtain optimum functionality in foods where gelation, emulsification and foaming properties are required, a highly soluble protein is desirable (Johnson, 1970).

Solubility measurements gave valuable information on a protein ingredient. The pH dependency reflects the complexity of a protein - system if several maxima, minima and inflection points are found. A solubility profile with a low solubility over a broad pH range is a sign of severe denaturation and insolubilization (Hermansson, 1967).

Denaturation and solubility are not always correlated. High solubility data are sometimes obtained from completely denatured protein (Altchul and Wilcke, 1985). Solubility measurement give no information whether a protein ingredient will bind water or contribute to the texture of a product. The ability of a protein under given conditions like pH, ionic strength and temperature, is the manifestation of the equilibrium between protein-solvent and protein-protein interaction.

Protein-solvent $\rightleftharpoons$ protein-protein + solvent-solvent.

Conditions that shift the equilibrium in favour of protein-protein interactions decrease the solubility and conditions that favour protein-solvent interactions would increase the solubility. The major forces involves in such interactions are electrostatic, hydrophobic and hydrogen bonding. A protein under particular solvent conditions possesses either a net negative charge or a net positive charge, and hence the protein molecules in solution experience electrostatic repulsive interactions between each other. This would tend to have a negative impact in the protein-protein interactions and increase the protein-solvent interaction which generally favours solubility (Herrnansson, 1967).

In general, the degree of solubility of a protein in a given aqueous systems is the net result of both electrostatic and hydrophobic interactions between the protein molecules. (Altchul and Wilcke, 1985). Conditions 'under which the electrostatic repulsions between the molecules is greater than the hydrophobic interactions between the nonpolar patches on the surface-favour increased solubility. Conversely, conditions under which the hydrophobic interactions are greater than the electrostatic repulsions will result in intermolecular aggregation and decreased solubility.

Fat/Oil Absorption Capacity

The fat absorption may merely be another aspect of emulsification. The mechanism of fat absorption or binding has not been explained. In ground meat product such as frankfurters or luncheon meat, fat "binding" by soy protein appears to involve the formation and stabilization of an emulsion plus the formation of a gel matrix which hinders migration of fat to the surface (Wolf and Cowan, 1977).

Fat absorption by soy preparation is closely related to protein content and a little affected by pH or temperature. The protective effect of soy protein in controlling fat absorption during frying has not been explained, this is because many important properties of food involve the interaction of proteins and liquids e.g. emulsions, fat entrapment in meats flavour absorption.

The amount bound is markedly affected by the method used, the protein content, surface area, charge and topography, hydrophobicity and liquidity of the oil. It is conceivable that the binding capacity is enhanced by denaturation of the protein which exposes polar amino acids, although by destroying hydrophobic domains denaturation might reduce fat binding as observed in some studies of (Altchul and Wilcke, 1985).

Natural or chemically formed lipoprotein complexes are functional components of egg yolk, meals, milk, coil tie, whiteners, dough and cake bailers. Therefore the capacity of soy protein to interact with lipid materials is important in food formulation arid processing (Lin et al., 1974). Addition of soy hour such as pancakes and doughnuts helps prevent excessive fat absorption during frying. The effect may involve heat dena1uration of the proteins to form a fat-resistant barrier at the doughnut surface e index (NSI) performs better than a flour of low NSI in which the proteins are already denatured (Altchul and Wilcke, 1985).

Emulsion Properties

Emulsion is a mixture of partially soluble liquid in which one is dispersed in the other in the form of finely divided globules. Emulsions are types of colloid and there are many naturally occurring emulsion, including milk, rubber latex, egg yolk, ice cream, cake butter and cosmetic creams. In an emulsion the phase that is distributed in globules (the dispersed phase) and the surrounding liquid (the continuous phase) are interchangeable depending on the relative proportion of the components (Encyclopedia Americana, 1980).

Emulsifying capacity and the emulsion stability measurements are often used in functional characterization of protein (Sathe *et al.*, 1981)

Emulsifying properties of protein play an important role in large number of food applications. The development of a standardized method to measure such properties would help food processors select the right protein for a given application. Because of the large diversity of food emulsions, it is difficult to develop one model system to measure emulsification properties which would be applicable in all cases. Therefore it is proposed that three model system be developed to stimulate three general types of food emulsion namely, comminuted meat sausages, low fat milk types emulsion and high fat mayonnaise-type emulsions (Magnuspyke, 1982).

Many naturally occurring emulsion are stabilized by protein. The capacity of protein to aid the formation and stabilization of emulsion is important in cake baking, coffee; whiteners, milk mayonnaise, salad dressings, comminuted meat and frozen desserts. In these and similar types of emulsion, stability results from the formation of a protective coating of the protein around each droplet of the dispersed phase, while emulsion instability results from the contact and distortion of emulsified droplets, which facilitates the coalescence of droplets, flocculation, creams; and the rupture of droplets. The capacity of proteins to absorb at interfaces and form 'cohesive films is critical in emulsion and foams' (Altchul and Wilcke, 1985).

In the above product, varying emulsifying and stabilizing capacities are required because of the differing composition and stresses to which these products are subjected. Emulsion of fats, and water are thermodynamically unstable because of high free energy contributed by interfacial tension. Agents that reduce interfacial tension between oil and aqueous phase increase thermodynamic stability. In a typical emulsion, oil droplet are dispersed in a continuous matrix (Altchul and Wilcke, 1985). The breaking of emulsion is necessary in many industrial operations, for example in the separation of water in-oil emulsion in the petroleum industry and in product recovery from emulsions produced by the steam distillation of organic liquids.

Emulsion may be broken by addition of multivalent ions of charge opposite to emulsions droplet, chemical action (addition of acids to emulsions stabilized by soaps), freezing, heating, aging, centrifuging, application of high potential alternating electric fields, and treatment with ultrasonic waves of low intensity (McGraw-Hill Encyclopedia, 1982).

In oil-water systems, dispersed protein diffuse to the interface, shifts the conformational equilibrium and unfolding of protein occurs to minimize free energy thereby exposing a polar segments to the poly peptides loops to lipid interface and polar ionic segments to the aqueous phase. Surface activity is a function of the ease with which protein can immigrate to, absorb at, unfold to a limited extent, rearrange and interassociate at interface.

Solubility of protein is an important pre-requisite for emulsifying properties of protein. This is reflected in the correlation between emulsifying capacity and protein solubility and the effects of pH on emulsion formulation, namely emulsion formulation tends to the significantly lower in the isoelectric range.

The effect of pH on electrostatic interactions becomes less pronounced with increasing ionic strength of the continuous phase. At pH values away from the isoelectric point, salt may facilitate greater protein. Protein interaction in films by minimizing charge repulsions and thereby strengthen the rheological properties of the film and enhance emulsification (Ogunsola, 1982), Salts may stabilize emulsion by reducing columbic interactions between neighboring droplets (Altchul and Wilcke, 1985).

2.6 PHYSIOCHEMICAL CHARACTERISTICS OF OILS

Physicochemical characteristics of oils are those characteristics that are necessary for the confirmation of the identity and edibility of the oil. They are broadly divided into two viz: Identity characteristics and Quality characteristics. The identity characteristics include refractive index, relative density, iodine value, saponification value, unsaponifiable matter and fatty acid composition. The quality characteristics are colour, odour, taste, acid value, free fatty acid, peroxide value and moisture and volatility (Pearson, 1976).

2.6.1 COLOUR

Colour is a psychological interpretation of a physiological response by the eye and brain to the physical stimulus of light radiation at different wavelengths. Colour is an important quality of oil that influences consumer decision. It is a quality attribute which together with flavour and texture plays an important role in lipid acceptability. Lipids comprises chemical compounds including the pigments. Pigments may change in colour during the processing of oil as a result of a change in physical state, or of chemical reaction with metals, metallic salts, acids, alkali, oxygen etc. They also vary in stability, in rate of reaction, and in the nature of the products formed from them. Lipid pigments can be flavonoids (anthocyanins and anthoxanthins), carotenoids (carotene and xanthophylls) and tetrapyrrole (chlorophyll and myoglobins). The most acceptable colour of refined oil is bright yellow (Hodge, 1967).

2.6.2 REFRACTIVE INDEX

This is a physical attribute of lipids, measured by the angle through it, which a beam of light is bent when passing through a thin film of melted fat. The index of each lipid falls within a range and can be used as a characteristic of the lipid in checking purity or searching for components of a mixture. It is temperature dependent and is usually measured at 40 ^{O}C, a temperature at which all lipids are liquid. A correction factor can be used if it is not possible to work at a selected temperature for which reference data are available (Ihekoronye *et al.,* 1985).

2.6.3 INSOLUBLE IMPURITIES

Determination of insoluble impurities is the measurement of solid matter which is not soluble in lipid solvents. This is complicated by the fact that some materials may be dispersed in the lipid but insoluble in the solvents. When the solvents are added during the estimation of impurities, these materials precipitate and according to the degree of dilution, may not be measured with the impurities (Mehlenbacher, 1960).

2.6.4 IODINE VALUE

The iodine value of an oil is defined as the weight of iodine absorbed by 100g of the sample. The iodine value of glyceride is related to its unsaturation, the higher the iodine value, the greater the unsaturation and the greater the liquidity.

There are three types of fatty acids which may be classified as follows:

(i) Saturated fatty acids in which there is single bond in the carbon chain e.g. stearic acid, lauric acid.

(ii) Unsaturated fatty acids in which there is one double bond in the carbon chain e.g. oleic acid.

(iii) Poly-unsaturated fatty acids (PUFA) in which there are two or more double bonds in the carbon chain e.g. linoleic acids, linolenic acid.

The degree of unsaturation is the measure of double bonds present in fatty acids. It is important in determining its properties. All natural lipids contain both saturated and unsaturated fatty acids (combined with glycerol), but the greater the proportion of the latter, the lower the melting point of the lipid. Lipids which are high in unsaturated fatty acids are therefore liquid at room temperature while those rich in saturated fatty acids are solid at room temperature.

The degree of unsaturation of an oil is measured by its iodine value. When iodine is added to a triglycerol formed from an unsaturated fatty acids, it reacts with the double bonds in the molecule, and the degree of unsaturation may be calculated from the amount of iodine absorbed.

$$— CH = CH — + I_2 \longrightarrow — CHI — CHI —$$

One molecule of iodine is used to saturate each double bond. The amount of iodine needed to saturate the oil is constant for a particular oil or fat, but the exact figure obtained depends on the particular technique used. Iodine value is often the most useful figure of identifying an oil or at least placing it into a particular groups. The greater the degree of unsaturation (i.e. the higher the iodine value), the greater is the liability of the oil or fat to become rancid by oxidation.

The iodine value is usually determined by Wijs' method (Pearson, 1976).

2.6.5 PEROXIDE VALUE

This is a measure of peroxide contained in the oil. Peroxide can be used to assess the degree of rancidity of oils and fats. During storage, peroxide formation is slow at first during an induction period which may vary from a few weeks to several months according to the particular oil or fat, temperature etc. Fresh oils usually have peroxide values well below 10mgEq/Kg. A rancid taste often becomes noticeable when the peroxide value is between 20 and 40mgEq/Kg, which however depends on the particular oil or fat. Volumetric determination of peroxide value depends on the reaction of potassium iodine in acid solution with the bound oxygen. This is followed by titration of the liberated iodine with sodium thiosulphate. Acetic acid - chloroform mixture is usually used as solvent (Pearson, 1976).

2.6.6 ACID VALUE OR FREE FATTY ACIDS (FFA)

The acid value of an oil or fat is defined as the number of milligram of potassium hydroxide required to neutralize' the free acid in 1 g of the sample. It is often expressed as the percentage of free acidity.

The glyceride in the oil can be attacked by lipase enzyme causing ': the decomposition of the oil. In the presence of heat and light the decomposition is accelerated. The extent of this decomposition is measured by their acid values. As rancidity is usually accompanied by free fatty acid formation, the determination of acid value is often used as a general indication of the condition and edibility of oils (Cocks *et al.,* 1966).

2.6.7 UNSAPONIFIABLE MATTER

The unsaponifable matter can be defined as the material present in oils and fats which after saponifiable of oil or fat by caustic alkali and extraction by a suitable solvent remains non-volatile on drying at 80^{o}C. The unsaponifiable matter includes hydrocarbobons, higher alcohols and sterols (e.g cholestrol, phytosterol). Most oils and fats of normal purity contain < 2% of unsaponifiable matter (Pearson, 1976).

2.6.8 SAPONIFICATION VALUE

The saponification value of an oil or fat is defined as the number of milligram of potassium hydroxide require to neutralize the fatty acids resulting from the complete hydrolysis of the sample. Saponification is a chemical reaction between a fatty acid and alkali to form soap (alkali salt of the fatty acid).

$$C_3H_5\,(C_{17}H_{35}COO)_3 + KOH \longrightarrow C_3H_5\,(OH)_3 + 3C_{17}H_{35}COOK$$

Strearin   Glycerol   potassium Stearate

The esters of the fatty acids of lower molecular weight require the most alkali for saponification, such that saponification value is inversely proportional to the mean of the molecular weight of the fatty acids in the glyecrides present. The lower the molecular weight, the greater the saponification value (Hamiton *et al.,* 1981).

MY CONTRIBUTIONS TO KNOWLEDGE

- **Mr. Vice-Chancellor Sir, distinguished ladies and gentlemen, permit me to present to you my modest contributions to knowledge in the area of Analytical /Environmental Chemistry; such as renewable energy, plant seed analysis for feed supplement and formulation, analysis of medicinal plant seeds, application of plant seed chemicals in oleochemistry etc.**

1. Ogunsuyi, Amoo and Ojo (2010) carried out the analysis of chemical composition and protein functional properties of *Pseudovigna argentea*, *Calopogonium mucunoides* and *psaphocharpua palustirs* seeds. It was discovered that the samples have high emulsion capacities and stabilities which make them useful in baked products production such as cake baking.

Table 3.1: Functional properties of the samples

Parameters	*Pseudovigna*	*Calopogonium mucuniodes*	*Psaphocarpua palustris*
Oil absorption capacity (%)	152.20 ± 0.5	207.85 ± 0.79	139.10 ± 0.9
Water absorption capacity (%)	285.10 ±0.03	358.90 ±0.01	295.15 ± 0.04
Foaming capacity (%)	10.00 ± 0.01	19.00 ± 0.02	15.00 ± 0.02
Foaming stability (%)	4.0 ± 0.01	5.0 ± 0.01	5.0 ± 0.01
Emulsion capacity (%)	48.98 ± 0.01	48.72 ± 0.07	47.92 ± 0.01
Emulsion stability (%) after 2hrs	28.60 ± 0.01	28.70 ± 0.01	28.40 ± 0.01
Least gelation (%)	4.0 ± 0.01	6.00 ± 0.01	6.00 ± 0.01

Source: Ogunsuyi, Amoo and Ojo (2010)

2 Akinyede, Amoo and Eleyinmi (2005) studied the chemical and functional properties of full fat and defatted *Dioclea reflexa* seed flours. The study showed that the samples of interest contained high water and oil absorption capacities which could influence the texture and mouth feel of food products such as meat and meat products, dough nuts and baked products.

Table 3.2: Functional properties of full fat and defatted *Dioclea reflexa* seed flour

Functional properties	Full fat	Defatted

Water absorption (WAC) %	610.00	670.00
Oil absorption (OAC) %	272.00	291.40
Emulsion capacity (EC) %	60.00	40.00
Least gelation (LGC) %	6.00	6.00
Foaming capacity (FC) %	13.72	17.65
Foaming stability (after 4hours) %	9.80	13.80

Source: Akinyede, Amoo and Eleyinmi (2005)

3. Amoo, Ogunsuyi and Ogunlade (2003) assessed the chemical composition, mineral contents and functional properties of leucaena (*Leucana leucocephala*) seed flours. The results of the assessment indicated that the sample has high foaming capacity. This function is of primary importance in the production of whipped toppings chiffon and also important factor in desserts angel cake making.

Table 3.3: Some Functional Properties (%) of *Leucaena leucocephala* seed flour

Functional properties	Mean ± SD
Least gelation concentration	2.00 ± 0.00
Water absorption capacity	408.00 ± 0.20
Oil absorption capacity	24.00 ± 0.00
Emulsion capacity	52.82 ± 0.00
Emulsion stability	26.44 ± 0.10
Foaming capacity	20.00 ± 0.00
Foaming stability after 2hrs	58.33 ± 0.03

Source: Amoo, Ogunsuyi and Ogunlade (2003)

4. Amoo (2004) investigated the effects of roasting on the chemical composition of coconut (*Cocos nucifera*) seed flour and oil. The research work revealed high level ofnutritionally valuable mineral most especially Zinc which formed co-enzyme in many enzymes such as carbonic anhydrase that takes part in the release of carbon dioxide in the red blood cells. Therefore the seeds can be used in the production of Zinc supplement.

Table 3.4: Mineral content of raw (A) and roasted coconut (B) seed flour.

Element	Sample	(mg/kg)

Iron	A	37.89
	B	67.78
Zinc	A	43.52
	B	119.60
Manganese	A	50.00
	B	81.83
Magnesium	A	178.10
	B	436.20
Sodium	A	32.89
	B	49.30
Calcium	A	92.00
	B	104.90
Potassium	A	228.80
	B	515.70
Phosphorus	A	184.20
	B	750.00

Source: Amoo (2004)

5. Oladebeye, Amoo and Oladebeye (2012) compared the physico-chemical properties of degermed flours of white and yellow maize (*Zea mays*) seed flour and affirmed the degermed flours of white and yellow maize possessed high calcium and phosphorus which are required for bones and teeth as calcium phosphate and therefore can be a good supplement in weaning food formulation.

Table 3.5: mineral composition (mg/100g) of the degermed flour samples

Minerals	White maize	Yellow maize
Ca	306.00±0.04	344.30±0.07
Na	18.44±0.01	16.74±0.01
K	395.40±0.05	401.20±0.03
P	248.30±0.02	248.50±0.03
Zn	2.54±0.01	2.32±0.01
Fe	6.77±0.02	5.83±0.03

Source: Oladebeye, Amoo and Oladebeye (2012)

6. Amoo (2003) investigated the effects of fermentation on the nutrient and mineral content of *Bauhinia raticulata*. The results of the investigation showed that the seed contained high amount of sodium and potassium which are involved in the transmission of nerve impulses and muscle contraction including heartbeat. The seed flour can therefore be processed and used as a source of sodium and potassium in many processed food supplements.

Table 3.6: Mineral content (mg/kg) of *Bauhinia reticulate*

Element	Unfermented	Fermented
Zinc	28.00	41.50
Iron	11.50	40.50
Manganese	ND	ND
Copper	ND	ND
Magnesium	340.50	255.50
Sodium	498.00	469.50
Potassium	480.0	511.50
Calcium	71.00	78.50
Cobalt	ND	ND

Source: Amoo (2003) ND = Not Detected

7. Amoo (2005) carried out proximate composition, minerals and physico-chemical properties of cashew nut and oil. The research work established that the sample contained high amount of magnessuim. Magnessuim is an activator of many enzymes system and maintain the electrical potential in nerves, hence the sample will enhance the dietary requirement of people that required high magnessium in their diet.

Table 3.7: Mineral composition of cashew kernel flour

Minerals	mg/100g
Na	251.1±0.02
Ca	652.9±0.01
Mg	452.0±0.02
Fe	150.7±0.02

K	251.1±0.02
Zn	6.52±0.02
P	502.3±0.01
Cu , Mn, Co	Not detected

Source: Amoo (2005)

8. Akinyede, Amoo and Eleyinmi (2005) examined the chemical and functional properties of full fat and defatted *Dioclea reflexa* seed flour. The high content of iron in the sample showed that the seed flour can be used for cereal- based food where it will serve as a source of iron to boost blood iron which transport oxygen round the body.

Table 3.8: Mineral content (g/kg) and some computed mineral ratios of full fat and defatted *Dioclea reflexa* seed flour

Functional properties	Full fat	Defatted
P	1.33	1.37
Zn	232.73	219.42
Fe	258.39	290.99
Mn	25.42	32.19
Mg	818.60	826.03
Na	129.83	182.45
Ca	983.13	963.14
K	937.68	865.04

Source: Akinyede, Amoo and Eleyinmi (2005)

9. Amoo and Akpambang (2009) studied the effect of boiling on the chemical composition of African walnut seed flour and physico-chemical properties of its oil. The study revealed that the extracted oil from the seed contained very low iodine values in both raw and boiled sample which implied that the extracted oil will be useful in the production of margarines by catalytic hydrogenation. The sample is also high in phosphorus which make it useful for production of phosphate fertilizer.

Table 3.9: Mineral composition (%) of African Walnut seed flour

Elements	Raw	Cooked
Mg	32.31±0.36	22.99±0.51
Ca	40.00±0.30	27.59±0.26
Na	30.77±0.10	12.64±0.03
Zn	32.31±0.04	19.54±0.08
P	365.39±0.08	251.44±0.14

Source: Amoo and Akpambang (2006)

10. Amoo, Eleyinmi, Ilelaboye and Akoja (2004) characterized the oil extracted from gourd (*cucurbita maxima*) seed flour. The very high crude fat content and very low acid value of the extracted oil implies that the oil is consumable and the seed can be used for commercial production of edible vegetable oil.

Table 3.10: Physico-chemical properties of *cucurbita maxima* oil

Properties	Mean ± S.D
Saponification value	126.09 ± 0.01
Peroxide value	2.80 ± 0.08
Acid value	0.36 ± 0.14
Iodine value	18.66 ± 0.02
Specific gravity	1.45 ± 0.15
Colour	Light yellow

Source: Amoo, Eleyinmi, Ilelaboye and Akoja (2004)

11. Amoo and Moza (1999) extracted oil from *Bauhinia racemosa* seed and carried out the physico-chemical properties of the extracted oil. It was observed that the oil contained high saponification value and very low free fatty acid which make the extracted oil suitable for making soap, shampoo because of high saponification value.

Table 3.11: Physico-chemical properties of *Baua racemosa* seed oil

Properties	Mean ± S.D
Specific gravity	0.89 ± 0.01
Refractive index	1.46 ± 0.02
Acid value	5.64 ± 0.19

Saponification value	343.73 ± 0.57
Iodine value	13.52 ± 0.08
Peroxide value	4.85 ± 0.05
Unsaponifiable matter	4.23 ± 0.11
Free fatty acid	0.06 ± 0.01

Source: Amoo and Moza (1999)

12. Amoo, Emenike and Akpambang (2008) researched into the chemical composition and nutritive significance of *Luffa aegyptical* and L. *castenae* sp seeds. The work identified the seeds of *Luffa aegyptica* as an excellent source of fat with high iodine value which make the seed oil applicable in the paint and varnish, alkyd resins production.

Table 3.12: Physico-chemical properties of *Luffa aegyptica* and L. *castenae* sp seed oil

Properties	*L. aegyptica*	*castenae* sp
Specific gravity	0.812	0.890
Refractive index	1.468	1.465
Acid value (mgKOH/g)	68.71±1.55	34.79±0.57
Iodine value	102.67±1.15	34.32±1.54
Saponification value	108.23±0.00	28.28±0.03
Peroxide value	21.66±0.15	89.93±6.71
Unsaponifiable matter	1.80±0.14	1.31±0.01

Source: Amoo, Emenike and Akpambang (2008)

13. Fagbenro, Smith and Amoo (2000) compared Acha (*Digitana exilis* stapf) meal with maize and sorghum meals as a dietary carbohydrate source for Nile Tilapia (*Oreochromis niloticus*). This study illustrates the potentials of this under exploited annual grass cultivated as a cereal in West Africa improving adequate nutrition for fishes. Thus, the seeds can be used as a carbohydrate source in fish food production

Table 3.13: Apparent digestibility coefficient (ADC %) in carbohydrate feedstuffs for *Oreochromis niloticus*

Feedstuff	ADC dry matter	ADC crude protein	ADC gross energy
Acha meal	50.48±1.03	80.17±2.45	54.52±1.30
Maize meal	64.46±0.82	74.98±2.25	61.59±1.11

Sorghum meal	63.91±1.12	76.26±2.73	60.96±1.57

Source: Fagbenro, Amoo and Smith (2000)

14. Fagbenro, Amoo and Smith (2003) assessed the winged bean-seeds soaked or autoclaved in trona solution as protein supplement in diets of Nile Tilapia *Oreochromis niloticus* (L) Fingerlings. These seeds provided up to 60% of total dietary protein required by the fingerlings and hence can be switched for the more expensive soybeans seeds in feeding Nile Tilapia.

Table 3.14: Nutritional quality of winged bean seeds autoclaved in distilled water or trona solution

Nutrient (g/kg dry weight)	Raw seeds	Cooking solution		SEM
		Distilled water	0.5% Trona solution	
Crude protein	368	381	403	2.88
Crude fat	158	172	175	1.35
Crude fibre	65	62	59	0.94
Total ash	42a	49a	61b	0.89
Nitrogen-free extract	376	336	302	2.60
Lysing (g/kg protein)	65	62	61	0.24
Methionine (g/kg protein)	11	14	12	0.11
Water absorption (%)	ND	207.8a	216.3b	
Texture (softness)	ND	106.1a	119.5b	
Solid loss (%)	ND	13.5a	17.6b	
Trypsin inhibitory activity (IU/g protein)	85819c	20597b	2575a	
Tannin content	31.04c	7.63b	1.50a	
Lectin activity	+	-	-	
In vitro digestibility coefficient	0.682a	0.828b	0.863b	

Source: Fagbenro, Amoo and Smith (2003) SEM = standard error of mean

15. Amoo, Ogunsuyi and Abdulrahman (2003) examined the chemical composition of seed flour of *Hura crepitan* seed oil. This work showed that *H. crepitan* seed is a viable

feedstock for vegetable oil production; even for industrial purposes. Its high crude fat content of 52.5% makes the oil useful for industrial processes such as biodiesel production, oleochemicals, soap making and so on.

Table 3.15: proximate Composition (%) of Hura crepitan seed flour

Composition	Mean ± S.D
Moisture content	0.65 ± 0.03
Ash	4.15 ± 0.05
Crude protein	25.71 ± 0.02
Crude fat	52.50 ± 0.04
Crude fibre	6.15 ± 0.04
Carbohydrate	10.84 ± 0.03

Source: Amoo, Ogunsuyi and Abdul Raman (2003)

16. Amoo and Owoeye (2004) studied the nutritive significance of snake gourd seed (*Trichosanthes cucumunia*). The work highlighted the significance of snake gourd seeds as a potential feedstock for industrial-scale oil production. It also showed that the seed can be used as feedstock for animal feed production.

Table 3.16: Proximate composition (%) of snake gourd seed

Parameters	Results
Fat	43.5
Ash	0.99
Crude fibre	0.22
Moisture	1.10
Protein	9.42
Carbohydrate	53.71
Vitamin C	9.96mg/100ml

Source: Amoo and Owoeye (2004)

17. Amoo, Adebayo and Oyeleye (2006) evaluated the chemical composition of winged beans (*Psophocarpus tetragonolobus*), pitanga cherries (*Eugenia uniflora*) and Orchid fruit

(Myristica). The study showed that just like soybeans, winged beans can be used in the formulation of infant feed. On the other hand, pitanga cherries can be employed by food manufacturing industries as sweetener, fruit jam production and sweets due to the presence of digestible sugars. Orchid fruit can be used as spices.

Table 3.17: The sugar composition (g/100g) of winged beans (*Psophocarpus tetragonolobus*), pitanga cherries (*Eugenia uniflora*) and Orchid fruit (*Orchid myristica*)

Sugar type	Winged bean	Pitanga bean	Orchid bean
Invert sugar in the presence of % sucrose. Nil	2.57	4.97	0.53
1%	2.51	4.90	0.52
5%	2.36	4.65	0.48
10%	2.25	4.50	0.46
25%	2.07	4.22	0.42
Dextrose	2.50	4.83	0.52
Fructose	2.65	5.13	0.55
Hydrated maltose	3.92	7.88	0.80
Anhydrous lactose	3.19	6.31	0.66
Hydrated lactose	3.36	6.64	0.69

Source: Amoo, Adebayo and Oyeleye (2006)

19. Amoo and Asoore (2006) investigated the effect of processing on the nutrient composition and oil of peanut (*Araclus hypogea*) seed flour. This work showed that processing methods such as cooking, roasting and frying of peanuts resulted in marked changes in the nutritional values of these seeds. Hence, food processing industries should be careful in the methods of processing that would be adopted in order to prevent loss of valuable nutrients in peanuts. The raw fat can be converted to epoxy fatty acids which can be used in plastic and coating industries while protein derived from the fried sample can be used for feed meal.

Table 3.19: Proximate composition (%) of peanut powder

Parameters	Samples	Mean ± SD
Total ash	1	2.49 ± 0.49
	2	3.13 ± 0.45

	3	4.92 ± 0.59
Moisture	1	3.46 ± 0.11
	2	3.11 ± 0.39
	3	2.44 ± 0.25
Crude fibre	1	2.28 ± 0.03
	2	8.33 ± 0.06
	3	3.24 ± 0.10
Crude protein	1	27.49 ± 0.59
	2	9.42 ± 0.84
	3	50.84 ± 0.31
Crude fat	1	52.91 ± 0.34
	2	35.22 ± 0.08
	3	37.45 ± 0.17
Total carbohydrate	1	11.37 ± 0.50
	2	40.30 ± 0.20
	3	2.55 ± 0.06

Source: Amoo and Asoore (2006) 1 = cooking 2 = roasting 3 = frying

20. Eleyinmi, Bressler, Amoo, Sporns and Oshodi (2006) examined the chemical composition of bitter cola (*Garcina kola*) seeds and hulls. It was revealed that the hull of bitter cola which, hitherto was often discarded, is a potential source of nutritionally viable nutrients and industrial raw materials such as ∝-linoleic acid, aspartic acid, glycine, etc

Table 3.20: amino acid composition (g/kg) of *Garcinia kola* seeds and hulls

Amino acid	**Seed**	**Hull**
Threonine	1.10	3.70
Tyrosine	0.60	1.00
Methionine	0.40	0.70
Valine	1.70	7.10
Phenylalanine	1.40	2.80
Isoleucine	1.60	3.80
Leucine	1.90	4.80
Lysine	2.40	4.10
Cysteine	ND	ND

Tryptophan	ND	ND
Total Essential amino acids	11.10	28.00
Arginine	5.50	3.30
Aspartic acid	2.40	7.50
Glutamic acid	6.80	8.10
Serine	1.20	4.30
Histidine	0.60	1.70
Proline	ND	ND
Glycine	1.80	5.30
Alanine	1.60	4.70
Total Non Essential amino acids	19.90	34.90

21. Amoo, Emenike and Akpambang (2008) evaluated the chemical composition of Custard Apple (*Annona cherimoya*) fruit. The work highlights the importance seeds of *Custard Apple* as a potential source of vegetable oil. The oil was highly unsaturated which makes it suitable for industrial application requiring highly olefinic oil feedstock.

Table 3.21: Physicochemical properties of *Annona cherimoya* seed oil

Components	Mean ± SD
Specific gravity	0.746
Refractive index	1.469
Acid value (mgKOH/g)	11.044±1.00
Iodine value	145.07±4.21
Peroxide value	24.04±0.04
Saponification value	52.11±3.20
Unsaponifiable matter	1.28±0.03

Source: Amoo, Emenike and Akpambang (2008)

22. Amoo and Jokotagba (2012) carried out comparative analysis of proximate, mineral and functional properties of *Tamarindus indica* pulp and *Ziziphusspina christi* fruit and seed. The analysis indicated that seeds of *Z christi* exhibited moderate water absorbtion capacity

and foaming capacity. These make the seed useful for imparting characteristic functional properties on food when applied in the industrial processing of food.

Table 3.22: Functional properties (%) of Tamarindus indica pulp, Ziziphus spina christi fruit and seed.

Functional Properties	Tamarindus indica pulp	Z. spina christi fruit	Z. spina christi seed
Water absorption Capacity	134.62 ± 0.70 a	182.61± 2.47 c	139.01 ± 0.77 a
Oil absorption Capacity	123.51 ± 0.71 a	197.27 ± 2.50 c	129.78 ± 0.66 b
Emulsion stability	42.70 ± 0.58 a	45.77 ± 0.67 b	44.96 ± 0.08 b
Emulsion capacity	49.31 ± 0.28 b	50.00 ± 0.00 c	43.69 ± 0.55 a
Least gelation Concentration	6.00 ± 0.00 b	4.00 ± 0.00 a	4.00 ± 0.00 a
Foaming capacity	11.67 ± 0.57 a	52.40 ± 0.53 c	14.00 ± 0.00 b
Foaming stability	3.60 ± 0.53 a	6.93 ± 0.12 c	3.94± 0.20 b
Bulk density (g/cm3)	56.95 ± 0.75 c	36.27 ± 0.49 a	48.79 ± 0.29 b

Source: Amoo and Jokotagba (2012)

23. Jokotagba and Amoo (2012) went further to carry out the effects of fermentation on the nutritive value of *Aspergilus nigger* and *Aspergilus fumigatus* fermented *Hura crepitans* seed flour. The work gave a remarkable revelation about the potential of fermenting on seed flour prior to extraction in order to improve the quality of the oil. This is evident in the fact that fermentation of seed flour with *A. fumigatus* resulted in an oil with significantly lower unsaponifiable matter. Hence, fermentation with *A. fumigatus* improved the oil for production of soap.

Table 3.23: Physicochemical properties of the extracted oil from fermented and unfermented Hura crepitan seed flour

Parameters	Unfermented sample	Fermented with A.niger	Fermented with *A.fumigatus*
Refractive index	1.46±0.01	1.45±0.01	1.45±0.01
Specific gravity	0.88±0.01	0.77±0.02	0.77±0.02
Acid value	2.82±0.03	13.42±0.03	11.18±0.03

Free fatty acid	0.07±0.01	0.97±0.02	0.07±0.02
Iodine value	22.63±0.32	13.82±0.25	14.47±0.28
Saponification value	64.52±2.80	75.73±2.81	79.47±4.28
Peroxide value	0.47±0.01	1.55±0.01	1.67±0.03
Unsaponifiable matter	26.02±0.04	18.15±0.04	16.26±0.05

Source: Jokotagba and Amoo (2012)

24. Akpambang, Amoo and Izuagie (2008) also worked on the comparative compositional analysis on two varieties of melon (*Colocynthris citrullus* and *Cucumeropsis*) and a variety of almond (*Prunus Amygdalus*). This work identified seeds of *Colocynthris citrullus* and *Prunus amygdalus* as excellent sources of vegetable oil due to their high crude fat content. Oils from those samples are all edible and could easily be made into margarines by catalytic hydrogenation due to their low iodine value.

Table 3.24: Physico-chemical properties of the extracted oils from two varieties of melon seed flours (*Colocynthis Citrullus* and *Cucumeropsis edulis*) as compared with almond seed (*Prunus amygdalus*)

Parameters	*Colocynthis Citrullus*	*Cucumeropsis edulis*	*Prunus amygdalus*
Refractive Index (at 40^{o}C)	1.47±0.02	1.47±0.02	1.47±0.02
Specific gravity (at 20^{o}C)	1.51±0.02	1.67±0.02	1.71±0.02
Saponification value (mgKOH/g)	8.00±0.03	9.90±0.01	9.40±0.02
Acid value (mgKOH/g)	8.02±0.07	9.36±0.03	9.66±0.07
Peroxide value mEq/kg	1.72±0.01	1.42±0.01	0.93±0.01
Iodine value (wijs)	3.45±0.02	3.02±0.02	2.65±0.01

Source: Akpambang, Amoo and Izuagie (2008)

25. Amoo, Atasie and Kolawole (2009) determined the proximate composition, nutritionally valuable minerals, protein functional properties and antinutrient content of *Mucuna preta*, *Mucuna ghana* and *Mucuna veracruz moatle*. This work highlights the applicability of these seeds in various food processing application such as gelling or thickening agents in snacks production. They are also found to be protein-rich feed for farm animals.

Table 3.25: Functional parameters of mucuna ghana, mucuna preta and mucuna veracruz mottle

Parameters	*mucuna ghana*	*mucuna preta*	*mucuna veracruz*
Water absorption capacity (%)	160.0 ± 0.02	145.0 ± 5.00	150.0 ± 10.00
Oil absorption capacity (%)	138.23 ± 5.00	130.86 ± 0.00	130.10 ± 0.00
Foaming capacity (%)	25.00 ± 0.00	17.00 ± 1.00	20.50 ± 0.50
Foaming stability (%)	12.00 ± 2.00	12.5 ± 1.50	9.00 ± 1.0
Emulsion capacity (%)	42.5 ± 2.50	35.71 ± 0.00	36.67 ± 2.04
Emulsion stability (%)	59.00 ± 1.00	62.00 ± 1.00	66.00 ± 2.00
Least gelation (%w/v)	2.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00

Source: Amoo, Atasie and Kolawole (2009)

26. Amoo and Agunbiade (2009) estimated some nutrient and anti-nutrient components of *Pterygota macrocarpa* seed flour, from the estimation, it was revealed that the seed of *Pterygota macrocarpa*, a forest tree, is capable of solving the problem of a major shortage in non-edible oil for industrial applications due to its very high crude fat content.

Table 3.26: Proximate Composition (%) of *Pterygota macrocarpa* seed flour

Proximate	Whole seed	Dehulled seed
Ash	$2.30^{b} \pm 0.0$	$1.57^{a} \pm 0.02$
Moisture	$7.27^{c} \pm 0.03$	$3.67^{a} \pm 0.04$
Dry matter	$92.73^{c} \pm 0.03$	$96.33^{e} \pm 0.04$
Crude protein	$7.21^{a} \pm 0.12$	$10.81^{c} \pm 0.28$
Crude fat	$63.97^{c} \pm 0.23$	$74.40^{e} \pm 0.57$
Crude fibre	$9.41^{d} \pm 0.05$	$7.58^{c} \pm 0.02$
Carbohydrate	$9.84^{e} \pm 0.21$	$1.97^{b} \pm 0.42$

Source: Amoo and Agunbiade (2009)

27. Akoja and Amoo (2011) determined the proximate composition of some under-exploited leguminous crop seeds. The results of the research work showed *Clitandra toglana* as a potential source of dietary energy and protein. It is interesting to note that this legume

has the highest soluble carbohydrate content indicating its potential use in fermentation products such as syrups.

Table 3.27: Proximate composition (%) and digestible crude protein of *Hexalobus crispiflorus, Clitandra togolana* and *Dioclea reflexa* samples

Components	*Hexalobus crispiflorus*	*Clitandra togolana*	*Dioclea reflexa*
Moisture	10.03±0.01	8.04±0.03	9.02±0.01
Dry matter	89.97±0.01	91.96±0.03	90.38±0.01
Crude protein	7.11±0.02	10.81±0.23	13.81±0.20
Fat (Ether extract)	35.86±0.41	9.90±0.53	8.30±0.30
Crude fibre	8.61±0.08	7.38±0.10	8.18±0.16
Ash	3.36±0.12	4.25±0.05	3.11±0.16
Nitrogen free extract (CHO)	35.03±0.41	59.62±0.80	57.58±0.38
Total energy (KJ/100g)	2055.18±2.45	1551.64±2.32	1507.33±0.91
Digestible crude protein (g/kg)	2.6156±0.02	6.6176±0.12	9.6476±0.10

Source: Akoja and Amoo (2011)

28. Ogundele, Oshodi and Amoo (2012) carried out the comparative study of amino acid and proximate composition of *Citurilus colocynthis* and *Citurilus vulgaris* seeds. The comparative work revealed that these seeds possess great potentials as a source of essential amino acids, and compare favourably with soyabeans in terms of the amino acids profile. Hence, they can be used to supplement diets with low protein especially for growing children.

Table 3.28: Amino acid profile and scoring of *Citrullus colocynthis* and *Citrullus vulgaris*

Amino acid	Amino acid contents (mg/g protein		Reference	Amino acid scoring	
	C. colocynthis	*C. vulgaris*	Soya bean	*C. colocynthis*	*C. vulgaris*
*Lysine	36.95±0.35	34.60±0.71	60.80	60.77	56.91
*Histidine	23.05±0.07	24.10±1.13	25.00	92.20	96.40
*Arginine	66.10±0.57	63.55±0.78	61.00	108.36	104.18
Aspartic acid	91.05±0.64	95.15±0.92	113.00	80.58	84.20

*Threonine	23.40±1.27	30.00±1.14	51.00	45.88	58.82
Serine	32.45±1.34	35.80±1.56	56.70	57.23	63.14
Glutamic	142.45±1.06	151.40±0.99	169.00	84.29	89.59
Proline	30.30±1.13	29.65±1.20	48.60	62.35	61.01
Glycine	29.50±2.12	36.45±0.78	40.10	73.57	90.90
Alanine	23.20±0.59	37.05±1.20	42.30	54.85	87.59
*Cysteine	9.30±3.68	10.01±4.51	17.00	54.70	58.88
*Valine	37.05±1.20	39.60±1.13	45.90	80.71	86.27
*Methionine	12.30±2.12	14.40±2.12	12.20	100.00	118.03
*Isoleucine	32.75±1.06	31.10±0.85	26.20	70.89	67.31
*Leucine	76.95±1.20	74.60±1.71	77.20	99.68	96.63
*Tyrosine	29.75±0.35	32.25±0.78	33.90	87.76	95.13
*Phenylalanine	41.70±2.75	45.90±0.59	48.40	86.16	94.83
1st Limiting EAA				Cysteine	Lysine
2nd Limiting EAA				Lysine	Cysteine

Source: Ogundele, Oshodi and Amoo (2012)

*Essential Amino Acids

29. Abass, Owolabi and Amoo (2013) researched into the effects of seed coat absence on the chemical composition of *Croton penduliflorus* seed and its oil. This work reveals that the removal of the seed coat resulted into less susceptibility of the seeds to microbial degradation. Besides, the physico-chemical analysis of the oil showed that the oil is not fit for human consumption, hence, can only be used as an industrial feedstock. Due to high levels of saturation in the oil, industrial application of the oil will be more of soap-making, metallurgy and other engineering applications such as lubrication and production of transmission fluids (subject to bulk modulus analysis).

Table 3.29: Proximate and Physicochemical properties of *Croton penduliflorus* seed oil

Proximate	Sample type	Mean ± SD
Moisture	With coat	3.92±0.04
	Without coat	6.12±0.44
Ash	With coat	3.55±0.20

	Without coat	3.26±0.43
Crude fat	With coat	40.50±0.99
	Without coat	34.01±0.14
Crude fibre	With coat	26.14±1.74
	Without coat	38.50±1.27
Crude protein	With coat	0.14±0.00
	Without coat	0.06±0.00
Carbohydrate	With coat	25.72±0.57
	Without coat	18.03±0.54
Parameters		
Acid value (mgKOH/g)	With coat	2.42±0.34
	Without coat	4.10±0.35
Free fatty acid	With coat	1.21±0.17
	Without coat	2.06±0.18
Iodine value	With coat	29.54±2.93
	Without coat	28.06±3.79
Saponification value	With coat	51.83±0.59
	Without coat	27.77±0.77
Peroxide value	With coat	2.10±0.26
	Without coat	3.43±0.15

Source: Abass, Owolabi and Amoo (2013)

30. Adesina and Amoo (2013) examined the chemical composition and produced biodiesel from snake gourd (*Trichosanthese cucumenia*) seeds. The biodiesel produced was analyzed, compared with standards and found out to meet established standards of quality and compete favourably with the commercial dissel

Table 3.30: Comparison of selected physical properties of Biodiesel from *Trichosanthese cucumerina* seeds oil with ASTM standards

Properties	Biodiesel	ASTM PS 121 standard
Flash point (^oC)	205	100 – 170
Kinematic viscosity (40^oC)	3.73	1.9 – 6.0
Relative density	0.92	0.88 (minimum)

Refractive index	1.47	No available data

Source: Adesina and Amoo (2013)

31. Abdulkadir, Amoo and Adesina (2013) further investigated the solvent efficiencies and biodiesel production from *Hura crepitans* seeds. This work also reports on the application of *H. crepitans* seed oil. The seeds were earlier found to have high crude fat content, hence its application for biodiesel production. The properties of the biodiesel produced met the established standards of quality. Therefore the seed oil can be used for biodissel production

Table 3.31: Comparison of Fuel Properties of HCSO Biodiesel with ASTM and EN standards

Fuel Properties	HCSO Biodiesel	ASTM D6751	EN
Flash point (oC)	153	>130	>101
Pour point (oC)	-3.0	-15 to 13	-15 to 13
Cloud point (oC)	6.0		
Specific gravity	0.8918	0.87 to 0.98	0.86 to 0.90
Viscosity (mm^2/s)	7.32	1.90 to 6.0	3.50 to 5.00
Acid value (mgKOH/g)	0.14	0.80 (max)	0.50 (max)
Calorific value (J/g)	10629.30		
Biodiesel yield (%v/v)	95		

Source: Muhammed, Amoo and Adeniyi (2013)

32. Ayoade, Amoo and Akpambang (2015) worked on the refined and non-refined oil extracted from African canarium seed and discovered that refining of the oil greatly reduce acid value and significantly increase iodine value whereby making the oil consumable in its refined form. It was also established that the oil contained a very high percentage of linoleic acid which is an indication that the oil is of high nutritional value for linoleic acid being an essential fatty acid with cholesterol-lowering activity.

Table 3.32: Physicochemical properties of crude and refined oils of Canerium fruit

Physicochemical	**Crude oil**	**Refined oil**
Colour (Lovibond unit)	11.2 units (Dark green)	4.3 units (Greenish yellow)

Specific gravity @ 25°C	0.9516 ± 0.13[a]	0.8621 ± 0.07[b]
Refractive index @ 35°C	1.4012 ± 0.02[a]	1.3034 ± 0.01[b]
Viscosity (pal/.s) @ 25°C	68.04 ± 1.01[a]	56.28 ± 0.03[b]
Moisture / volatile matter	ND	ND
Acid value (mgKOH/g)	1.14 ± 0.03[a]	0.64 ± 0.01[b]
Free fatty acid (as oleic acid)	0.57 ± 0.01[a]	0.32 ± 0.00[b]
Peroxide value (meq/kg)	1.08 ± 0.01[a]	0.71 ± 0.01[b]
Iodine value (mg iodine/g)	96.51 ± 1.02[b]	117.29 ± 0.84[a]
Saponification value (mg/kg)	148.3 ± 1.13[a]	126.8 ± 1.05[b]
Unsaponifiable matter (%)	1.73 ± 0.01[a]	1.21 ± 0.01[b]
Soap content (ppm)	212.5 ± 2.01[b]	128.63 ± 1.01[a]
Freezing point °C	- 7.5 ± 0.15[a]	- 13.0 ± 0.11[b]
Melting point °C	43 ± 0.10[a]	39 ± 0.05[b]
Smoke point °C	187 ± 2.17[b]	203 ± 2.03[a]
Flash point °C	283 ± 3.14[b]	317 ± 2.08[a]
Fire point °C	345 ± 3.01[b]	358 ± 4.12[a]

Source: Ayoade, Amoo and Akpambang (2015) Mean ± standard deviation of triplicate determinations

NB: Mean values followed by the same superscript within the rows are not significantly different at p<0.05

33. Ogundele, Oshodi, Sanni and Amoo (2013) worked on the protein isolation of gourd melon seeds and discovered that the sample has very high protein content, foaming capacity and protein solubility at the iso-electric points. These qualities will enhance the availability and uses of these gourd seed protein isolates as protein substitutes for animal protein and as good protein supplement in the food and pharmaceutical industries. Since the protein is also

soluble in both acidic and basic medium, the seed can be used in production of vegetable beverage.

Table 3.33: Proximate composition (%) and functional properties of protein isolates of gourd seeds

Parameters	*C .colocynthis*	*C. vulgaris*	*L. siceraria l*	*L. siceraria ll*	*L. siceraria lll*
Protein	88.19±1.20	89.34±1.91	90.91±3.00	88.62±1.95	89.14±5.58
Fat	1.14±0.41	1.67±0.89	0.65±0.13	1.03±0.09	0.84±0.05
Moisture	4.81±0.46	3.73±0.23	5.13±0.22	5.13±0.14	5.02±1.13
Ash	4.70±0.92	4.84±1.17	3.29±0.16	4.24±1.73	4.54±0.25
Carbohydrate	1.14±0.47	0.41±0.04	0.02±0.00	0.98±0.48	0.46±0.06
WAC (g/g)	2.67±0.00	3.33±0.29	2.83±0.29	3.00±0.00	3.50±0.50
OAC(g/g)	2.24±0.45	2.84±0.26	2.99±0.26	2.69±0.00	3.14±0.45
Bulk density (g/ml)	0.49±0.03	0.45±0.04	0.51±0.02	0.45±0.03	0.46±0.03

Source: Ogundele, Oshodi, Sanni and Amoo (2013)

34. Raheem, Oladele and Amoo (2015) investigated the physicochemical and antimicrobial properties of cashew nut (*Anacardium occidentale*) oil. From the results, it was concluded that the oil extract from the nut contained high content of linoleic acid, an unsaturated and essential fatty acid, that would be very useful nutritionally and also that the oil had moderate antimicrobial activities which shows that the oil may be of good use as preservatives, antimicrobial in pharmaceutical industries.

Table 3.34: Fatty acid Composition and Antimicrobial Properties of Raw and Roasted Cashew Seed

Fatty acid (%)	**Raw**	**Roasted**
Palmitic acid	15.10±0.01	14.4±0.00
Palmitoleic acid	0.19±0.01	0.21±0.01
Margaric acid	0.06±0.00	0.07±0.00
Stearic acid	12.89±0.01	10.19±0.01
Oleic acid	13.06±0.0	16.41±0.0

Linoleic acid	57.95±0.01	58.12±0.01	
Linolenic acid	0.46±0.01	0.33±0.00	
Arachidic acid	0.17±0.00	0.16±0.01	
Arachidonic acid	0.00±0.00	0.00±0.00	
Behenic acid	0.11±0.01	0.11±0.01	
Erudic acid	0.00±0.00	0.00±0.00	
Lignoceric acid	0.00±0.00	0.00±0.00	
Inhibitory effects of extracted oil			
Microorganisms	Raw	Roasted	Streptomycin sulphate
B.subtilis	4.80±0.43	1.85±0.03	8.90±0.3
E.coli	1.51±0.01	0.00±0.00	12.02±0.18
C.albican	3.56±0.13	2.22±0.20	7.15±0.12
B.cereus	3.50±0.02	1.21±0.01	11.03±0.20
P.aeruginosa	2.52±0.01	3.13±0.11	14.05±0.13
P.syringine	3.54±0.22	1.92±0.07	8.99±0.23
X.oximopoides	2.57±0.01	0.00±0.00	14.00±0.22

Source: Raheem, Oladele and Amoo (2015)

35. Ayoade, Aderibigbe and Amoo (2015) made a careful study of the effects of different processing operations on the chemical composition and functional properties of African breadfruit (*Treculia africana*) seed flour. The results showed that the sample contained high nutrients such as carbohydrate and protein which imply that the seed is a good source of energy food, nutritionally valuable minerals such as iron, calcium, phosphorous, zinc and magnesium which play important roles in blood and bone formation, muscle contraction and maintenance of enzymes metabolic process.

36. Ayoade, Amoo and Gbolahan-Ayoade (2015) analyzed the phytochemical composition and antioxidant potential of purple canary (*Canarium Schweinfurthii*) fruit. The seed contained an appreciable amount of antioxidants and phytochemicals which implied that the sample can be used in pharmaceutical industries for production of drugs and supplements.

Table 3.36: Phytochemical and Antioxidant Properties of Canerium Fruit in Various Extracts

Phytochemicals	n-hexane	Acetone	Ethanol	Water
Tannin (%)	0.34±0.00[c]	0.34±0.00[c]	2.06±0.17[a]	1.83±0.05[b]
Saponins (%)	0.42±0.03[c]	0.16±0.01[d]	1.87±0.02[a]	1.24±0.03[b]
Flavonoids (mg/g)	1.18±0.11[d]	2.61±0.13[c]	4.84±0.32[a]	3.01±0.01[b]
Alkaloids	0.62±0.03[c]	0.33±0.00[d]	3.26±0.00[a]	2.53±0.02[b]
Glycosides	0.51±0.01[c]	0.11±0.00[d]	2.91±0.15[a]	2.14±0.00[b]
Terpenoids	0.87±0.05[c]	0.28±0.01[d]	6.62±0.81[a]	4.21±0.63[b]
Total	**3.94**	**3.83**	**21.50**	**14.96**

Antioxidant Properties of Canerium Fruit Extracts

Solvents	Total phenol	Ferric reducing power	DPPH	Total flavonoids	Vit. C (mg/100g)	Vit. E (ppm)
n-Hexane	416.14±2.71[c]	106.28±8.13[d]	48.15±4.13[a]	1.83 ± 0.00[c]	32.85±1.03[c]	487.2±17.21[a]
Acetone	412.03±6.63[d]	232.03±15.07[c]	32.27±1.05[b]	1.68 ± 0.02[d]	31.32±0.03[d]	451.4±15.62[b]
Ethanol	620.31±15.82[a]	358.96±21.72[a]	13.61±1.26[d]	3.06 ± 0.15[a]	34.21±1.01[b]	338.0±13.15[c]
Water	598.47 ± 13.9[b]	284.11±13.21[b]	17.28±0.17[c]	2.71 ± 0.34[b]	45.31±2.14[a]	338.0±13.15[c]

Source: Ayoade, Amoo and Gbolahan-Ayoade (2015)

37. Akintelu and Amoo (2016) studied the chemical composition and physicochemical properties of milk bush (*Thevetia peruviana*) seed flour. The results of the work done showed that the sample contained high amount protein and fat which shows that the sample can be

used in food and feed formulation while the high saponification value showed that the sample oil can be used for soap production.

Table 3.37: Proximate composition (%) of both raw and boiled thevetia peruviana seed

Proximate	Raw	Boiled
Moisture	2.00±0.00	2.89±0.19
Ash	3.33±0.00	2.96±0.01
Crude protein	30.10±0.00	29.6±0.00
Crude fibre	4.79±0.01	5.21±0.46
Crude fat	58.30±0.00	59.20±0.00
Carbohydrate	1.80±0.00	0.30±0.00
Energy KJ/g	2524.50	3521.10
Physicochemical properties	Raw	Boiled
Acid value	1.71±0.00	1.41±0.00
Peroxide value	3.85±0.00	11.51±0.00
Iodine value	83.89±1.22	76.20±2.81
Saponification value	224.26±0.00	193.78±0.00
Free fatty acid	0.86±0.00	0.71±0.00
Unsaponifiable value	2.04±0.00	1.59±0.00
Relative density	0.89±0.00	0.88±0.00
Specific gravity	0.91±0.00	0.93±0.00
Refractive index	1.46±0.00	1.47±0.00
Viscosity	28.21±0.00	30.59±0.00

Source: Akintelu and Amoo (2016)

38. Amoo, Balogun and Jogbodo (2017) evaluated the chemical composition and glycemic index of Lablab Purpureus and Phaseolus Lunatus bean seed flour. It was observed that the seed contained most of the essential and non-essential amino acids in a reasonable high concentrations. This indicates that the sample can be a cheap source of the amino acids that are lacking in most of the food materials and also an alternative protein source to alleviate protein energy-malnutrition among economically weaker section of the people in developing countries and also improve food production for diseases control (in press).

Table 3.38: Amino Acid composition (g/100g protein) of Lablab Purpureus and Phaseolus Lunatus seeds

Essential Amino Acid	***Lablab purpureus*** **Concentration (g/100g protein)**	***Phaseolus lunatus*** **Concentration (g/100g protein)**
Leucine	6.48	8.72
Lysine	5.67	6.41
Isoleucine	4.97	5.66
Phenylalanine	4.79	6.56
Tryptophan	0.89	1
Valine	4.82	4.38
Methionine	1.25	1.65
Arginine	6.79	6.36
Histidine	3.16	3
Threonine	3.94	4.77
Non-Essential		
Proline	3.14	3.45
Tyrosine	3.61	3.78
Cystine	0.48	0.84
Alanine	3.33	3.49

Glutamic Acid	13.93	14.53
Glycine	3.65	4.44
Serine	3.86	3.67
Aspartic Acid	8.8	11.69

Source: Amoo, Balogun and Jogbodo (2017)

39. Amoo, Jogbodo and Mamukuyomi (2017) evaluated the chemical composition and in-vitro glycemic index of Velvet and African yam bean flour. The work revealed that yam bean seed contained high amylose content which resulted in a considerable low glycemic index and this suggests that the sample can be recommended to diabetic patients as food.

Table 3.39: Amylose, Amylopectin and Total sugar Content index of Velvet Bean and African Yam Bean Seeds

Glycemic indices	VELVET BEAN	AFRICAN YAM BEAN
AMYLOSE (mg/g)	33.75±0.20	92.92±0.98
TOTAL SUGAR (mg/g)	13.02±0.04	2.81±0.04
AMYLOPECTIN (mg/g)	53.22±0.23	4.28±0.94
GLYCEMIC INDEX	59.28±0.01	42.34±0.02

Source: Amoo, Jogbodo and Mamukuyomi (2017)

40. Ayoade, Amoo, Jabar, Ojo and Maduabuchi (2017) further carried out the proximate, minerals and amino acid profile of (*Canarium schweinfurthii*) seed pulp of canarium. The report from this research work showed that the sample can be used for making essential amino acids supplement which our body cannot synthesized.

Table 3.40: Amino acid profile (g/100g protein) of canarium seeds

Amino acid	Results
*Lysine	3.51±0.02
*Histidine	5.21±0.01
*Arginine	6.09±0.01
Aspartic acid	13.19±0.03
*Threonine	2.70±0.00
Serine	2.17±0.00
Glutamic	11.67±0.01
Proline	2.03±0.01
Glycine	3.08±0.02
Alanine	3.50±0.02
*Cysteine	0.80±0.00
*Valine	4.00±0.05
*Methionine	1.63±0.01
*Isoleucine	7.28±0.03
*Leucine	5.30±0.00
*Tyrosine	2.22±0.01
*Phenylalanine	8.63±0.02
Classifications	
Total amino acid (TAA)	83.01
% (TAA)	100.0
Total essential amino acid (TEAA)	45.15
% (TEAA)	54.39
Total non-essential amino acid (TNEAA)	37.86
% (TNEAA)	45.61

Source: Ayoade, Amoo, Jabar, Ojo and Maduabuchi (2017)

41. Amoo, Olugbemisoye and Adeniyi (2017) carried out research work on preparation and application of calcium carboxylate from *Luffa cylindrical* seed oil by metathesis and the effect of the metal carboxylates was tested on concrete's hydrophobicity at different mixture

of concrete formulation. Water sorptivity test showed that 260.00g casted concretes of 0.8% concentration of the metal carboxylates presented the hydrophobicity showing a good resistance to permeability. This will be of importance to cement manufacturers.

Table 3.41: Sorptivity test of hydrophobicity on casted concretes at different concentrations

Percentage concentration/weight	0.60% (261.00g)		0.80% (260.00g)		1.00% (245.00)	
Time (mins)	Length (mm)	Sorptivity (g/h $^{0.5}$)	Length (mm)	Sorptivity (g/h $^{0.5}$)	Length (mm)	Sorptivity (g/h $^{0.5}$)
10mins	1.58	0.0031	1.20	0.00047	2.47	0.0042
20mins	1.85	0.00089	1.50	0.00043	2.97	0.00042
30mins	1.98	0.000057	1.70	0.00020	3.30	0.00037
40mins	2.10	0.000051			3.57	0.000083
50mins	2.23	0.00042			3.67	0.000067
60mins	2.25	0.00023			3.72	0.0000083
70mins	2.30	0.00013				
80mins	2.39	0.000076				
90mins						
100mins						
110mins						
120mins						

Source: Amoo, Olugbemisoye and Adeniyi (2017)

42. Amoo, Abiola and Adeniyi (2017) extracted oil from *Cucurbita pepo* seeds, thermally polymerized in the presence of copper carboxylate as catalyst to produce bio-based resin (binder) and used in printing ink production. The results of the physical properties of the ink formulated with the binder produced in this research showed that the binder has high drying speed without drying agent, exhibits good adhesion and provides a corresponding binder for printing ink. Therefore, the seed oil will be of important use in production of ink.

Table 3.42: Properties of formulated ink

Properties	Values
pH	8.7

viscosity (mm2/s)	5.5
Tack	Fairly tacky
Chemical drying	Within 3 hours
Setting (physical drying)	Set on the surface of the substrate
Adhesion	Adhere well to substrate

Source: Amoo, Abiola and Adeniyi (2016)

43. Ibeto and Amoo (2016) studied the nutritional, antinutritional, functional properties and glycemic index of *canavalia ensiforms* and *canavalia gladiate* seeds. From the results of the work, the samples exhibited good antioxidant activities and low glycemic indexes with nutritional qualities. They can therefore be recommended as food for diabetic patients.

Table 3.43: Glycemic Indexes of *C. ensiformis* and *C. gladiata* seeds

Samples	**Total sugar (%)**	**Amylose (%)**	**Amylopectin (%)**	**Amylose /Amylopectin ratio**	**Glycemic Index (%)**
C. ensiformis	1.15 ± 0.01	42.36 ± 0.42	57.64 ±0.42	0.73	59.20 ±0.01
C. gladiata	1.06 ± 0.00	45.28 ±1.11	54.72 ±1.11	0.83	48.25 ±0.39

Source: Ibeto and Amoo (2016)

Glycemic Index value of 70% or higher = high,

56%—69% = medium,

55 or lower = low.

4. CONCLUSION

Plant seed chemicals are those chemicals that can be extracted, isolated from the plant seeds whose physicochemical properties, functional properties and their modifications determine their usefulness in chemical-related industries. Examples are protein, carbohydrate, fats, terpenoids, alkaloids, tannin, resin, saponin, flavonoid, minerals etc.

Mr. Vice-chancellor Sir, In the course of my academic career, I have investigated over 52 number of plant seeds in which their chemical composition, mineral; the physicochemical and functional properties where necessary were determined. The physico-chemical and functional properties allowed us to identify the potential utilization of these raw materials. Some of the plant seed chemicals whether in native or modified form may be substituted for imported raw materials in chemical industries. The substitution of these seed chemicals will provide opportunity to expand further our national industrial base.

From the research work;

i. biodiesel has been produced from the extracted oil of snake gourd seeds which significantly meet the established standards of quality.

ii. the oil extracted from *Curcubita pepo* seed has been polymerized to produce bio-based resin (binder) and used in the formulation of printing ink of good quality.

iii. chemicals from *Canavalia ensiformis, Canavalia gladiate,* velvet bean, rice bean and lablab bean seeds exhibited good antioxidant activities, low glycemic indexes with nutritional qualities and therefore can be used as food for diabetic patient.

iv. winged bean – seed was used to compound fish meal diet for Nile Tilapia (*Oreochromies niloticus* (L) fingerlings as protein supplement. The seed flour was found to provide up to 60% of the total dietary protein required by the fingerlings and hence can be used to replace the more expensive soybeans in feeding Nile Tilapia.

v. the research conducted on the comparison of acha meals as a dietary carbohydrate source for Nile Tilapia reported that methionine and cysteine contents of acha meal were higher than those of maize and sorghurm meal, the digestibility of acha meal is similar to those of maize and sorghum, the growth response and feed utilization by *O. niloticus* fed acha, maize and sorghum meals were reasonable while the weight gain was highest in acha meal. It was considered that the use of acha meal as a source of energy could be an effective means of reducing tilapia feed and production cost.

vi. metal carboxylates have been produced from *Luffa cylindrica* seed oil and tested on concrete's hydrophobicity at different concrete formulations. The results showed a good resistance to absorption of water by capillary movement and this can prevent water absorption in buildings erected in water logged areas which negatively affected their life span. This will be good for the building and construction engineers as well as cement manufacturers.

5. RECOMMENDATIONS

1. I wish to recommend that the production of plant seed chemicals be encouraged to supplement petrochemical because they:
    a. are renewable;
    b. are sustainable;
    c. are biodegradable;
    d. environmentally – friendly;
    e. cost effective;
2. From my academic experience in the university, we should focus more on:
    i. need – driving research work i.e applied research that meet the current situation of our needs.
    ii. there should be interdisciplinary research so as to have robust research output;
    iii. collaboration with industries to make our research directional and for proper utilization of our research findings/output;
    iv. government and education authorities / executives should make supply of electricity a priority for better and efficient research output;
3. Government at all levels should provide research funding to our tertiary institutions and research institutes to encourage researchers;

Generally, we need to revisit/review our curriculi so as to be in line with what is currently going in other institutions all over the world.

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