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CHARACTERIZATION AND EVALUATION OF CHICKEN EGGSHELL FOR USE AS A BIO-RESOURCE

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Abstract

Chemical compositions of chicken eggshell were determined with the aim of finding economic uses for it; instead of becoming a nuisance to the environment. The concentrations obtained were (mg/L): calcium 2300.33 ± 3.80, magnesium 850.00 ± 1.24, sodium 33.83 ± 0.72, potassium 17.06 ± 1.04, iron 1.4 ± 0.03, zinc 0.99 ± 0.04 and copper 0.063 ± 0.01. The proximate showed that the eggshell contained, 0.95 ± 0.89, moisture; 45.29 ± 0.06, ash; 1.40 ± 0.25, crude protein; 0.37 ± 0.06, lipid; 4.38 ± 0.32, crude fibre; 47.63 ± 0.32 (%), carbohydrate and 811 ± 12.71 (cal/g), calorific value. Further analysis revealed the presence of carbon and oxygen in the eggshell in right proportion as a good alternative adsorbent for removal of heavy metals and dyes from aqueous solutions. Findings from the study shows that the chicken eggshell potentially represents a natural source of food nutrients.

Keywords: Eggshell, calcium, carbohydrate, functional group, animal feed, food supplement.

1. Introduction

Eggs contain many essential nutrients, including high-quality protein and this has made it form part of human diets for centuries. Eggs serve as a very good source of proteins to human beings besides milk. It is also rich in amino-acids, carbohydrates, easily digestible fats and minerals, as well as essential vitamins (Bashir *et al.*, 2015). There are several species of eggs which include; chicken egg, quail egg, and guinea fowl egg. They all have similarities in nutritional composition and potential food usage (Dudusola, 2010). A chicken egg is an inexpensive single-food source of protein and this has led to its high consumption rate and consequently high eggshells production (Bashir *et al.*, 2015).

The chicken egg is made up of three major component parts: shell, the white or albumen and the yolk (Figure 1a). Many studies have been and are still being carried out on the various components of chicken egg (Dudusola, 2010), with little or no information on the chicken eggshell.

The chicken eggshell consists of the cuticle, crystal layer, spongy calcareous layer pores, cores and mammillary layer (Figure 1b). The membranes located on the inner surface of the eggshell appear like a single layer but can be divided into two distinct layers of fibrous material. One layer surrounds the albumen while the other is attached to the "tips" of the calcified material of the shell. They are regarded as the inner and outer shell membranes respectively (Figure 1b) (Hamilton, 1986). The membranes can be used as an adsorbent for the removal of reactive dyes from colored waste effluents and to remove heavy metal ions from dilute wastewaters (Schaafsma *et al.*, 2000).
The eggshell membranes also consist of collagen as a component which when extracted can be used for diverse purposes such as; medicine, biochemical, pharmaceutical, food, and cosmetics industries (King'ori, 2011).

Therefore, the efficacy of converting eggshells to beneficial use becomes an idea worth investigating. The eggshell is composed of about 95.1% inorganic matter and 3.3% protein. The eggshell was reported to weigh on average 1.6% of the total chicken egg-based on wet weight (Adeyeye, 2009) with a thickness between 0.33 and 0.35 mm (Tadesse *et al.*, 2015). Eggshells vary widely in texture but, it is predominantly made up of calcium carbonate and glycoprotein matrix. The outside of the shell is a thin proteinaceous layer, the cuticle that blocks the entrance of bacteria from entering the embryo (Al-awwal and Ali, 2015).

A

B

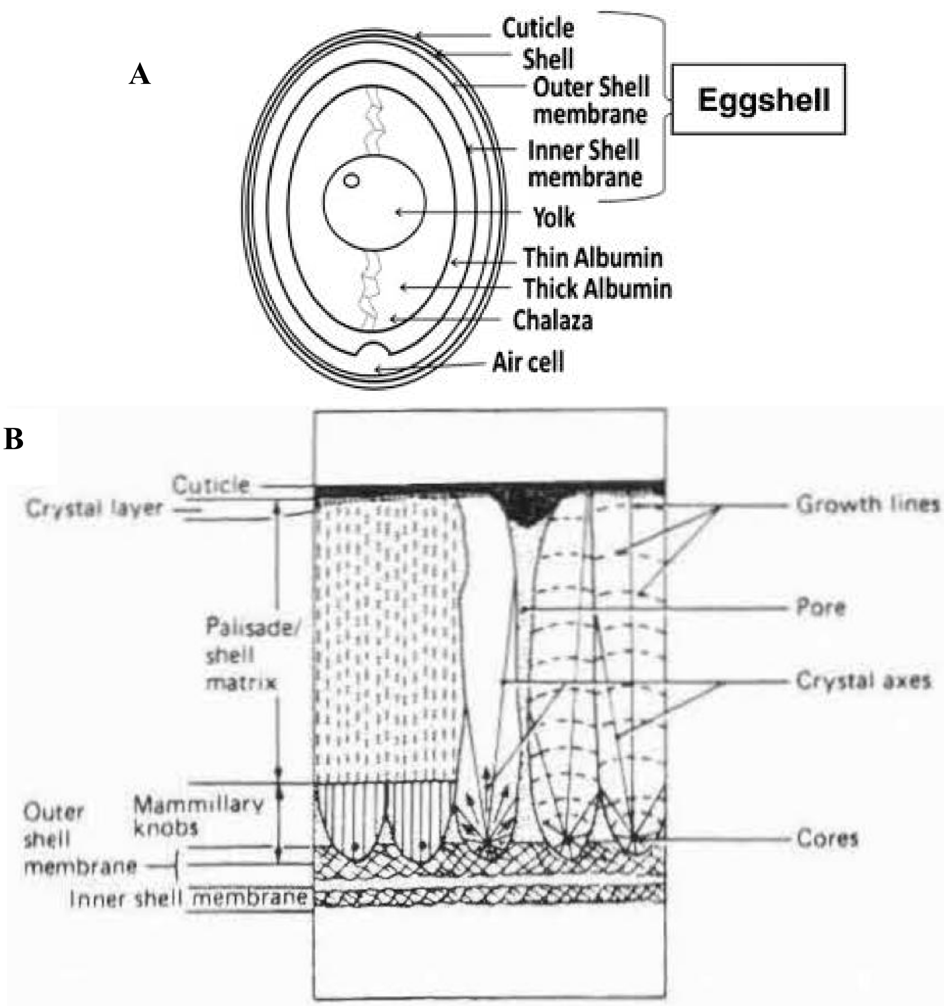

Figure 1: Schematic Diagrams of a Typical (A) Whole Egg and (B) Eggshell
Sources: (Hamilton, 1986; Mittal *et al.,* 2016)

Primarily, the eggshell provides nutrient, a perfect package, and protection to the enclosed embryo from mechanical damage and contamination. It is being used on a moderate scale as an additive in foods (Hunton, 2005).

Chicken eggshells are agricultural wastes which could lead to environmental pollution when not properly disposed of (Mtallib and Rabiu, 2009; Phil and Zhihong, 2009). They are found in hatcheries, homes and fast food industries and are readily abundantly available for collection (King'ori, 2011).

There are numerous challenges associated with its disposal which ranges from a cost of disposal, availability of disposal sites, odor, flies, and abrasiveness (Phil and Zhihong, 2009).
However, it can be processed into more useful products such as fertilizer, animal feeds, medicines, and building materials.

It can also be used for human consumption, as a food flavor in the food industry, especially in this era of ever-increasing endeavors to convert waste to wealth (Mtallib and Rabiu, 2009).

Eggshell can be used in the artwork for the production of mosaics, glue in musical instruments, and photography aids in photography (King'ori, 2011). The eggshell membrane powder can also be used in the paper industry, or in agriculture as a lime substitute or calcium supplement.
Other possible uses of eggshell include the production of biodegradable plastics from eggshell membrane proteins; altering of food-borne bacterial pathogen heat resistance with an eggshell membrane bacteriolytic enzyme; as human dietary calcium supplement especially for post-menopausal women (Dudusola, 2010).

Eggshells have been found to contain calcium, magnesium, copper, iron, manganese, molybdenum, sulfur and many more other useful elements. However, the proportions have not been reported in literature and, it could be a natural source of calcium (King'ori, 2011). Calcium, one of the content in eggshell had been clinically tried to provide effective prevention of osteoporotic fractures in elderly community-dwelling residents (Chang *et al.*, 2007). It is an acceptable practice for eggshell to be dried and used as a source of calcium in animal feeds.
The recycling of the nutrients of eggshell back to the animal portends that the nutritional composition of various eggshells should be evaluated to establish its suitability as animal feed (Adeyeye, 2009), hence this study.

The aim of this study was to examine the proximate analysis, elemental composition, functional group, surface morphology and composition of the natural waste chicken eggshell. These are with the intension of ascertaining the quality and quantity characteristics of the chicken eggshell in order to find a more economic value for it.

2. Materials and methods

2.1 Material preparation

The unboiled chicken eggshells were collected from household and restaurant wastes in Ilorin, Kwara State, Nigeria. The eggshells were washed with distilled water, without peeling off the membranes. It was sun-dried to constant weight, ground to a powder using a grinding machine and sieved to a fine powder by using a 0.5 micrometer sized sieve. The sieved eggshell was oven dried at 38°C until constant weight was obtained. The prepared eggshell was charged into a polyethylene and kept in a desiccator.
The eggshell was digested using aqua regia (HNO_3 67%: HCl 37% = 3:1) method, in order to make it suitable for analyses. A calibrated microwave oven (Berghof MWS-2) with 6 closed PFA 100 ml high-pressure vessels was employed for the digestion and a procedure according to Chen and Ma (2001) was followed.

2.2 Atomic Absorption Spectrophotometer (AAS) and Flame Photometer (FP)

The model of AAS used for the analysis of the chicken eggshell sample was AAS Buck scientific Accusys 211 equipped with air-acetylene for the flame. The automatic hollow cathode lamp switch attached to the AAS was used to measure the absorbance and concentration of the metals by direct aspiration into the burner through the sample introduction system at wavenumber corresponding to each element as given by the manufacturer.

Calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn) and copper (Cu) were determined using AAS (Jatto *et al.,* 2010). While flame photometer was used to determine the concentration of sodium (Na) and potassium (K) (Al-awwal and Ali, 2015). The results obtained were statistically analyzed using IBM SPSS statistics 19.

2.3 Proximate Analyses

The carbohydrate, crude protein, crude fat, moisture and ash contents were determined using the AOAC standard methods as was described by Jatto *et al.* (2010). The IBM SPSS statistics 19 was used for the statistical analysis of the proximate analyses.

2.4 Scanning Electron Microscope (SEM)

Scanning electron microscopy (SEM, FEI ESEM Quanta 200) and energy-dispersive X-ray spectrometry (EDX, FEI ESEM Quanta 200) were used to determine the morphology and elemental composition of the chicken eggshell respectively. The chicken eggshell was prepared and put in a Scanning Electron Microscope stud using a double-backed cellophane tape. The stub and sample were coated with gold and examined using the scanning electron microscope (Kaewmanee *et al.*, 2009).

2.5 Fourier Transform Infrared Spectroscopy (FTIR)

FTIR analysis of the eggshell was carried out using potassium bromide (KBr) pellet in a Fourier transform infrared (FT-IR) spectrophotometer, model Shimadzu (8400S) Japan. The FT-IR was domiciled in the Department of Chemical Sciences, the Redeemer's University, Ede, Osun State Nigeria. The spectra were observed at wavenumber 450–4000 cm^{-1} with a resolution of 4 cm^{-1}.

3. Results

Table 1 presents the results obtained from the AAS/FP analyses of the chicken eggshell and was compared with elemental dietary daily consumption for human beings. The chicken eggshell proximate composition for moisture, ash, crude protein, lipid, crude fibre, and carbohydrate are presented in Table 2. The morphology of the chicken eggshell and the elemental analysis of the chicken eggshell are depicted in Figure 2. The EDX of the chicken eggshell in Figure 3 shows the elemental compositions present as carbon 51.40%, oxygen 39.94%, Chlorine 0.2% and Calcium 8.46%. The FTIR patterns of the natural chicken eggshell are presented in Figure 3 and the analyses are as shown in Table 3.

4. Discussion

4.1 Atomic Absorption Spectroscopy/Flame Photometer

Calcium content (mg/L) in the chicken eggshell is 2300.33 ± 3.80 (Table 1) which is much higher than that of duck eggshell (42.3) and turkey eggshell (50.1) (Adeyeye, 2009). This shows that the chicken eggshell could be a good source of calcium which can be used to meet the daily consumption of calcium This can be as a supplement in bone development since the recommended daily consumption is between 700 – 1300 mg (Table 1) (Al-awwal and Ali, 2015). The recommended quantity of calcium for people with osteoporosis is 400-500 mg per day to supplement dietary sources (King'ori, 2011), and this can be gotten from the eggshell. It can also be used as a supplement in formulating animal feeds (Chang *et al.*, 2007).

Table 1: Comparative View of Chemical Composition of Chicken Eggshell and Daily Diet

Elements	Chicken Eggshell (mg/L)	Dietary (mg/day)
Calcium	2300.33 ± 3.80	700 – 1300
Magnesium	850.00 ± 1.24	130 – 420
Sodium	33.83 ± 0.72	1000 – 1500
Potassium	17.06 ± 1.04	3000 – 4700
Iron	1.4 ± 0.03	7 – 11
Zinc	0.99 ± 0.04	5 – 11
Copper	0.063 ± 0.01	0.7 – 0.9
Sources	This study	Food and Nutrition Board (2004)

Table 2: Proximate Composition of Chicken Eggshell, Duck Eggshell and Dietary

Nutrients	Chicken Eggshell (%)		Duck Eggshell (%)	Dietary (g/day)
Moisture	0.95 ± 0.09	0.5 ± 0.03	3.49	-
Ash	45.29 ± 0.06	43.5 ± 0.03	3.44	-
Crude protein	1.40 ± 0.25	1.35 ± 0.40	65.20	30 - 56
Lipid	0.37 ± 0.06	-	5.32	20 – 35
Crude fibre	4.38 ± 0.32	3.0 ± 0.30	0.11	26 -38
Carbohydrate	47.63 ± 0.32	51.70 ± 0.44	22.5	130
Total Calorific (cal/g)	811 ± 12.71	-	1687	
Sources	This study	Al-awwal and Ali (2015)	Adeyeye (2009)	Food and Nutrition Board (2004)

Table 3: Evaluation of the FT-IR Spectrum of the Chicken Eggshell

S/N	Band wave number (cm^{-1})	Assigned functional group
1	3421	A weak stretching vibration of O-H/N-H bond
2	2360	Moisture peak
3	2978, 2874	The C-H stretching of aliphatic alkanes
4	1797	carbonyl stretching of the amide group
5	1612, 1471	The vibration of the C=C stretching of unsaturation was depicted as a shoulder
6	1425	The C-H bending vibration of alkanes and alkenes

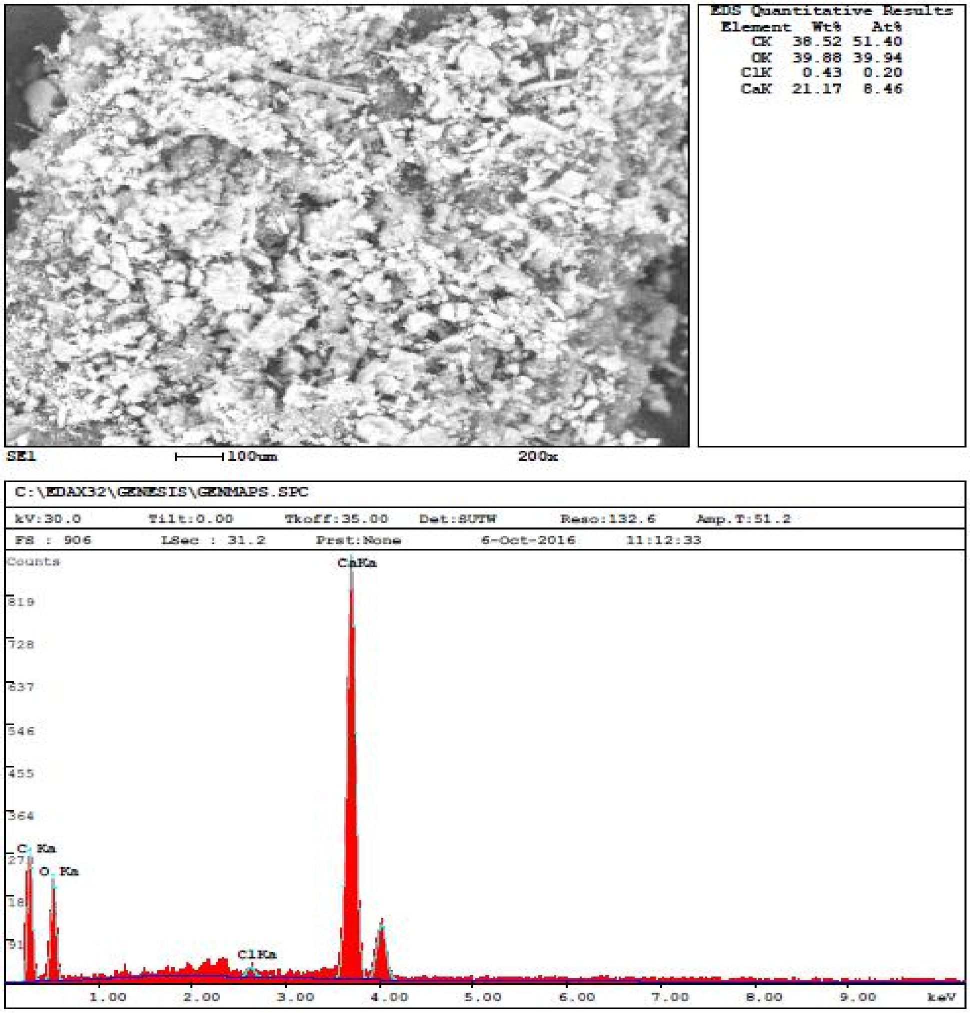

Figure 2: Surface Morphology and the EDX of Chicken Eggshell

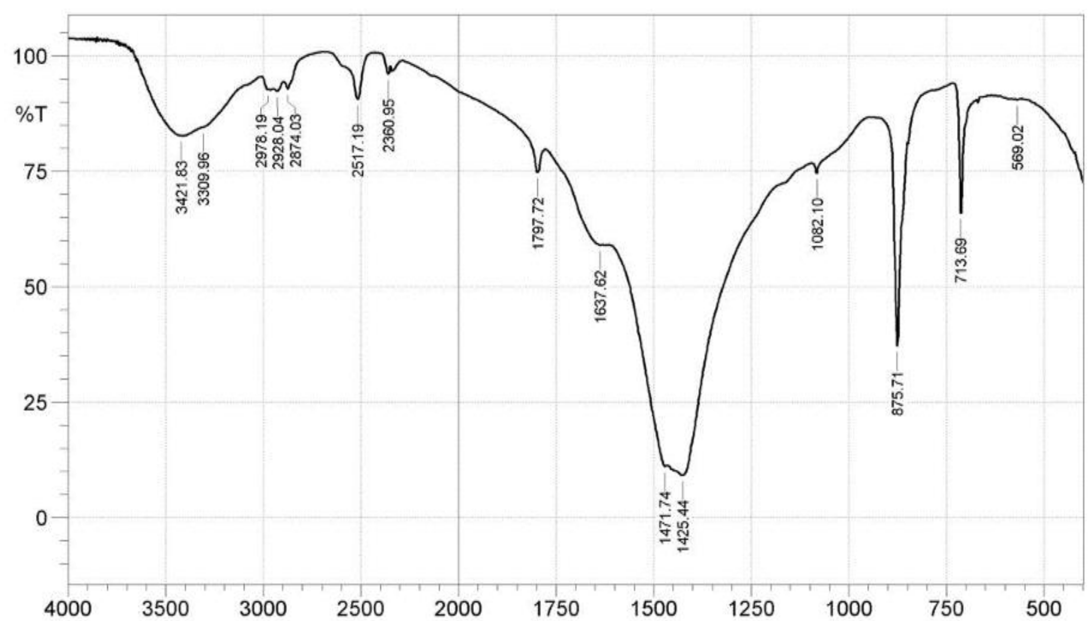

Figure 3: FTIR Spectra of Chicken Eggshell

The eggshell can be used in making fertilizer because it contains high quantity of calcium. This will make the fertilizer inexpensive and environmentally useable. The eggshell can be used as an alternative to sand in making hollow blocks because it contain calcium carbonate that can provide the required hardness and strength in block making (King'ori, 2011). Calcium is synonymous with bone, it gives bone its hardness, but it does not provide any flexibility. Hard bone without any flexibility would be synonymous with chalk that is hard, but brittle, and very easy to break. Magnesium is crucial in giving bone flexibility via improved trabecular integrity and bone density (Tucker, 1999). Since calcium and magnesium compete for absorption in the gut, too much of one can cause a deficiency in the other (Hardwick, 1991). Magnesium (mg/L) obtained in the chicken eggshell was 850.00 ± 1.24, which is a great quantity that can successfully meet the recommended daily consumption of 130 – 420 mg (Table 1). Magnesium deficiency can compromise cardiovascular health, increasing the risk of hypertension, stroke, and heart attack (Altura and Altura, 1982; Gröber *et al.*, 2015).

Magnesium is an essential electrolyte for living organisms; its presence in chicken eggshell with further processing can make the eggshell suitable as magnesium supplements to those patients with a deficiency. The deficiency can cause pre-eclampsia, arrhythmias, arteriosclerosis, diabetes mellitus, and metabolic syndrome in humans. Therefore, magnesium supplementation in those patients can be of benefit in most cases (Gröber *et al.*, 2015).

Chicken eggshell may be processed as magnesium dietary supplement. Lack of magnesium in the animal diet can result in a number of diseases and sometimes death.

Sodium has been found to be essential for neuromuscular transmissions and, this mineral was found in chicken eggshell. The concentration obtained in the eggshell was 3.83 ± 0.72 mg/L, and this was far less in comparison with the required daily dosage for man (1000 – 1500 mg) as shown in Table 1. Sodium in eggshell can be used as a supplement in animal feed as it is an important mineral element (Al-awwal and Ali, 2015).

Potassium (K) is an essential element to all forms of plant and animal life. In man, it is responsible for nerve action; very important in the regulation of water, electrolyte, and acid-base balance in the blood and tissues (Bashir *et al.*, 2015). In agriculture, potassium is referred to as potash, which is being used as fertilizer. The combination of potassium with calcium in chicken eggshell can make it a suitable raw material for fertilizer production. The potassium obtained in chicken eggshell was 17.06 ± 1.04 mg/L. Though lower than the recommended daily dosage (3000 – 4700 mg), it can be harnessed and used as a source of potassium in pharmaceutical production. As potassium is an essential ingredient in many pharmaceutical products.

The iron content of the eggshell (1.4 ± 0.03 mg/L) was found to be lower than the required daily dosage for man (7 – 11 mg). Therefore, eggshell cannot be used as a source of iron to meet daily diet of man; however, it can be used as a source of supplement in the body for oxygen transport by hemoglobin and enzymatic oxidation reactions (Michelle, 1962). It can also be a source of iron to improve the nutrition status of people especially in the risk of iron deficiency or anemia particularly infant, children and pregnant women. The eggshell can be a source of iron in improving anaemic condition in iron-deficient diabetic patients (Bashir *et al.*, 2015).

Chicken eggshell was found to contain 0.99 ± 0.04 mg/L of zinc. Though the quantity in the eggshell is low, it can be harnessed to meet daily human consumption of man which is between 5 – 11 mg. It can be a source of zinc for pharmaceutical products and other industrial uses. The eggshell can be used together with soya beans and magnesium to improve the quality of animal feed, particularly in egg-laying hens.

The copper content was found to be very low in chicken eggshell as it contains 0.063 ± 0.01 mg/L, but can be a source of copper for human consumption as the daily dosage is between 0.7 – 0.9 mg (Table 1). Turnlund *et al.* (1997) observed that when a healthy adult male consumed a diet of 0.38 mg/d for 42 days, there is a decrease in measures of copper-deficient status (serum copper and ceruloplasmin concentrations). This indicates that the chicken eggshells contain an appreciable quantity of copper which is a very important mineral element that helps in maintaining body health including muscles, nerve and oxidase enzymes in the body (Tacon, 1995). Copper performs several functions in both man and animals. These include as essential element in mammalian nutrition as a component of metalloenzymes where it acts as an electron donor or acceptor is needed for homeostatic maintenance that requires tightly coordinated orchestration of copper uptake, distribution, and efflux in cells and the organism as a whole. Several dietary sources of copper exist such as; mushrooms, potatoes, beans, peas, wheat, rye, lemon, raisins, peanuts and pecans. It is commonly found in fruits like lemons and raisins. Some mollusks are exceptionally rich in copper with levels reaching as high as 5 mg/kg wet weight (Stern *et al.*, 2007).
Therefore, eggshells can also be included in the list of copper dietary for animals and can be processed as supplementary in human dietary. Copper is necessary for human nutrition for normal iron metabolism and the formation of red blood cells, as it is closely associated with iron metabolism in the oxidation of ferrous to ferric iron. Anaemia is a clinical sign of deficiency of both iron and copper (Angelova *et al.*, 2011; Siulapwa *et al.*, 2014).

Elements such as zinc, iron, molybdenum, lead, or cadmium influence dietary copper absorption in the human body by inhibition and compete with one another for transport and/or by increasing intestinal metallothionein concentrations (Stern *et al.*, 2007). Chicken eggshell that is rich in iron and zinc is a good diet for making animal feed and with further processing, can be suitable as a food supplement. Copper in the chicken eggshell for animal feed can activate lysyl oxidase, which is an integral enzyme in elastin and collagen formation in birds (Angelova *et al.*, 2011; Siulapwa *et al.*, 2014). Deficiency and excess of copper in both animals and human beings can produce several adverse health effects in the blood and hematopoietic system, the cardiovascular, connective tissue and bone, the nervous, and the immune system as shown in Table 4 (Aggett, 1999; Stern *et al.*, 2007). Effect of deficiency of copper in animals and human beings among others include; bone abnormalities due to abnormal collagen synthesis, calcium depletion which leads to abnormal shell formation, structural and neurobehavioral abnormalities which include brain lesions, skeletal malformations, cardiovascular lesions, severe growth retardation, convulsions, and hyperirritability to noise (Table 4). Severe copper deficiency in rats during gestation induces fetal resorptions or stillbirths. The offspring of pregnant rats given a copper-deficient diet during gestation have increased postnatal mortality (Stern *et al.*, 2007; Siulapwa *et al.*, 2014). Hence, chicken eggshell as a source of copper in animal dietary and food supplement will mitigate some of this adverse health effect due to copper deficiency in the body.

Table 4: Effects of Daily intake of Copper by Human beings

Dose range	Approximately daily intakes	Health outcomes
Excessive and toxic	>5.0 mg/kg body Weight	Death; Gross dysfunction and disturbance of metabolism of other nutrients; hepatic "detoxification" and homeostasis overwhelmed. Gastrointestinal metallothionein induced (possible differing effects of acute and chronic exposure)
Adequate	100 µg/kg body weight	Plateau of absorption maintained; homeostatic mechanism regulates the absorption of copper;
	34 µg/kg body weight	Hepatic uptake, sequestration and excretion effect homeostasis; glutathione-dependent uptake of copper; binding to metallothionein; and lysosomal excretion of copper Biliary excretion and gastrointestinal uptake normal.
	11 µg/kg body weight	Hepatic deposit(s) reduced; conservation of endogenous copper;
	9 µg/kg body weight	gastrointestinal absorption increased
Deficient	8.5 µg/kg body weight	Negative copper balance
	5.2 µg/kg body weight	Functional defects, such as lysyl oxidase and superoxide dismutase activities reduced; impaired substrate metabolism;
	2 µg/kg body weight	Peripheral pools disrupted; gross dysfunction and disturbance of metabolism of other nutrients; death

Source: (Aggett, 1999)

4.2 Proximate Analyses

The moisture content of the eggshell is 0.95 ± 0.09% which shows a low moisture content, an indication that the eggshell would be very stable with good quality and shelf life. Because high moisture content tends to promote microbial contamination and chemical degradation in many substances. (Der-Jiun *et al.*, 2012).

The ash content is a measure of total amount of inorganic compounds such as minerals in the eggshell (Der-Jiun *et al.*, 2012; Segura-Campos *et al.*, 2013). The chicken eggshell was found to contain 45.29 ± 0.06% ash. This value is relatively high and much higher than that of duck eggshell (3.44%) (Table 3) (Bashir *et al.*, 2015). Therefore, the eggshell can be used in pharmaceutical industries as a source of raw materials for mineral synthesis and as an animal feed supplement. However, very high ash content in any substance may not be good for adsorption as it affects the activation of carbon by reducing the overall activity of the activated carbon. It also reduces the efficiency of reactivation, as the lower the ash value, the better the activated carbon for use as an adsorbent (Bello *et al.*, 2015).

Proteins are polymers of amino acids and they are essential components of the living cell needed by man and animals for the maintenance and growth of the body cells. The amino acids in proteins are utilized by the cells of the body to synthesize all the numerous proteins required for the function of the cell (Abolaji *et al.*, 2007). Protein intake into the body can contribute to the formation of hormones which controls a number of body functions such as growth, repairs, and maintenance of the body (Bhattacharjee *et al.*, 2013). The percentage crude protein of chicken eggshell was found to be low (1.40 ± 0.25%) (Table 3) and may not be sufficient to meet the daily recommended dose of between 28 – 65 g for children and adult. However, it can serve in part as a good source of protein for animal nutrition and can be processed as a protein supplement for human beings (Fakai *et al.*, 2015).

Lipid is very important in the body where it serves as a thermal insulator. From Table 3, the chicken eggshell has low lipid composition of 0.37 ± 0.06%. Though low, it can be used as a source of lipid. High lipid content in the dietary intake has some adverse health potentials, especially for the overweight. The consumption of excess lipid has been recognized as the dietary factor aiding increased level of cholesterol. Besides the cholesterol implications, high fat intake can also cause obesity, a factor in the causes of many diseases.

Therefore, low crude fat in the eggshell can make it preferred as a good raw material for food supplements because it may reduce the risk of coronary heart disease and lower the risk of hypertension (Bhattacharjee *et al.*, 2013).

The crude fiber obtained for the chicken eggshell is 89.9 – 91.1%. This value is very high which is a good quality of the eggshell as it could be useful in making animal feed and food supplement. The fiber content in the feed and food supplement helps to satisfy the appetite and assist in moving food through the alimentary canal by aiding the muscular action of the intestine, thereby preventing constipation (Al-awwal and Ali, 2015). Crude fiber is beneficial nutritionally as it aids absorption of trace elements in the gut and reduces absorption of cholesterol (Abolaji *et al.*, 2007).

Sufficient dietary intake of fiber helps to lower the serum cholesterol level in the body and reduce the risk of coronary heart disease, hypertension, constipation, diabetes, colon, and breast cancer (Mohammed and Mann, 2012).

High quantity of fiber has been identified as anti-tumorigenic and hypo-cholesterolaemic agent (Olagbemide and Ogunnusi, 2015). Therefore, chicken eggshell can be processed to make a dietary supplement and can be a source of fiber in animal feed owing to the large content of fiber in it. Other benefits of crude fiber are; as a useful tool for the control of oxidative processes in food products and as a functional food ingredient.

Crude fiber aids the conversion of starch to simple sugars, an important factor in the management of diabetes. Thus the high percentage fiber contents in the chicken eggshell can make it very effective and useful if explored, in the management of diabetes mellitus, colorectal cancers and weight reduction in obese individuals (Bhattacharjee *et al.*, 2013; Olagbemide and Ogunnusi, 2015)

The carbohydrates present in the chicken eggshell is 47.63 ± 0.32%, and this can be a source of energy in man and animal diets. Meanwhile, carbohydrate is the primary source of energy in the body and this high amount found in the eggshell shows it can play a great role in human health. Aside from the supply of energy, carbohydrates have numerous importances in biochemical reactions that are not directly concerned with energy metabolism; it can be an alternative source of glucose (Bhattacharjee *et al.*, 2013). Chicken eggshell as a source of glucose can be used as carbon source in bioethanol production, organic acid synthesis, and other biochemical products.

The gross energy (cals/g) obtained from the chicken eggshell is 811 ± 12.71, which is relatively high but lower than that of most cereals such as wheat, 3913, and sorghum, 3953 (Cervantes-Pahm *et al.*, 2014).

It may serves as an alternative to cereals when harnessed in animal feed making and human use, as it can provide a reasonable source of energy (Adeyeye, 2009; Der-Jiun *et al.*, 2012). Calories are needed to keep the body warm and to furnish energy for muscular work (Passmore *et al.*, 1974).

4.3 Scanning Electron Morphology (SEM) and Energy Dispersion X-ray (EDX) Analyses

The morphology of the chicken eggshell as shown in Figure 2 showed clusters of rough, irregularly arranged and spongy particles, aggregated together with microspores scattered on the surface of the sample. The small size of the grains and aggregates could provide higher specific surface areas since the size of the particle should directly respond to the surface area. The microporous surface area of the eggshell can be enhanced by calcination to improve the surface area and its activation through heat treatment. (Viriya-empikul *et al.*, 2012). The enhanced pores of the chicken eggshell may be useful for several applications such as adsorption, solid catalyst for biodiesel production and much more. Elemental analysis of the eggshell was also determined through EDX analysis. The EDX of the chicken eggshell is shown in Figure 2 with carbon of 51.40%, oxygen of 39.94%, Chlorine of 0.2% and Calcium of 8.46% observed. The EDX spectrum shows that the particle contains mainly calcium oxide, which could serve as a good material for heterogeneous catalyst in biodiesel production. The carbon present in the elemental composition can make it suitable as catalyst support since the carbon can make it capable of building the pores onto the carbon surface and enables it to be treated as a heterogeneous catalyst (Dhawane *et al.*, 2016).

The higher the amount of carbon (51.40%) and, the lower the amount of oxygen (39.94%), the more the effectiveness of materials for adsorption. The implication of this is that the chicken eggshell which is rich in carbon content and less in oxygen content can be an efficient adsorbent (Bello *et al.*, 2015).

4.4 FTIR Analysis

The FTIR patterns of the natural chicken eggshell is shown in Figure 4 and analyzed in Table 4. The FTIR spectrum of the eggshell indicated a weak stretching vibration of O-H/N-H bond at 3421 cm^{-1}. Moisture peak was observed at 2360 cm^{-1} and C-H stretching of aliphatic alkanes was observed at 2978 and 2874 cm^{-1} while the peak at 1797 cm^{-1} corresponds to carbonyl stretching of the amide group. The vibration of the C=C stretching of unsaturation was depicted as a shoulder at 1612 and the sharp peak at 1471 cm^{-1} while the C-H bending vibration of alkanes and alkenes was observed at 1425 cm^{-1}. The presence of various functional groups in the chicken eggshell makes it a potential adsorbent (Mittal *et al.*, 2016).

5. Conclusions

The chicken eggshell, therefore, could be used as food supplement and animal feed for man and animals respectively. It could also be used in paper industries and in agriculture as a substitute for lime and for fertilizer production. In building block making, chicken eggshell can be employed due to the high concentration of calcium present in it. The pores in the morphology made it suitable for heterogeneous catalyst in biodiesel production. The presence of various functional groups and the high carbon content in the eggshell makes it a potential material for the adsorbent to remove heavy metals and dyes in wastewater treatment.

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