INFLUENCE OF CORN COBS INCLUSION IN PIG DIETS ON GROWTH PERFORMANCE, CARCASS CHARACTERISTICS AND BLOOD PARAMETERS

BY

GIFTY ZIEMAH BUMBIE

(10443870)

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DECLARATION

I, Gifty Ziemah Bumbie, hereby declare that the work herein submitted as a thesis for the Master of Philosophy (Animal Nutrition) degree is entirely my own conducted research and has neither been presented nor is being presented concurrently for any other degree elsewhere.

However, works of other researchers and authors, which served as sources of information were duly acknowledged by reference of the authors**.**

Gifty Ziemah Bumbie (10443870)	…………………………….	………………………..
(Student Name and ID)	Signature	Date
Dr. Thomas Nii Narku Nortey	…………………………….	………………………..
(Principal Supervisor)	Signature	Date
Prof. Augustine Naazie	…………………………….	………………………..
(Co-Supervisor)	Signature	Date
Dr. Sarpey Wesley Anthony Rhule	…………………………….	………………………..
(Co-Supervisor)	Signature	Date

DEDICATION

This work is dedicated to my parents, Mr. Paul Dassah and Mrs. Janet Dassah and my daughter, Marcelle E-Sung

GOD BLESS YOU DAD

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ABSTRACT

Most pork produced in Ghana tend to be very fatty as most famers do not feed balanced diets to their animals because of the high cost of feed ingredients. High levels of cholesterol and fat from animal products have been associated with coronary heart diseases and stroke in humans and fear of this has led to some instances of negative impact on acceptance of pork for human consumption. Dietary manipulation to reduce fat and cholesterol in pork, if feasible will therefore be important. A 16-week trial was conducted to determine the influence of feeding corn cobs to grower pigs on carcass quality and fat content. A total of 40 Large White grower pigs with a mean live weight of 27 ± 5 and consisting of 20 females and 20 males were selected for the feeding trial. The 40 pigs were randomly assigned to five dietary treatments i.e. 0% corncob, 15% corncob without enzyme, 15% corncob with enzyme, 25% corncob without enzyme and 25% corncob with enzyme and labelled treatments A, B, C, D and E, respectively. All the five diets were iso-nitrogenous. Each treatment consisted of four females and four males with four replicates per treatment and two animals per replicate in a completely randomised design. Pigs were fed on a restricted basis, a daily amount of feed equivalent to 5% of the individual live weight. Water was provided *ad libitum*. The pigs were individually weighed weekly and slaughtered on attaining a live weight of 70 ± 5kg and their carcass characteristics measured. Data collected indicated no significant ($p > 0.05$) difference in the initial live weight, average daily gain and total feed intake among treatments but there was significant ($p < 0.05$) difference in final live weight, average daily weight gain, total weight gain and feed conversion ratio. There were no health-related problems that could be attributable to the inclusion of the graded level of the corn cob with or without enzyme. Although the feed cost/kg of the control was higher than the tested diets, the feed cost/kg gain were similar ($p > 0.05$) among the five dietary treatments. The corn cobs inclusion had influence on the carcass characteristics. There was a significant ($p < 0.05$) difference between the control diet (A) and the corn cobs containing

diets (B, C, D, and E) for both back fat and P2 measurement. The values obtained for the measurement of the major joints were not significantly ($p > 0.05$) different among treatments except rump streak.

The dietary treatments did not have any significant ($p > 0.05$) impact on the various haematological parameters measured. The biochemical parameters that were measured showed significant ($p < 0.05$) differences among treatments, with the pigs on the corn cobs diet having the lowest values except for total protein and globulin which were not significantly ($p > 0.05$) different among treatments.

It was concluded that corn cobs have some potential for use as a dietary ingredient and it can be included up to 25% in pig diets without compromising health, growth performance, carcass and blood and also reduced cost of producing lean pork.

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LIST OF ABBREVIATIONS

ADF	Acid Detergent Fibre
ADFI	Average Daily Feed Intake
ADG	Average Daily Gain
ADWG	Average Daily Weight Gain
AIBPs	Agro-Industrial By-Products
ALBP	African Locust Bean Fruit Pulp
ANF	Anti-Nutritive Factors
ANOVA	Analysis Of Varience
BCG	Bromocresol Green
BSG	Brewers Spent Grain
CF	Crude Fibre
CP	Crude Protein
CPH	Cocoa Pod Husk
CSIR-ARI	Council For Scientific And Industrial Research – Animal Research Institute
DCP	Dried Cashew Pulp
DE	Digestible Energy
DF	Dietary Fibre
DM	Dry Matter
EDTA	Ethylene Diamine Tetra Acetic Acid
EE	Ether Extract
FCR	Feed Convention Ratio
G	Grams
GIT	Gastro Intestinal Tract

HB	Haemoglobin
HCT	Haematocrit
HDL	High Density Lipoprotein
IEL	Intra-Epithelial Lymphocytes
KG	Kilogram
LDL	Low Density Lipoprotein
LR	Landrace
LW	Large White
LWG	Live Weight Gain
MB	Maize Bran
MCH	Mean Cell Haemoglobin
MCHC	Mean Cell Haemoglobin Concentration
MCV	Mean Cell Volume
ME	Metabolizable Energy
MDFI	Mean Daily Feed Intake
MDWG	Mean Daily Weight Gain
MJ	Mega Joules
NCFR	Non-Conventional Feed Resources
NDF	Neutral Detergent Fibre
NE	Net Energy
NRC	National Research Council
NSP	Non-Starch Polysaccharides
PCV	Packed Cell Volume
PKM	Palm Kernel Meal

PLT	Platelet
RBC	Red Blood Cell
RCT	Reverse Cholesterol Transport
SBM	Soya Bean Meal
SBMR	Soya Bean Milk Residue
SSF	Solid State Fermentation
TC	Total Cholesterol
TFI	Total Feed Intake
TP	Total Protein
TWG	Total Weight Gain
VFA	Volatile Fatty Acid
WBC	White Blood Cell
WFI	Weekly Feed Intake
WHC	Water Holding Capacity

CHAPTER ONE

1.0 INTRODUCTION

Inadequate nutrition is one of the key limitations to pig production in Ghana as feed resources are limited in both quantity and quality (Okai, 1998). Feed constitutes a major factor, in magnitude of 60 to 80 % of the total cost of the production of pig (Odeyinka, 2001). To improve this challenge and sustain production in the tropics, other feed resources have to be explored as the cereals used for feeding also constitute staples for the human population. The feeding of agro industrial by-products (AIBPs) and residues of crops has been considered, as these are not consumed by man and can be converted by pigs into desirable meat (Odeyinka, 2001).

Corn cobs are readily available agricultural waste. However they are of a low nutritive value with a composition of 4.4% CP, 34.9% CF, 91.5 DM, and 4.2% EE (Rajmane and Deshmukh, 2000) with appreciable levels of phosphorus, magnesium, and copper (Onwuka *et al*., 1997). Corncob contains 32 mg/kg DM Zn, 16 mg/kg DM Fe, and the Ca content is about 1.4 mg/kg DM. Its high crude fibre fraction is composed of 15% lignin, 45% cellulose, and 35% hemicellulose (Sun and Cheng, 2002). The fibre is mostly 80%NDF (Trezona, 2008).

Although corncob is highly fibrous it could have a crucial agricultural application as fibre has been found to effectively lower the levels of cholesterol in the blood (Trezona, 2008). Increase in dietary fibre (DF) intake by pigs can lead to specific changes in the structure of the belly. When dietary fibre was increased through the addition of distiller's dried grains with solubles at 10, 20 and 30% of the diet, the thickness of the belly primal was considerably reduced from 3.15 to 3.00cm, 2.84 and 2.71cm, respectively, signifying decreased fatness (Whitney *et al*., 2006). Partanen *et al*. (2002) observed that although percent carcass lean, thickness of the backfat and growth performance were similar between pigs fed medium-fibre (NDF grower:

188g/kg DM; finisher: 196g/kg DM) and high-fibre (NDF grower: 240g/kg DM; finisher: 285g/kg DM) diets. Pigs fed the high-fibre diets had considerably lower side-fat depth (15.6 vs. 14.3 mm).

The growth of a litter was improved by about 20% during the second parity when diet based on corncob (53%) and wheat bran (43%) was fed during the first and second parities (Matte *et al*., 1994). Corn cobs have been included at different levels in the diets of pigs in determinations to decrease high cost feed (Kanengoni *et al*., 2004; Ndubuisi *et al*., 2008). However, increasing the levels of the corn cobs led to reduction in feed intake and average daily gain (Kanengoni *et al*., 2004; Frank *et al*., 1983) which was ascribed to the high content of fibre of the corn cobs (573 g ADF/kg DM and 930 g NDF/kg DM), and it is regularly lignified by the harvesting time (Kanengoni *et al*., 2002). There is evidence that cell wall non-starch polysaccharides (NSP) have anti-nutritional activity in many mono-gastric animals (Choct *et al*., 2004).

In an effort to ensure the extreme utilization of all the nutrients in any feed ingredient, scientific methods such as treatment through physical, chemical and biological means have been established to increase the nutritional value of feed ingredients.

Physical treatment, such as boiling, milling, pelleting, steaming and soaking, leads to an increase in surface area and metabolizable energy (Beadsley, 1993).

Chemical treatment methods include soaking by use of chemicals mainly alkali and acids, like calcium hydroxide and sodium hydroxide. Treatment with chemicals are more effective compared to the physical methods.

Biological treatments with microorganisms such as bacteria and fungi, for example white rot fungi, have numerous benefits when compared with chemical and physical methods. In this case, hydrolysis of polysaccharides happens through microbial enzymes through fermentation under much milder situations, do not produce unwanted products and are friendly to the environment (Smith *et al*., 1996; Rubin, 2008). According to Davinia *et al*. (2013), white rot fungi nurture well and produce lignocellulosic enzymes under solid state fermentation (SSF) because the medium conditions are closer to their natural habitats.

1.1 PROBLEM STATEMENT

Most pork produced in Ghana tends to be very fatty as most famers do not feed balanced diets to their pigs, because of the high cost of feed ingredients. High levels of cholesterol and fat from animal products have been associated with coronary heart diseases and stroke and fear of this has had negative impact on acceptance of pork. This study seeks to address this problem through dietary manipulation to reduce the total fat and cholesterol content of pork.

1.2 HYPOTHESES

1. Corn cob in well balanced diets for grower finisher pigs will not adversely affect performance
2. Pork from pigs fed diets with added corn cobs will have lower fat and cholesterol levels compared to pork from pigs fed diets without corn cobs
3. The use of corn cob in diets for grower finisher pigs will result in a reduced cost of lean pork production.

1.3 OBJECTIVES

1. To improve pork quality by reducing the cholesterol and fat contents through dietary manipulation using corn cobs as a feed ingredient
2. To enhance feeding value of corn cobs by enzymatic modification
3. To determine the economy of gain using corn cob as a feed ingredient

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. PIG PRODUCTION IN GHANA

The most commonly consumed meat worldwide is pork (FAO, 2012). People eat different products from pork including; ham, pork chops, sausage and bacon. Several valued products or by-products are derived from pigs (Delgado, 2003). Lately, rearing pigs and producing pork have attracted the interest of farmers in Ghana who seek to change enterprises as well as existing farmers considering other alternatives following a period of low profitability (Delgado, 2003).

In the last ten years, Ghana's consumption of pork has been increasing on a notable level which is well beyond that of products from other livestock. The increase in pork consumption in several regions of Ghana has been moulded by numerous factors such as technological progress, demographic growth, economic and scientific as well as policies aimed at increasing production (Banson, 2014). The religious taboos and other sanitation problems which have put people off pork have mostly been overcome by the high level of meat hygiene and husbandry practices in the pig industry. Pork and pig-rearing are gaining acceptance in many communities in Ghana (Koney, 2004).

The production of pigs is vital in several parts of the world because it produces economical tasty meat and additional products such as pigskin, bone, bristles, blood meals, manure and lard over a short period. Pigs are raised mainly for pork production in the tropics (EPA, 2012) but pork may also be processed into several forms like sausages, ham and bacon. Pigs are capable of eating different foods.

Although pigs like to graze, they cannot digest too much fibre and also they cannot live wholly on roughage unlike domestic ruminants (Williamson and Payne, 1989). They thrive under less optimal conditions but they require balanced and adequate diets, good management including adequate veterinary care and housing just like all other animals. In developing a pig industry, it is important to consider factors such as the use of improved breeds and feed, good management practices and measures to control disease (Koney, 2004).

2.1.1 GHANA'S PIG POPULATION AND DISTRIBUTION

The population of pigs in Ghana increased from 139,453 in 1973 to 224,487 in 1980. By 1990 the pig population had reached 473,946. This figure however was reduced to 354,690 by 1996 due to high cost of feed, inadequate veterinary cares, diseases outbreak like African swine fever, low interest of many farmers and religious barriers (Koney, 2004). Out of the 354,690 pigs in the country in 1996, 12.3% were in the Western Region, 12.9% in the Northern Region, 13.5% in the Volta Region and 19.4% in Upper West Region. The rest are: 10.4% each in the Brong Ahafo and Upper East Regions with 4.6, 5.7, 5.4 and 5.8% in the Central, Eastern, Ashanti and Greater Accra Regions respectively (Koney, 2004).

The pig population estimated for 2007/2010 was 2,054,000. Table 1 shows the production of pigs and pork in Ghana from 2001 to 2010.

TABLE 1: PRODUCTION OF PIGS AND PORK IN GHANA FROM 2001 TO 2010.

Year	Pigs	Pork (tons)
2001	312,000	10,500
2002	310,000	10,416
2003	303,000	10,164
2004	300,000	10,080
2005	290,000	10,248
2006	477,000	15,456
2007	491,000	16,506
2008	506,000	16,968
2009	521,000	17,506
2010	536,000	17,506
Average	404,600	13,535

Source: (FAOSTAT, 2012)

2.1.2 THE POTENTIALS OF PIG PRODUCTION IN GHANA

When compared with ruminants, pigs have major potential merits. They are more capable in converting concentrated feed to meat and are very prolific. A sow produces on the average 9 – 10 piglets per farrowing after 114 days of pregnancy. Thus, if the sow raises 20 piglets in a year; in view of the fact that they attain market weight fast, they will provide animal protein faster (Awuku *et al.*, 1991; Koney, 2004).

Pigs produce meat without causing any harm to natural grazing lands and increase the cultivation of maize since maize form a major component of their diet. The pig has also contributed a great deal in medical research as it has been used to investigate certain diseases which are common in humans (Koney, 2004). Maximum use can be made of their manure and effluent if kept under intensive system of farming. Pigs require a small space in which to live. For example, a mature sow or boar requires 3 – 4 metre square of living space. Pig production has been found to have a quicker income rate on investment compared with cattle and other ruminants (Koney, 2004).

2.1.3 CONSTRAINTS TO PIG PRODUCTION IN GHANA.

Apart from the socio-cultural and religious problems, there are other constraints to pig production in Ghana. Pigs compete directly with humans for food especially the staple cereal grains and oil seeds (legume grains). This could lead to increasing cost of grains and scarcity. However, this problem can be partly overcome by making use of a crop by- products and waste foods and grains unsuitable for human consumption (Holness, 1995). Also if manure is not properly disposed off, it creates a build-up of flies and it also smells but the manure can be profitably used as fertilizer or in bio-gas plants to solve this problem.

2.2 NUTRIENT REQUIREMENTS OF PIGS

A nutrient is an element or a substance which is found in food or feed that aids in the support of life (Gillespie, 1992). Animals and for that matter pigs, require nutrients for the replacement of worn out tissue in mature animals and building of new tissue in pregnant and young animals. Pigs also require nutrients for maintenance of vital body processes such as circulation, respiration and manufacture of internal secretion(s) and also enhance productive activities such as milk yield. In the absence of feed, the nutrients required to support maintenance activities must come from breakdown of body tissues itself and this is revealed by a loss in weight in the affected animal. Nutrients are therefore needed by animals for maintenance, growth and reproduction (Gillespie, 1992; Koney, 2004). Nutrients become part of the cells of the body and are vital for cells to live, grow and function properly. Animals require different types of nutrients in their right quantities and proportions. In pig nutrition, the nutrients are grouped into six, namely, carbohydrates, fats and oils, proteins, vitamins, minerals and water (Gillespie, 1992).

2.2.1 PROTEIN AND AMINO ACIDS REQUIREMENTS OF GROWER FINISHER PIGS IN THE TROPICS

In nutrition of pigs, a good excellent protein is a protein that offers the ten indispensable amino acids needed for the standard function of the body in the quantities and fractions required for the specific need of the pig. Meeting the necessary amino acid requirement of pigs while not overfeeding protein is not only economical, but nutritionally beneficial and environmentally friendly (Peader *et al*., 2005).

Traditionally, pig diets are compounded based on the crude protein percentage. This means the content of nitrogen of the feed ingredients x 6.25 (NRC, 1988). Amino acids are important nutrients needed by all categories of pigs for the functional processes of growth, maintenance, lactation and gestation. Therefore the levels of protein are determined for the various weight of classes of pigs so that the limiting amino acids (cysteine, lysine, threonine, tryptophan and methionine) will be present in adequate amounts (Peader, 2005). Fashina (1991) reported that amino acids are chemical constituents of protein which are usually provided to the pig from the crude protein in the diet. Inefficient feed utilization, poor growth, reduced reproductive performance and increased carcass fatness are as a result of feed ingredients with insufficient amounts of high quality source of protein and also failure to supplement a diet low protein (Adesehinwa and Ogunmodede, 1995). The suitability of the level of dietary protein is determined by the ability of a diet or feed ingredient to offer adequate nitrogen and essential amino acids for the production of non-essential amino acids (NRC, 1988).

Therefore, the necessity for a nutritionally well-adjusted feed in an economically sustainable system of the production of pigs (Adesehinwa, 1992). The quality of protein therefore becomes alike with the balance of amino acid. Requirements of amino acid percentage of the diet reduces as the pig become weightier, thus, the requirements are higher through the growing periods of animals that are young (Conrad, 1984). The young animal was reported as not only growing at a more rapid rate as indicated by the percentage increase in the weight but that the proportion of the protein in the entire body weight is higher than during the finishing period. These changes in the rate of growth and body composition are the basis for recommending different dietary protein levels to meet the amino acid requirements during the life of the pig (Fanimo, 1991). Fetuga (1984) reported the protein and amino acid requirements for the tropics to be higher than those recommended by NRC (1988) for the temperate.

2.2.2 ENERGY REQUIREMENTS OF PIGS

Energy is the most vital nutrient needed by the pig and will most rapidly influence its survival if withdrawn. Energy can be defined as the ability to do work and it occurs in various inter-convertible forms such as thermal, radiant or chemical energy (Mavromichalis, 2006). Mavromichalis (2006) reported that dietary energy is provided by carbohydrates, lipids, protein, and some fermentable fibre. The main precursor of energy is carbohydrates. In Africa and other developing countries, the main sources of carbohydrates are cereals (maize, sorghum, millet) and root and tubers (e.g. cassava, cocoyam, sweet potato and yam) (Awuku *et al*., 1991). Other sources of energy include by-products of cereals (e.g. wheat bran, maize bran, rice bran, brewer's spent grains, etc) and by-products of root and tubers (e.g. yam, cassava, cocoyam peels, etc) (Awuku *et al*., 1991).

Holness (1995) reported that the requirements of energy of pigs are very variable depending on the health status, reproductive stage, age of the pig and type of ingredients fed. According to Serres (1992), the energy requirement increases as body weight increases, because basal metabolism and requirements for maintenance are relative to live weight in addition to the level of growth .The animal requires more energy to sustain its growth the more it grows. From weaning up to 20 kg, 1 kg of live weight signifies about 3000 calories while 5000 calories represent 90 kg, and it is beyond 6000 calories for pigs that are fat. This is because, as the animal grows it deposit increasingly more fat than protein and the energy cost for depositing 1 kg protein is much less than 1 kg fat (Serres, 1992).

Energy provided to the animals are determined as metabolizable, digestible or gross. The gross energy is the quantity of energy liberated during the whole burning of the diet, which is of little significance as a measurement. Serres (1992) reported that digestible energy is what is left following digestion and it is projected from the difference between energy of faeces voided and energy of feed consumed. Whereas, the metabolizable energy is the digestible less energy lost in the urine. Morgan and Whittemore (1982) suggested that digestible energy is better in defining the content of energy in pig feeds as digestible energy is more easily and accurately determined than metabolizable energy. The gaseous loss of energy in the pig's gastrointestinal tract is normally between 0.5 and 1.0% digestible energy (Fuller and Boyne, 1972). These values are ignored because they are insignificant and not measured (NRC, 1988). Protein quantity and quality in the diet was reported to impact on the connection between metabolizable energy (May and Bell, 1971) and digestible energy (den Hartog and Verstegen, 1984). There is a reduction in ME if the quality of protein is low and with additional protein since the amino acids that are not used for the production of protein are catabolized and used as energy source and the nitrogen comes out as urea (NRC, 1988).

The level of energy in diets needs to be associated with other constituents. The formulation of a good diet needs a steadiness between the percentage crude protein and the number of energy units in the diets (Longe, 1988). In support of this view, Fashina (1991) reported the presence of a relationship between energy in diet and pigs requirement of protein. Energy to protein ratios that differ from the ones that will make animals perform better will hence result in clear difference in performance (Longe, 1988). The best measure of energy accessible to an animal for production and maintenance is net energy (NRC, 1988), and it is lesser than metabolizable energy due to losses related with the biochemical paths inside the animal (Serres, 1992). The net energy defines the effectiveness of utilizing metabolizable energy for the purposes of production. The net energy value is affected by the age, level of feed intake, composition of the feedstuff, breed, sex, balance of nutrients in the diet, environmental situations under which the animal is maintained, body condition of the pigs and percentage of energy retained as protein (Fashina, 1991). The requirement of digestible energy of grower pigs was defined by NRC (1988) as the summation of its requirements for maintenance, fat retention, retention of protein and cold thermogenesis. The requirements of energy for maintenance include needs for all functions of the body and uncertain activity and it is stated on a basis of metabolic weight. A kilogram of tissue muscle that is lean is just 20 to 22% protein, although the mean cost of energy per kg of fat or protein deposited are almost equal (Serres, 1992). Therefore, the cost of energy for producing muscle is significantly lesser than that for the production of fat (NRC, 1988).

Cold thermogenesis impacts the requirements of energy when the ambient temperature is below the critical temperature that is the point below which an animal needs to increase the production of heat to make it warm. Therefore, the content of energy of a diet usually regulates the quantity of daily feed consumed *ad libitum* (Cole, 1984) and pigs will make up for increase or reduction in the density of nutrient of the diet by increment or reduction in their intake of feed. According to NRC (1988), this compensation stabilises the intake of energy within limits. However, intended intake of feed differs significantly among individual pigs on daily basis (Frank *et al*., 1983). Noblet *et al*. (1994) reported that the metabolic use of heat increment or the metabolizable energy differ depending on chemical features of the diet and the production type (growth, maintenance, milk secretion, fat and protein deposition etc). Averagely, the effectiveness of utilizing the metabolizable energy for these diverse purposes have been shown to vary noticeably in pigs: about 80% for maintenance or fat gain (kg); 75% for weight gain (kg) during growth; 60% for protein deposition and 70% for milk production (Noblet and Henry, 1993).

Measurement of energy is usually in heat units and in modern nutrition of livestock, the Mega joule (MJ) is the most commonly used unit (1MJ = 0.239 Mcal) (Holness, 1995).

2.2.3 PROTEIN TO ENERGY RATIO OF GROWER FINISHER PIGS IN THE TROPICS

Efficient utilization of protein depends on the amount of energy available. Thus the amount of protein per unit of digestible energy is more important than the absolute concentration of protein. The protein to energy ratio is guided by the age of the pig and the genotype. Protein ratio changes steadily as the pig grows, being highest in the young animal and lower in the older pig, where protein requirements per kg live weight are less. Generally, exotic breeds of pigs, for example, require a higher protein to energy ratio than local unimproved pigs because they have higher lean to fat ratio in their bodies (Holness, 2005).

2.2.4 VITAMINS

Vitamins are organic nutrients that are important for standard growth and development but are needed in much smaller amounts than the essential amino acids (Neil *et al*., 2000). Most vitamins serve as coenzymes or part of coenzymes; they have catalytic purpose and are used metabolic reactions. Even though required in only little amounts, these substances are totally essential and deficiencies can cause serious problems (Neil *et al*., 2000). On the other hand, excess vitamins can be dangerous. Pigs require fourteen vitamins and these are either water-soluble or fat-soluble (Neil *et al*., 2000). Examples of vitamins that are fat soluble include A (retinol), E (tocopherol), K and D. Examples of vitamins that are soluble in water are C (ascorbic acid) and the B – complex vitamins which include niacin, pantothetic acid, folic acid, cyanocobalamin, choline, inositol, thiamin, riboflavin and pyridoxine (Neil *et al*., 2000).

Coenzymes (vitamins B1, B6, B12, folic acid and biotin) are used in the breakdown of sugars, amino acids and fats. Vitamin B2, macro pantothenic acids, forms part of coenzymes central to cellular respiration (Gillespie, 1992). According to Gillespie (1992), some of the other vitamins like Vitamin K is necessary for blood clotting. Vitamin D controls the absorption and use of phosphorus and calcium in bone and teeth formation. Vitamin A also supports growth and health of teeth, protects lining of the eye and is vital for the normal active of the eye. Vitamin E is essential for normal metabolism and normal reproduction. And lastly Vitamin C aids in teeth and bone development and prevention of infections (Gillespie, 1992).

2.2.5 WATER

Water is one of the most vital of all nutrients. Animals can live for a longer period without feed than they can without water. Fortunately, under most circumstances, it can be freely provided in abundance and at a small cost. Sources of water for animals include water in feed and body tissues, drinking water and metabolic water which is water provided by the combustion of nutrients such as carbohydrates, protein, and fat in the cells (Koney, 2004).

Water is one of the key single constituents of the animal body, varying in amount from 40% in fat pigs to 80% in new-born pigs. Water also constitutes 90% of blood. Water in the animal's body acts as a carrier of many substances. It also serve as an intermediate in which food is transported to the cells and unwanted products are removed from the body (McDonald *et al*., 1998). It assists with the regulation of temperature of the body, e.g. cooling the animal by evaporation from the skin and acts as a solvent for many chemicals which can afterward be noticed by taste buds. Water in the body of the animal helps in gas exchange during breathing by protection the alveoli of the lungs moist (McDonald *et al*., 1998).

It is essential to the life and form of every cell and is a component of every fluid in the body, for example, blood and milk. Water is necessary for numerous vital chemical reactions of digestion and metabolism. Water restrictions or deficiency leads to reduction in the rate of growth, decrease feed intake, poor metabolic rate and utilization of feed and decrease the production of milk in lactating sows (McDonald *et al*., 1998).

2.2.6 MINERALS

In the area of nutrition, minerals are chemical elements other than carbon, hydrogen, oxygen and nitrogen, the supplier of organic compounds (Neil *et al*., 2000). Dietary minerals are grouped into major/macro minerals and micro/minor/trace minerals based on the amount required by the animal for normal growth and development. The macro minerals include P, Ca, Cl, K, Mg, S and Na and the minor minerals include Mn, Zn, Mo, Si, I, Cu, Fe, Ni, and Se. Calcium and P are required in relatively larger amount by pigs to build and sustain the skeleton (bones). Calcium is also essential for the standard functioning of nerves and muscles and phosphorus is a constituent of ATP and nucleic acids. Sulphur is a vital constituent of numerous electron carrier molecules that function in cellular respiration. It is also a section of haemoglobin. The oxygen transporting protein of red blood cells is iron (Neil *et al*., 2000).

Iodine is needed for the production of the hormone thyroxin, which controls metabolic rate while Cl, Na, and K are vital in nerve function and aid in maintaining the osmotic balance of cells (Neil *et al*., 2000). Common Salt is the core source of Na and Cl but is inadequate in a natural environment and must be added to pig diets (Neil *et al*., 2000).

2.2.7 FIBRE

Fibre is the indigestible fibrous material and is made up mostly of cellulose. It is not actually a main feed ingredient for pigs but small amounts of it is needed to stimulate the gut muscles to contract properly to enable free movement of food through the gut and thereby facilitate free bowel movement and prevent constipation (Grieshop *et al*., 2001). The enzymes in the pig's digestive tract cannot digest fibre, which occurs to some extent in all plants material. In general, a high content of fibre in diets will decrease the accessibility of other energy sources, particularly if the feedstuff is not ground (Grieshop *et al*., 2001)

2.2.7.1 EFFECTS OF DIETARY FIBRE

Fekete (1995) reported that the existence of fibre in the diet reduces the prevalence of constipation by encouraging peristaltic movement of the gut and the rapidity of clearing the content in the gut. The digestibility effect of fibre to the supply of nutrients of pig is lower than fat or protein in diet, it therefore has an important functional effect on the role of the whole gut and hence on the other nutrients utilization (Fekete, 1995; Schmidt, 1995). Fekete (1995) reported that because of the anti-nutritional and physiological function of fibre, there is an ideal fibre supply in relations to conversion of feed subjected to the age of the pig.

Non-starch polysaccharides might have influence on the activity and production of digestive enzymes, the population of microbes in numerous sections of the gut, some hormones secretion (gastric inhibitory polypeptide, insulin, glucagon, and perhaps cholecystokinin and secretin) and intestinal morphology (cell proliferation) (de Lange, 2000). It is challenging to say with confidence the influence of numerous fibre constituents (Insoluble Dietary Fibre or Soluble Dietary Fibre for example) on digestibility is due to their differences (Johnston *et al*., 2003). Noblet and Le Goff (2001) however reported that dietary fibres that are soluble increases the thickness of the digesta. When viscosity is increased in the small intestine, it may slow time of gut transit because of blocked contractions in the intestine and this leads to reduce mixing of dietary constituents with enzymes in the digestive system (Johnston *et al*., 2003). In the GIT of sows and grower pigs, the mean retention time was lesser for diets with wheat bran, or maize bran (200 g DF/kg DM) than corn-soybean meal based diet (100 g DF/kg DM) and sugar beet pulp based diet (200 g DF/kg DM), which provides inulin and pectin. He concluded that, unlike soluble fibres, insoluble fibres makes the time of transit of the digesta shorter via the GIT. It is usually recommended that when the time of transit is short, it permits less time for degradation by digestive enzymes. Similarly less time present for hindgut fermentation and the fast passing of digesta might decrease the efficiency of this course (Morel *at al*., 2006).

According to Wilfart *et al*. (2007), dietary treatment had no effect on ileal nutrients digestibility when they used diets containing high, medium and low fibre by substituting barley and wheat with wheat bran. However, increasing the content of insoluble fibre of the diet had a negative influence on the digestibility of ether extract, CP and energy of fecal samples. In diets that are high insoluble fibre, the time of passage is only decreased in the hind gut, and the time of passage for the digesta via the small intestine is not prolonged or affected. Kesting *et al*. (1991) found that in situation of diets with high content of insoluble fibre, the amount of digesta is surely larger and the total time of transit is lesser when quantities of digesta that goes into the caecum increases. Alternatively, Le Goff *et al*. (2002) observed that energy in diets and digestibility of nutrients, especially the proportion of fibre in diets, increased when the body weight pigs from growing to finishing increased. In conclusion the variations in the physical features of the content of the intestine due to existence of specific fibre constituents that may influence the clearing of the GIT, dilution of enzymes in the gastrointestinal tract and compounds absorption in the gut and slow enzymes, nutrients and substrates movement to the absorptive surface area (FAO, 1998).

The influence of refined nutrients are however not similar to nutrients components in feed. In situations of many nutrients, the influence on individual one can be improved, hence the digestion can also be influenced by nutrient interaction (Pettigrew, 2000). Apart from issues causing decrease of digestibility, numerous positive influence of fibre diets on the microflora of the gut and hence the health of the gut, animal welfare and emission of ammonia from slurry are known. The form and purpose of the gastrointestinal tract is closely influenced by dietary fibres (Pettigrew, 2000). Some of the exact constituents of dietary fibre could have substantial effect on the animal's health. Oligosaccharides such as galacto-oligosaccharides, mannan-oligosaccharides and fructo-oligosaccharides cannot be are assimilated and can restrict the populace of bacteria that are pathogenic by increasing microbes that are beneficial in the gastrointestinal tract (Pettigrew, 2000). Epithelial cells Production is sustained by butyrate, and it is produced in the dietary fibre fermentation and absorption in the gastrointestinal tract (Montagne *et al*., 2003). Fermentation in the hindgut and reduction in the possibility for the occurrence of non-pathogenic diarrhea is supported by feeding dietary fibre (Johnston *et al*., 2003). Correa-Matos *et al*. (2003) stated that dietary fibre that are fermentable decreases

Salmonella Typhimurium severity infection. Whitney *et al*. (2006) also observed decreased severity of infections of the intestine of *Lawsonia Intracellularis* by feeding distillers dried grains based diets, which have high content of hemicellulose. Also piglets diets which are high in fibre that cannot dissolve seem to defend more proficiently against bacteria that are pathogenic than high soluble fibre diets.

2.2.7.2 SOLUBLE AND INSOLUBLE FIBRE

Including rapid fermentable non starch polysaccharides like from pectin or sugar beet pulp in the diets of pig, both ileal and fecal digestibility of amino acids or protein reduced (Zervas and Zijlstra, 2002a; Mosenthin *et al*., 1994). Reduced supply of ileal digestible protein due to dietary dissolvable fibre could be initiated by pectin and other forming gel polysaccharides decreacing absorption of peptides and amino acid, suppressing these from absorbing (Mosenthin *et al*., 1994). den Hartog and Verstegen (1984) however reported no influence of pectin on fecal or ileal digestibility of amino acids and protein in diets. The lack of reaction might be the reason of feeding a diet compounded of feedstuffs containing natural non starch polysaccharides (soybean meal, barley, corn) while high digestible semi-refined diets based on corn starch, which are more responsive to pectin supplementation of, were used in a trail by Mosenthin *et al*. (1994). Yin *et al*. (2000) reported a negatively influence on apparent digestibility of amino acids and protein of both total tract and ileal when they included of neutral detergent fibre in diets. Though some researchers observed a lower influence of undissolvable dietary fibre at about 100 g/kg addition (Li *et al*., 1994). There was a linear decrease in true and apparent digestibility of amino acids, and in precise of lysine by neutral detergent fibre addition from soy hulls (ranging between 27 and 76 g per kg in diet) (Dilger *et al*., 2004). It was however acknowledged that though in soy hulls, roughly 45 % of dry matter is the form of cellulose (Lo, 1989), it is normally considered as carbohydrate that are very fermentable (Bakker, 1996).

The influence of mixed fibre from natural sources and pure cellulose therefore might not be similar. The influence of refined dietary fibres on gut role are not certainly the same to those of unrefined fibres in feed ingredients, probably because of the existence of fibre related substances like lectins and phytate which are existing in feeds ingredients, and a likely reaction among fibre proportions that are not similar (FAO, 1998). According to Bach Knudsen and Jorgensen (2001), the total tract and ileal apparent digestible of protein reduced intensely (0.14 and 0.13 unit, respectively) when content of insoluble and soluble non starch polysaccharides (NSP) increased in diets from 14 and 20 g per kg to 44 and 52 g per kg, accordingly. Comparing the influence of insoluble and soluble non starch polysaccharides on protein digestibility, Robertfroid (1993) found that soluble non starch polysaccharides (such as pectin) were predictable to hold a more bad influence than undissolvable non starch polysaccharides (neutral detergent fibre).

2.2.7.3 FIBRE-PROTEIN INTERACTION

Different types of fibre have been reported to affect amino acids and protein digestibility. It is however remarkable to consider whether the level of protein diets hinders the impact of fibre on nitrogen digestibility. Research on a likely interaction of protein and fibre on digestibility of protein is critical when the strong relationship among pig performance (protein deposition, feed conversion and average daily gain) and ileal digestible protein and/or amino acid is considered. In a work done by Zervas and Zijlstra (2002a and b), dietary fibre and protein did not interact for nitrogen-retention or variables of nitrogen excretion, hence the effect was proposed to be additive. Fan and Sauer (2002) also reported no interaction between the intake of neutral detergent fibre and amino acid or protein with respect to the apparent amino acid and protein digestibility. The influences of additive of both dietary fibre and protein are reinforced by the study of emission of ammonia as well. Reducing dietary protein decreased the emission of gaseous ammonia. Similarly, the increase of fermentable fibre, and the mixture of fibre and protein decreased the emission of ammonia (Kreutzer *et al*., 1998). Schultze *et al*. (1994) reported that increasing neutral detergent fibre diets increases the losses of amino acid and endogenous nitrogen.

2.3 GROWTH AND DEVELOPMENT OF PIGS

According to Whittemore (1987), growth in animals relates to gain in weight, brought about by cell multiplication (as in pre-natal cleavage), cell enlargement (as in post–natal growth of muscles) and incorporation of materials directly in cells (as in lipid inclusions in fatty tissues). Pond and Maner (1974) identified three phases of growth in the post-natal period in pigs and these are commonly based on live weight of the pigs. The phases include the weaner or starter phases (5 – 20 kg liveweight), grower phase (20 – 45 kg liveweight) and fattening or finisher phase (45 – 90 kg liveweight). The rate of growth varies with breed. English *et al*. (1988), reported that pigs with a liveweight range from 20 to 50 kg are able to grow at a rate of 900 g/day. According to Serres (1992), improved breeds of pigs can grow at a rates of 400 g/day following weaning, 500 g/day at 30 kg and over 600 g/day up to 40kg. Development occurs as the pigs grow from the infant stage to maturity. The body of a young pig is estimated to be 80% water, which is reduced to 40% at 150 kg live weight (English *et al*., 1988).

The elements which influence the capability of an animal to grow and the ultimate attainment of maximum size are fixed by heredity. However, English *et al*. (1988) identified other factors which affect growth and performance of pigs as feed, sex, environmental temperature, management and stockmanship. According to English *et al*. (1988), nutrition is an important factor determining whether the optimum growth will be reached, and an optimum nutritional management is one which allows the organism to take full advantage of its heredity.

2.4 FEED AND GROWTH PERFORMANCE OF PIGS

According to McDonald *et al*. (1998), feed is defined as the material which after eating by animal is capable of being digested, absorbed and utilized, while growth may be explained as an increased in weight and size, associated with changes in shape, until they pig reaches maturity. The most important measurement of growth in growing pigs is gain in body weight, usually expressed as mean weight gain per day (g/day). Other ways of expressing growth of pigs is weight gain as a percentage of initial weight, which eliminates the effects of initial weight as heavier pigs tend to gain more weight than lighter pigs of the same age (Mavromichalis, 2006).

Feed is the most vital factor, which plays a significant role in the animal in exhibiting its genetic potential in growth. The timing, composition and feeding regimes all affect the growth performance of individual animals. Armah *et al*. (2008) fed Dried Cashew Pulp diets to starter-grower pigs and reported that live weight gain of pigs fed the 0, 50 and 100g/kg, dried cashew pulp diets were significantly ($P < 0.05$) higher compared to their counterparts fed the diets containing the utmost amount of dried cashew pulp (150g/kg). It was explained that the inferior live weight gain of pigs fed the 150g/kg dried cashew pulp diet was because of the level of high crude fibre of the diet. Fanimo *et al*. (2003) observed that adding fibre to diet led to decreased apparent digestibility of crude protein, starch, peptides and fat and prevented them from absorption. Tengan *et al*. (2012) fed varying levels of African Locust Bean fruit pulp (ALBP) to growing pigs and observed that the average daily weight gain (ADWG) of pigs on the diet without ALBP (control diet) was significantly ($p < 0.05$) lower compared to the ALBP -5 group. The ADWG values were a reflection of the values for the ADFI and TFI. Usually a higher feed intake of a well-balanced diet would lead to a higher growth rate.

2.5 FEED AND CARCASS CHARACTERISTICS

The state of nutrition and the type of ingredients used in feeding livestock have influences on their carcass characteristics. Pigs that are fully fed a concentrate diet, yield much fat in carcass and eventually are less able to convert feed to meat that is lean than pigs fed slightly lower than *ad libitum* energy intake (Aberle *et al*., 2001). Attoh-Kotoku *et al*. (2007) also fed maize bran to grower starter pigs and observed that, the chilled and warm dressing percentages as well as the loin eye area, back fat thickness and carcass length, were similar ($p > 0.05$) among pigs on the 4 dietary treatments. They also observed that pigs on 200 gkg^{-1} maize bran diet had slightly lower warm dressing percentage, loin eye area, and chilled dressed percentage as well as reduced back fat thickness than those on 0 and 100 g maize bran kg^{-1} diet. They established that maize bran has no negative influence on performance of growth and carcass triats characteristics of growing pigs. Armah *et al*. (2008) reported that carcass parameters were similar ($p > 0.05$) among the animals on the different diets when they fed Dried Cashew Pulp (DCP) at varying levels to growing pigs.

2.6 NON- CONVENTIONAL FEED RESOURCES

According to Devendra (1992), non-conventional feed resources (NCFRs) are the feed ingredients that have not been used conventionally in animal feeding and/or are not used commonly in preparing commercial feed for animals. Several agro-industrial by-products

(AIBPs), aquatic herbages, animal wastes and forest waste have been identified, treated and used as feed ingredients in the compounding of diets for farm animals and are designated as non-conventional or unconventional feeds. These AIBPs include cocoa pod husk, rice bran, biscuits waste, copra cake, cassava peel, bakery waste, blood meal, corn cob, maize bran and cassava chips. Others include citrus pulp, pito-mash, molasses, oil palm slurry, yeast, groundnut skins, bone meal, brewer's spent grains, copra cake and wheat bran (Rhule *et al*., 2007). Shrub leaves (Leaucaena spp, Caltiandra spp, Sesbinia spp, etc), aquatic plants, fruits (guava, papaya, palm oil fruit) and small animals (snails, earthworms) can also be used in formulations feed for poultry (Sonaiya, 1990). Rhule *et al*. (2007), defined agro-industrial by-products (AIBPs) as the products derived from an industry after processing crops. They can be associated with residues of crop, and are more concentrated and less fibrous. They also have high content of crude protein. Some examples of AIBPs includes; wheat bran, pineapple waste, molasses, corn cob, pawpaw peel, rice bran, plantain peel, maize bran, orange pulp, blood meal etc. It is convenient to carry out laboratory analyses to establish the quantities of crude protein, moisture, crude fibre, and micro and macro minerals and also to find out if there are no contaminants or toxins in the feedstuffs before they are added in animal feeds (Rhule *et al*., 2007).

2.6.1 BY-PRODUCTS THAT SERVE AS ENERGY SOURCES

2.6.1.1 MAIZE BRAN

In most areas maize is a main energy source in the feed of monogastrics, probably due to its abundance, economy, and high digestibility. It is quite free from problems related with Anti-Nutritional Factors (ANF). It contains a higher percentage of carbohydrate than any other. Maize is a good source of Linoleic acid which is a vital fatty acid (North, 1984).

A by-product of milling dry maize is known as Maize Bran (MB). It consists of the maize germ and bran coating and edible to all categories of farm animals and the feeding value is almost as the maize grain although it has more fibre due to the inclusion of the hulls. It has a crude fibre and crude protein content within the ranges of 10-15% and 22-29% respectively (McDonald *et al*., 1992).

2.6.1.2 RICE BRAN

The key by-products gained from the milling of rice are rice meal and rice bran. The bran is obtained after the husks have been removed to produce brown rice. White rice is produced when it is further polished after the husks have been removed. The residues are called rice meal. The value of feeding rice meal depends on the degree of milling the grains have been exposed to (Fetwell and Fox, 1978). Fetwell and Fox (1978) gave a figure of 12-13% oil and 11-12% crude protein for milled rice produced in India. North (1984) reported that rice bran contains about 13% crude protein and about half as much energy as maize. He added that the fat content of rice bran (13-15%) makes it a fairly good monogastric feed. McDonald *et al*. (1998) also concluded that rice bran contains about 12-14.5% crude protein and 11-18% oil. Both the meal and bran can be used in a considerably high levels if they have little rice hulls and the high levels of oil in them can be alleviated by an anti-oxidant in order not to lose much of the energy value through oxidative degradation (Daghir, 1995). The level of inclusion of rice bran in non-ruminants diet may be critical because it fibre content is high (Farrell, 1978) and can contain up to 21% of silica (McDonald *et al*., 1998) and this may be a reason in the reduction of the accessibility of some dietary nutrients in layers (Farrell, 1978). Farrell (1978), reported that the content of phytate of rice bran is also high and varies from 2 to 7% of the bran and this may also have influence on mineral nutrition. They have sharp edges as well which might irritate the intestine.

2.6.1.3 WHEAT BRAN

Wheat bran is composed of the outer layer of the kernel of wheat. North and Bell (1990) and North (1984) reported that wheat bran contains 1322Kcal ME/kg and 15.6% crude protein. They have starch to protein ratio of about 6:1. Wheat bran is a beneficial feed ingredient as it is palatable and is a reliable source of Iron, vitamin B complex and Manganese. However, its quantity cannot be increased to more than 30% in monogastrics feed because fibre content is high (Rhanjan, 1999). Wheat bran has a fairly high level of cellulose and a satisfactory content of nitro-compounds, which restricts its energy level. Because of this, it is usually limited to monogastrics with lower energy requirements. In feed for layers and 8-20 week old pullets a maximum rate of 40% for bran is acceptable (Say, 1995).

2.6.1.4 BREWERS SPENT GRAIN (BSG)

Brewer's yeast and brewers spent grains after fermentation of substrates are available as by-products of breweries. They are intermediate sources of energy and protein. They are bulky in the wet form, has a moderate crude protein level (about 22%) but high content of crude fibre (about 21%) (Lamptey, 1978). The digestibility is high and can be used for all categories of farm animals. It has a fairly high protein value and is particularly ideal for feeding poultry and pigs. Several replacement levels of brewers spent grain for cereals as the main energy source have been utilized in pig and poultry diets (Lamptey, 1978).

2.6.2 BY-PRODUCTS THAT SERVE AS PROTEIN SOURCES

2.6.2.1 FISH MEAL

Fish meals commercially prepared from whole fish have excellent total nitro-compound values (65-70%) with high lysine content which represents 7-8% of the total nitro-compounds. Their good content of sulphurated amino acids and tryptophan makes them valuable supplement to cereal-based diet (Say, 1995). In balanced meals, the protein has a digestibility range from 0.93-0.95. They have a high content of mineral which is about 21%, and it is of value nutritionally since it has a high proportion of phosphorus (3.5%) and calcium (8%) and also some trace elements such as Iodine, Manganese and Fluorine. It is also an upright source of vitamins of the B-complex (McDonald *et al.*, 1995).

2.6.2.2 BLOOD MEAL

Say (1995) reported that blood meal is a product gotten by drying the blood of slaughtered animals. It is a dark chocolate coloured powder with a typical smell, which consists solely of amino acids (85%) and has little or no cellulose and its nitro-compound content varies between 60-70%. It contains about 80% crude protein, small amount of Ash and oil and 10% of water. Blood meal is one of the richest sources of lysine, methionine, cysteine, leucine, and arginine but very poor in isoleucine. It has a low biological value and low digestibility (0.2). The meal is unpleasant and its use has resulted in decreased in growth rate in poultry. McDonald *et al.* (1995) reported that in pigs and poultry feeding, rations containing blood meal always give poorer results than those containing fish meal, other things being equal. Best results are obtained with 2-4% blood meal.

2.6.2.3 MILK BY-PRODUCTS

The major by-products from milk are dried skim and dried whey. Dried skim milk is the leftover after separating the cream from the milk by centrifugal force. The content of fat is very low and it is below 1% and the protein content ranges from 32 to 35%. The gross energy of this by-product is much decreased to about 1.5 MJ/kg as compared the content of energy of the raw milk. Dried skim milk is used mainly as a protein supplement in monogastrics diets. It is mostly efficient in the improvement of the amino acids deficiencies of the largely cereal diets of young poultry. For feeding to poultry, dried skim milk is typically used as a powder and may form up to 15% of the diets (Say, 1995). According to McDonald *et al*. (1995) and North (1984), dried whey contains a minimum of 65% lactose, about 12.5% protein and low levels of arginine, glycine and cystine but it is high in riboflavin. Milk by-products are often too expensive compared to other available animal proteins for use in least cost diets.

2.6.2.4 SOYBEAN MEAL (SBM)

The dominance of soybean meal (SBM) is explained by its richness in the essential amino acids, notably Lysine, and it’s free from toxic substances and its price is moderate. SBM has 40-45% crude protein, 2% fat and 3.5% cellulose (Say, 1995). The cellulose of the SBM is partially digested by monogastric animals. The protein of SBM has all the indispensable amino acids, but the volume of methionine and cystine are less than optimum (Say, 1995). The soybean meal is a low source of vitamin B and this must be given in the form of an animal protein such as fish meal or as a supplement (Say, 1995).

2.6.2.5 GROUNDNUT CAKE

This cake is the residue of the extraction of oil from groundnut. It is one of the richest sources of vegetable protein containing about 45-50% crude protein. The groundnut meal protein has sub-optimal amounts of Methionine and Lysine. Say (1995) reported that the cake contains about 5-7% cellulose. According to Onwudike (1986), groundnut cake used to be the most common of the vegetable protein source, but it is prone to infestation by the fungus *Aspergillus Flavus.* Onwudike (1986) explained that, whole groundnuts with the shells have an average content of 25% crude protein. It has high content of fibre and it is very high in the content of metabolizable energy due to its high oil content of 36%. Smith (1990) observed that, groundnut meal is very palatable and the protein quality is good, placing it close to that of soya bean meal. The groundnut cake may be decorticated or not. Fibre content is very high in the decorticated groundnut cake. The undecorticated product that is usually fed to monogastric animals. This product has a low content of fibre of 6-10% and a protein level of 40-48%. Groundnut cake is poor in methionine and lysine (Rhanjan, 1999). When groundnut cake is however used in high cereal diets, adequate supplementation with animal protein is essential since its crude protein has sub-optimal quantities of methionine and cystine. Although the limiting amino acid is lysine and such supplementations also ensure that the required vitamins B12 and calcium are met particularly for fast growing animals such as pig and poultry (McDonald *et al*., 1992).

2.6.2.6 PALM KERNEL CAKE (PKC)

Palm kernel cake is a by-product gained following the removal of oil from the palm kernel. In the tropics, it is abundant and efforts have been made to feed it to livestock (Abu *et al*., 1984).

It has comparatively low protein content which is however of high quality, the first limiting amino acids being Methionine. The ratio of calcium to phosphorus is much encouraging than in several other oil seed remains. The cellulose content of palm kernel cake is moderate (5-7%). Despite the high quality of the protein and the relatively satisfactory calcium and phosphorus balance, palm kernel cake is not used extensively in diets of poultry. This is due to its unpalatability and its high level content of fibre of 15% which decreases its apparent digestibility (Abu *et al*., 1984). According to Onwudike (1988), the cake can be given to laying hens at high levels if there is fish meal in the diet. The highest palm kernel cake level commended in the diets of poultry is about 20% (McDonald *et al*., 1995). Say (1995) recommended an inclusion level of about 5%.

2.7 CHARACTERISTICS ASSOCIATED WITH AIBP

2.7.1 ANTI-NUTRITIONAL SUBSTANCES IN FEED RESOURCES

The anti-nutritional factors (ANF) present in feed resources limit their use as feed ingredient. These factors include phytates, haemaglutinin-lectin and trypsin inhibitors. These anti-nutritional factors hinders nutrients digestibility and availability of feedstuffs and due to this reason, feed ingredients with ANF are used in poultry or livestock feed as an ingredient of low quality (McDonald *et al*., 1998). Research has shown that the other entire undesirable features except phytates present in rice bran are protein in nature. It may be suggested that it can be treatment with mild acid and alkali and thermal cooking can denature or change the proteins structure (Latif and Rajoka, 2001). In order to exploit the nutritional potential of feed ingredients efficiently, it is necessary to eliminate these ANFs to improve their nutritional quality. Many efforts have been made in the past to eliminate these anti-nutritional factors but these were mostly focused to eliminate one or the other toxic factor only (Kerr and Shurson, 2013). Many researchers have developed effective approaches to stabilize the ANF in feed ingredients and utilized them as possible source of nutrients (De Vries *et al*., 2012).

2.7.1.1 TRYPSIN INHIBITORS

Chymotrypsin and trypsin inhibitors are the key familiar inhibitors of protease and are found in large amounts in beans, soybeans and peas. Performance on growth in pigs is decreased by trypsin inhibitors which affect protein digestion and absorption. (Gueguen *et al*., 1993; van Heugten, 2001).

2.7.1.2 PHYTATES

Phytates are phytic acid salts and are present in virtually all feeds originated from plant. The phytates are existing in relationship with protein and mostly feeds high in protein contain high levels of phytates, for example groundnut cake, mustard cake, soyabean cake, sesame cake, cotton seed cake and wheat bran. Phytic acid has high chelating capability and in plants it is present as phytates of numerous minerals which are mostly not accessible by monogastric animals as they lack the phytase enzyme. Using phytase (enzyme) as a feed additive has been made feasible in some countries due to its cheaper commercial production with the application of biotechnological processes (Pathak, 1997).

2.7.1.3 LECTINS

Liener (1994) and Grant and van Driessche (1993) defined lectins as glycol-proteins that bind to particles having carbohydrates. Gatel (1994) reported that soybeans have higher contents of lectins, whereas field beans and peas have lower contents. They are resilient to proteolytic degradation in the digestive tract.

2.7.1.4 TANNINS

According to van Heugten (2001), tannins are polyphenolic compounds that also bind to carbohydrates but also have the ability to bind to proteins preventing their absorption. Sorghum grains contain high concentrations of tannins, faba beans contain moderate concentrations, and barley, millet, peas, Phaseolus beans, chickpeas, cowpeas and lentils contain low concentrations (Jansman, 1993; Jansman and Longstaff, 1993).

2.7.1.5 NON-STARCH POLYSACCHARIDES

Non-starch polysaccharides are complex carbohydrate present in feedstuffs. They are the major part of dietary fibre and can be measured more precisely than total dietary fibre. It includes cellulose, pectin, glucans, gum and inulin (Longland *et al*., 1994).

Longland *et al*. (1994) reported a work done on other sources of non-starch polysaccharides or digestible fibre such as sugar beet and concluded from his findings that, carbohydrates have the ability to decrease the moisture content, increases the dry matter content of feed and act as a lactic acid source for optimum condition lowering the pH for satisfactory fermentation to occur. Goransson (1997) also observed reduced incidence of post-weaning diarrhoea in pigs. Again, non-starch polysaccharides consist of many different plant polymers, including β-glucans, pentosans, cellulose, hemicellulose, pectic substances and α-galactosides (Xavier, 2005). Non-starch polysaccharides are present in legume seeds in the form of oligosaccharides, hemicellulose and pectin, and in grasses as β-linked glucans and pentosans (Xavier, 2005).

NSP increase the excretion of nitrogen in faeces by reducing the absorption of protein therefore lowering plasma urea (Xavier, 2005). Swine diets contain anti-nutritional factors that interfere with digestion of proteins and carbohydrates (Xavier, 2005). The most important anti-nutritional factors in swine diets are protease inhibitors, lectins, and tannins because they are found in cereal grains and at high levels in soybeans (Huisman, 1989). Other anti-nutritional factors include non-starch polysaccharides (NSP), phytate, alkaloids and estrogens. These compounds have negative effects on digestive and metabolic processes of pigs (van Heugten, 2001). It is difficult to predict the effect of anti-nutritional factors on animal growth performance and metabolism because it is dependent on a variety of factors including animal age, stage of production, type of feedstuff, level of inclusion, and diet composition. Also, due to presence of anti-nutritional factors in different combinations in the diet of pigs (van Heugten, 2001).

2.8 ENZYMES

McDonald *et al*. (1992), defined enzymes as organic catalyst which affect and speed the rate of chemical reaction without appearing in the final product. Kerr and Shurson (2013) reported that, the inclusion level of enzymes for a range of diet increased the digestion and absorption of nutrient and therefore the rate of growth. (Boateng *et al*., 2013) also reported that the addition of enzymes to feed improved the growth performance. Yang *et al*. (1999) also said that scientists obtained inconsistent results when enzymes are fed to animals due to the diet composition, type of enzymes activities, stability of enzymes, method of enzymes application and quantity of enzyme given.

2.8.1 TYPES OF ENZYMES

2.8.1.1 PROTEIN-DEGRADING ENZYMES

Protease is of specific concern because protein is the second most expensive item in animal diets next to energy. Protease enzyme supplementation is thought to be beneficial particularly in young pigs, 4-6 weeks of age, due to the fact that the proteolytic and amylolytic digestive system is not fully developed. Supplemental enzymes may be used during the weaning period to lessen the nutritional stress of abruptly switching from a liquid diet to a solid diet. Proteases can also be used to increase the availability of protein origin from plant sources such as soybean meal by helping to breakdown proteinaceous ANF. The response of pigs to supplementation of diets with proteolytic enzymes alone had been studied in earlier experiments. The results were inconclusive (Caine *et al*., 1997; Gdala *et al*., 1997). Caine *et al*. (1997) found that neither spraying nor incubating soybean meal with protease improved the growth performance or apparent digestibility of crude protein and amino acids in pigs that are newly weaned.

2.8.1.2 FIBRE-DEGRADING ENZYMES

Fibre, a type of non-starch polysaccharide, is defined as the plant cell wall components that are left over after enzymes break down starch, fat and protein. Pigs do not produce enzymes to digest fibre. There is a direct, negative correlation between dietary fibre content and metabolizable energy value (Grieshop *et al*., 2001). As fibre content increases, the ability of the pig to utilize the energy of the feedstuff decreases. Fibre also produces negative effects on amino acid and fat digestibility (Grieshop *et al*., 2001). Corn and soybean meal have a relatively low content of fibre compared to other ingredients (NRC, 1998). Supplemental enzymes have been explored to improve the digestibility of fibre to improve growth performance and reduce the incidence of digestive disorders linked with fibre that are not digestible in the diet.

2.8.1.3 STARCH-DEGRADING ENZYMES

Feedstuffs digestibility is normally measured relative to corn due to its reliability of high digestibility (Sheppy, 2001). According to Sheppy (2001), corn is not 100% digested, hence it can benefit from the inclusion of an exogenous enzyme for degrading starch. Addition of amylase to pig diets can help increase the break-down of starch and this will increase the absorption of nutrient and improve rate of growth.

Tangendjaja *et al*. (1988) studied the evaluation of cellulase and amylase as a means to improve the significance of feeding rice bran as a feed ingredient in pig diets. Rice bran contains about 29% NDF and more than 30% starch. The high fibre content limits factor in the utilization of rice bran for non-ruminants. The daily weight gain of pigs that were on rice bran treated with enzymes were similar. The addition of enzyme increased feed intake and this caused feed per gain ratios to be higher than their counterparts on cooked rice bran or untreated rice bran (Tangendjaja *et al*., 1988). Inborr *et al*. (1993) found no significant difference in growth performance when comparing a barley-wheat based control diet with a diet supplemented with a multi-enzyme preparation (β-glucanase, xylanase, and α-amylase). Crude protein digestibility was numerically higher in pigs fed the enzyme-treated diets compared with the pigs fed the control diet. Results agree with Officer (1995) and Medel *et al.* (2002). Officer (1995) indicated that multi-enzyme supplementation of unpelleted wheat-based diets had either no effect, or was detrimental to piglet performance. Responses seen in pelleted feeds are often more prevalent than responses seen in unpelleted feeds. This is because the pelleting of diets is an effective way to improve feed efficiency for all phases of swine production. Medel *et al*. (2002) found no effect of the multi-enzyme preparation (α-amylase, xylanase, and β-glucanase) supplementation of barley-based diet on growth performance or feacal digestibility of piglets.

Gill *et al*. (2000) reported no significant difference in feed intake or average daily gain when comparing diets based on barley or diets based on sugar beet pulp (control) versus diets supplemented with enzyme. However, piglets that were on diets supplemented with enzyme significantly improved feed conversion ratio compared with their counterparts given unsupplemented diets.

2.8.1.4 PHYTIC ACID-DEGRADING ENZYMES

All feed ingredients of plant origin have phytate as the majority of P in these feedstuffs is present as phytate-P. The P component of phytate (282 g kg −1) is however only partially available to pigs due to endogenous phytase activity produced by the mucosa of the small intestinal is inadequate to dephosphorylate phytate effectively. Phytate, derived from feed ingredients of plant origin, is always present in practical poultry and swine diets. Enzymes that degrades phytate in feed have been added to the diets of monogastric for the past fifteen years and this is now commonly practice (Kemme *et al*., 2006).

Phosphorus is supplemented in swine diets because most of the phosphorus found in feedstuffs is tied up as phytic acid and cannot be broken down by endogenous enzymes (Sheppy, 2001). Phytase can be added to the diet to break down phytic acid in feedstuffs, and allow the pig to utilize the phytate phosphorus. This helps the environment because the pig produces less phosphorus in feaces, and it can also reduce the cost of feed because supplemental phosphorus can be reduced or eliminated from the diet (Sheppy, 2001). In nutrition of pigs, there are four likely sources of phytate-degrading enzyme activity. These include (i) microfloral enzyme activity that is mainly present in the large intestine (ii) intrinsic plant phytase activity derived from particular feed ingredients, which may be present in the diet depending on prior heat treatment (iii) the dietary addition of exogenous phytase feed enzymes and (iv) endogenous enzymes produced by the small intestinal mucosa. Phosphatases are also involved in the degradation of phytate in swine and have been shown to be existing in some feed ingredients (Viveros *et al*., 2000). Phytase efficiently represents a viable, alternative source of phosphorus and reduces the excretion of phosphorus, which is environmentally useful and global phosphorus reserves are not renewable.

Phosphorus pollution of the environment is a key concern, which is being gradually transposed into legislation designed to control losses of P in effluent from poultry and swine units. Selle and Ravindran (2007) reported that microbial phytases capable of increasing the digestibility of phosphorus and reduction of phosphorus excretion in swine.

2.8.2 THE IMPACT OF ENZYMES ON FIBRE

According to Dierick *et al*. (1994), monogastrics animals are not able to exploit cell walls effectively as ruminants except fermentation through the hindgut. Therefore nutrients from the break-down of fibre must be made available for digestion within the small intestine prior to entering the ileum (Dierick *et al*., 1994). This is a primary objective of the use of feed additives. This approach may increase the number of feed ingredients used in pig diets, for example lower quality feedstuffs may be used, as well as improve the utilization of currently used feedstuffs (Dierick *et al*., 1994). Non-starch polysaccharides are complex, and for that reason an enzyme must have many different specifications. Protein and storage polysaccharides may be released from the partial degradation of endosperm walls, causing an increase in the amount of diet digested in the small intestine (Dierick *et al*., 1994).

As fibre content in a diet increases, the ability of the pig to utilize the energy of the feedstuff decreases. With an increase in fibre digestion from the addition of enzymes, an increase in animal performance is to be expected. Also a report by Choct (1997) showed that cell walls of cereal grains, legumes and oil seed meals are comprised of complex carbohydrates commonly known as non-starch polysaccharides which are not easily digested due to insufficient amount of endogenous enzymes produced by swine normally at the stage of pre weaning.

2.9 NEED FOR ALTERNATIVE/NON-CONVENTIONAL FEED STUFFS

The increasing cost of feedstuffs mainly protein and energy sources has been a serious limitation to the survival of the livestock industries in Ghana and other developing countries (Okai *et al*., 2000). There is the need to therefore shift attention towards the use of other feedstuffs or non-conventional feed ingredients that may be available locally. Most of these non-conventional feed ingredients may be considered waste and are comparatively cheaper as to conventional feedstuffs.

The free range pig is observed feeding on a wide range of items, from herbage to rejected agro-by-products. Agro-Industrial by-products (AIBPs) and other palatable waste materials are used replace for important feed ingredients either totally or partially. They are seen as a way of resolving the high cost of conventional feedstuff which are scarce and thereby supporting the livestock industry. Their usage must however be done with care. According to Myer and Hall (2004), the following must be considered when using edible waste or by-product as an alternative feed source: it must not have bad influence on the end products of the animals, it should be free from possible health hazards like aflatoxins, it must be palatable to the animal, it must be available and easy to obtain, information on the content of nutrient must be well-known, and processing, handling, and storage should not involve additional cost.

There are a lot of edible wastes and agro-industrial by-products that are yet to be evaluated and used as feed for livestock. Soybean milk residue is one of such untapped by-products available in Ghana. The residue is usually rejected after the production of kebab and soybean milk. Disposing off the soybean milk residue is a problem in some communities. The nutritional information on the soybean milk residue is scanty, particularly on its value for pigs. Also, it is foreseen that if the nutritive potentials of soybean milk residue and other by-products are established, more Non-Conventional Feed Resources will be available and at a relatively cheap cost. It will also eradicate the problems of disposal of most of these by-products. Because of the relatively low cost of these by-products, farmers will be encouraged to use these by-products and therefore decrease the cost involve in pig production in Ghana and other developing countries.

2.9.1 CONSTRAINTS IN THE USE OF NON-CONVENTIONAL FEEDSTUFFS

The slow growth rate of livestock when fed some by-products has been attributed to poor digestibility and feed intake. This is so because of the high content of fibre of most of these by-products which decrease intake because of their bulkiness. Some animals, especially the monogastric animals, cannot digest fibre. The low feed intake experienced with non-conventional feedstuffs, could also be attributed to low palatability of most of these by-products. Farm animals generally will eat more of a palatable diet than unpalatable feed (Anyika *et al*., 2009). Another major constraint in the use of non-conventional feedstuffs is the anti-nutritional factors (ANF) contained in most of them. To make these feed ingredients harmless for use, there is the need to remove the anti-nutritional factors by various treatments such as biological, physical and treatments (Korte *et al*., 1972).

2.10 BLOOD AND ITS COMPOSITION

According to Isaac *et al*. (2013), blood is a vital special circulatory tissue which is composed of cells suspended in a fluid intercellular substance (plasma) with the main purpose of maintaining homeostasis. Lewis *et al*. (2002) defined blood as a complex mixture that has several functions in the body.

2.10.1 PLASMA

The medium of blood is liquid plasma that has several suspended or dissolved biochemical substances. Blood plasma comprises of more than half of the volume of blood, which is 90-92% water, 1% dissolved molecules comprising of nutrients, salt, hormones, gases and metabolic waste (Lewis *et al*., 2002). Blood plasma also contains 7 to 8% dissolved proteins of about 70 different types (Lewis *et al*., 2002). Lewis *et al*. (2002) reported that protein concentration in the plasma at a given time is a function of hormonal balance, state of health, water balance and nutritional status.

2.10.2 BLOOD CELLS

Erythrocytes (RBC) are the most abundant of the formed elements (about 5 million RBC (×10/L). Lewis *et al*. (2002) and Frandson and Spurgeon (1992) reported that their precursor forms are within red bone marrow at a rate of 2 - 3 million per second. A matured red blood cell has no nucleus and therefore cannot carry out metabolism or divide.

Red blood cells that are matured are biconcave, disc-shaped and filled with heamaglobin. Red blood cell carries carbon dioxide away from the tissues and oxygen to the tissues because of the presence of heamoglobin. Normal body pH fluid is also maintained by red blood cell, and help sustain the specific gravity and viscosity of blood (Bone, 1988).

Leukocytes (WBC) are not many as the red blood cell in the circulating blood (Swenson, 1970). The types of white blood cells that exist in order of abundance in normal organisms are five. They are lymphocytes, neutrophils (T cells and B cells), basophils, monocytes and eosinophils. These cells offer defence against infectious organisms, toxins and to some point, cancer. White blood cells are higher than red blood cells and their nuclei is retained. They are originated in the lymph system and bone marrow (Lewis *et al*., 2002).

2.10.3 THROMBOCYTES OR PLATELETS

Platelets are small and colourless cell fragments in mammals that live about 1 week and initiate the clotting of blood. Platelets are originated as part of a huge bone marrow cell called a megakaeryocyte (Lewis *et al*., 2002). They secrete factors that increase local platelets aggregation, enhance vasoconstriction and promote blood coagulation.

According to Swenson (1970), parameters that are often measured under haematological profile are red blood cell (RBC) and white blood cell (WBC) counts which deal with the number of RBC and WBC in a given sample of blood. Others are packed cell volume (Haematocrit) referring to the volume of packed red blood cell in the sample, mean cell volume (MCV), mean cell haemoglobin concentration (MCHC), mean cell haemoglobin (MCH). These parameters give the average proportion of the mean cell size (MCV) occupied by the haemoglobin (Hb).

2.11 FEED AND BLOOD PROFILE (HAEMATOLOGY AND BLOOD CHEMISTRY)

The function of the haematological constituents is to enable the animal to respond physiologically to its external and internal environments. In other words, haematological profile reveal the manner and way the animal reacts to its environment externally and internally, which include feeding and feed (Esonu *et al*., 2001). Madubuike and Ekenyem (2006) reported that serum biochemical and haematological assay of livestock show the physiological nature of the animal to their nutrients. It is therefore always possible to take blood sample from animals and analyze to find out if a non-conventional feedstuff has had any undesirable influence on the animal's physiology or blood profile. Baiden *et al*. (2007) observed no significant ($p > 0.05$) difference in blood parameters (WBC, RBC, Hb, PCV) between animals on control diet and tested diets when they fed West African Dwarf sheep with sun dried cassava pulp. The outcome indicates that the dried cassava pulp has no harmful influence on the profile of blood of sheep. Feeding varying levels (0, 5, 10 and 15%) of Ipomoea asarifolia leaf meal (IALM) to grower pigs had effect on the haematological parameters such as Hb, WBC, MCHC, RBC, PCV, MCV, MCH. There was an increase in blood clotting time and values for WBC with increasing levels of *Ipomoea Asarifolia* leaf meal, and this suggest that the leaf meal contained a substance or substances which affected clotting. The levels for Hb, MCH, PCV, MCHC and MCV also showed that the inclusion of Ipomoea asarifolia leaf meal in pigs diet reduced the values obtained of these parameters. The general conclusion was however that, addition of Ipomoea asarifolia leaf meal up to 15% had no harmful influence on the serum biochemistry and haematology of grower pigs (Ekenyem and Madubuike, 2007).

2.12 BLOOD CHOLESTEROL

Hanukoglu (1992) stated that cholesterol is a modified steroid or sterol. It is a vital structural component of cell membranes of all animals that is needed to establish suitable membrane permeability and fluidity. The major sterol synthesized by animals is cholesterol. Cholesterol in vertebrates is formed primarily in the liver and is also totally not present in prokaryotes. The liver oxidizes cholesterol into a variety of bile acids and is conjugated with sulphate, glycine, glucoronic acid, or taurine. There can be the low density lipoprotein cholesterol (bad cholesterol) which is related with the cause of strokes, heart attacks, and other severe medical problems and the high density lipoprotein which are believed to transport cholesterol back to the liver for excretion or to other tissues that use cholesterol to synthesize hormones in a reverse cholesterol transport (Tymoczko *et al*., 2002). According to Lewis *et al*. (2002), having larger numbers of high density lipoprotein particles is associated with better health outcomes.

2.13 CORN COBS

Corn cob is a readily available agricultural waste. According to Menon and Rao (2012), the high crude fibre fraction of corn cob is composed of lignin (20% to 30%), hemicellulose (25% to 35%), and cellulose (45% to 55%) The necessity to increasing the inclusion of corn cobs into the diets of pig is a strong appreciative of their physical and chemical attributes which have a straight effect on the rate of fermentation, gut fill and whole diet digestion. The physical and chemical attributes of concern are chemical composition, water solubility, bulk density, and water holding capacity (WHC) and viscosity.

2.13.1 NUTRIENT AND CHEMICAL COMPOSITION OF CORN COBS

Table 2 shows the dry matter, crude protein, ash, neutral detergent fibre, acid detergent fibre and acid detergent lignin of corn cobs. Huang *et al*. (2015) reported that the mean ether extract (7.5 g/kg dry matter), ash (45.3 g/kg dry matter), and crude protein (30.2 g/kg dry matter) of corn cob (Table 2) are fairly lower than wheat bran (ether extract 28.3 g/kg dry matter, ash 51.2 g/kg dry matter, and CP 175 g/kg dry matter) which is conventional source of fiber. According to Huang *et al*. (2015), the average components of fiber (neutral detergent fibre 816.4 g/kg dry matter and acid detergent fibre 520 g/kg dry matter) are higher compared to wheat bran (neutral detergent fibre 378.8 g/kg dry matter and acid detergent fibre 111.3 g/kg dry matter). A value of digestible energy of 11 MJ/kg dry matter (Viljoen, 1993) and a value of metabolizable energy of 7 MJ/kg dry matter (Bredon *et al*., 1987) were observed.

TABLE 2: NUTRITIONAL COMPOSITION OF CORN COBS

Nutrient (g/kg dry matter)	1	2	3
Dry matter	908.3	885.2	900
Crude protein	38.9	32.6	25
Ether extract	5.7	-	6
Ash	76.7	72.6	26
Crude fiber	286.9	-	324
Nitrogen free extract	-	-	529
Neutral detergent fiber	706.3	929.8	-
Acid detergent lignin	168.8	-	-
Acid detergent fiber	515.8	573.2	-
Cellulose	347.0	-	-
Hemicellulose	190.5	179.6	-
Reference	Akinfemi (2010).	Kanengoni *et al*. (2004). Chimonyo *et al*. (2001).	Bredon *et al*. (1987).

Szyszkowska *et al*. (2007) found that the composition of corn cobs is influenced by methods of production, climate, cultivar, stage of maturity and soil. Mature cobs are lower in crude protein and starch and higher neutral detergent fibre, acid detergent fibre, dry matter than less mature cobs. There is positive relationship between the content of dry matter and the starch content in cobs, and negative with the content of acid detergent fibre and neutral detergent fibre fractions. The tested cultivars in the afore-mentioned trail had a similar content of acid detergent fibre, neutral detergent fibre and starch. The mineral structure depended on the cultivar and actual sum of temperature (Szyszkowska *et al*., 2007). Corn cobs separated into nutritionally different unit sizes having a woody portion and a soft portion comprising of clippings, glumes, fine dust, grain and core when milled. Corn cobs with 1-mm-sized have higher ether extract, crude protein and are low in hemicellulose, cellulose, acid detergent fibre and neutral detergent fibre than particle size of 2 and 3 mm. (Božović *et al*., 2004). This may influence mixing of feed negative as they will not be uniform and this will allow pigs to select during feeding. Cellulose is a polysaccharide of irregular linear glucose units connected together by β-(1→4)-glycosidic bonds and aids as the key structural section of the cob's cell walls. It is surrounded in a medium of hemicellulose and lignin, which are branched hetero-polymers of pentoses (xylose, arabinose) and hexoses (glucose, mannose, galactose), occasionally replaced with uronic acids (or their O-methyluronic derivatives), acetyl groups and phenolic compounds in numerous fractions (Deutschmann and Dekker, 2012; Menon and Rao, 2012). The holo-cellulose (the addition of hemicellulose and cellulose) fraction, is between 73% and 87% of the total mass (Božović *et al*., 2004; Kumar *et al*., 2010). The holo-cellulose comprises of α- and β-cellulose (composed of degraded cellulose) and γ-cellulose (comprising primarily of hemicelluloses) in fractions of 5.2:2.8:3.0 (Kumar *et al*., 2010). Apart from the provision structural support, hemicelluloses in certain conditions act as seed storage carbohydrates (Scheller and Ulvskov, 2010). Half of corn cobs hemicellulose are xylans

(Ebringerová and Heinze, 2000; Vázquez *et al*., 2006). Xylan is one of the hemicelluloses that has been researched lengthily, owing to its various requests (Ebringerová and Heinze, 2000; Vázquez *et al*., 2006). Cellulose and xylans impute water-holding properties, which can result in substantial bulking of digesta (Ndou *et al*., 2013).

2.13.2 WATER SOLUBILITY AND BULK DENSITY

It is uncertain in what way hemicelluloses is linked with lignin and cellulose, and influence degradation of biomass and cellulose crystallinity (Xu *et al*., 2012). However, these connections regulate the solubility of water and properties of bulk density related with the cobs of maize. The solubility of water of corn cobs is between 4% and 11% and its ability to absorb water is between 1.08 and 5.80 g/g depending on the size of particles (Van Nevel *et al*., 2006; Božović *et al*., 2004). Božović *et al*. (2004) reported that maize cobs were twice more soluble in sodium hydroxide than in water. Pathak *et al*. (1986), compared the bulk density, equilibrium moisture content (EMC) at 80% relative humidity and gross energy of corn cobs with other crop residues such as Arhar stalks, cotton sticks, maize stalks and rice straw. The EMC describes the moisture state of a hygroscopic material as it equilibrates on a moisture basis with its environment and has implications on shelf life (Igathinathane *et al*., 2005). Corn cobs had a bulk density of 100 kg/m3 which ranked as medium compared with Arhar stalks (180 kg/m3) and wheat straw (60 kg/m3). Low bulk density residues present handling and storage problems, including poor flow properties. Pathak *et al*. (1986), reported an EMC of 28% for corn cobs. This compares favorably with the EMC ranges reported by Igathinathane *et al*. (2005) of 3.9% to 56.4%, for maize leaf, 3.1% to 41.1% for stalk skin and 2.7% to 71.5% for stalk pith. The relatively high EMC values for corn cob explain the greater propensity for the onset of mold growth and may determine minimal storage requirements. Molds increase the risk of mycotoxicosis.

2.13.3 EFFECTS OF CORN COB INCLUSION ON FEED INTAKE AND NUTRIENT DIGESTIBILITY

It would be advantageous to be able to predict feed intake when feeding bulky feeds because they reduce nutrient density and digestibility. This could provide guidance as to the correct concentration of nutrients in diets to ensure adequate intake. Ndou *et al*. (2013) reported that feed intake was similar in diets containing corn cobs at 80, 160, and 240 g/kg levels which was attributed to the low water holding capacity (WHC) of corn cobs. WHC, NDF, and ADF contents of bulky feeds provide relationships with scaled feed intake that can be used to predict gut capacity in weaner pigs even though threshold values for each were different. Increases in corn cob level in the diet reduced the digestibility of DM, NDF, ADF, hemicellulose, nitrogen, and energy (Kanengoni *et al*., 2002). This was attributed to increased rate of passage and sequestration of nutrients in the fiber preventing their digestion (Stanogias and Pearce, 1985a). Fevrier *et al*. (1992) also reported a decrease in nutrient digestibility as a result of an increase in rate of passage of digesta in pigs fed diets high in inclusion levels of wheat bran. The reduction was, however, less in certain breeds like the Mukota, an indigenous pig from Southern Africa, and in older pigs (Kanengoni *et al*., 2002). In the Mukota pigs, digestibility of NDF decreased by about 37% while in the Large White×Landrace crosses (LW×LR) it decreased by about 46% when the inclusion level of corn cobs in the diet was increased from 0 to 300 g/kg (Kanengoni *et al*., 2002). Similarly, ADF digestibility reduced by 43% and 72% for the Mukota and LW×LR crosses, respectively, as the corn cobs was increased from 0 to 300 g/kg in the diet.

Frank *et al*. (1983), reported individual variability in ability to utilize the higher level corn cob diets such that the pigs could be separated into distinct high, medium and low performance groups. The differences in responses to high fiber diets were attributed to genetic and physiological determinants of feed intake (Frank *et al*., 1983). Similarly, the Mukota pigs demonstrated an ability to utilize corn cob diets better than commercial breeds (Ndindana *et al*., 2002; Kanengoni *et al*., 2004). In a growth performance study, the LW×LR crosses decreased growth rate by 26% and the Mukota by 19% as the corn cobs were increased from 0 to 300 g/kg in the diet (Kanengoni *et al*., 2004). No clear explanations for these differences were given. An understanding of the adaptive mechanisms employed by the pigs which performed better could be used to better exploit fibrous agricultural by-products leading to either better diet formulations, more precise selection criteria identifying pigs with enhanced ability to utilize fiber or both. On the other hand, because sub-Saharan Africa and the Asian sub-continent have significant populations of indigenous breeds raised by smallholder farmers, these results suggest that they can benefit from corn cob based diets (Chimonyo *et al*., 2005; Nidup and Moran, 2011). For commercial breeding stock, incorporating high fiber diets with corn cobs is a potentially economically viable proposition.

2.13.4 EFFECT OF CORN COB INCLUSION ON GUT FERMENTABILITY AND METABOLISM

Grower pigs have the capacity to extract up to 25% of energy required to maintain growth from output of fermentation and this has been documented (Yen *et al*., 1991). This is obtained from volatile fatty acids, which primarily include butyrate, acetate and propionate. Tungland and Meyer (2002) reported that volatile fatty acids absorption takes place in the colon while metabolism takes in the muscle and liver. The volatile fatty acids stimulus variations in uremia, lipidemia and nitrogen balance. According to Guilloteau *et al*. (2010), volatile fatty acids have a trophic epithelial influence as butyrate is used mainly by the colonocytes, and offers a key source of energy for its metabolic activities. Research on corn cons fermentation produced different findings. According to Stanogias and Pearce (1985c), diets with added corn cobs produced the same concentration of volatile fatty acids to diets containing lucerne stems, lupin, wheat bran and hulls in pigs proximal colon. The finding was in contrary to Van Nevel *et al*. (2006) who reported that, there was degradation of corn cobs with the incubations of the content of the small intestinal and merely to a small amount in cecal incubations in vitro compared to wheat bran, sugar beet pulp and chicory roots. However, the volume of lactic acid in the colon and cecum was increased when corn cobs were added in a diet fed in vivo (Van Nevel *et al*., 2006). They ascribed this to high quantities of fibre from corn cobs getting to the hindgut and possibly being present for degradation and fermentation by the flora. Ziemer *et al*. (2012) suggested that pigs on diets that are high fiber content are possible to have high volumes of glucose in the serum due to increased available sugars from fibre fermentation. Frank *et al*. (1983) however, observed a linear reduction of glucose in serum and an increase in the volume of urea in plasma of pigs fed diets containing 7.5% and 15% corn cobs and the cobs served as sources of fiber. The reduction in glucose was ascribed to less starch in the diet since corn cobs were added to replace grain in the diet, while the increase in urea was due to high production of ammonia by the microbes in the intestine. Blood urea is a principal product of the catabolism of protein and its concentration can act as an indicator of body protein status (Kohn *et al*., 2005). It appears that serum energy metabolite concentrations will vary depending on the breed of pig and level of corn cobs in the same way their concentrations vary in response to type of fiber as reported by Weber and Kerr (2012). Mashatise *et al*. (2005), reported no differences in plasma glucose, urea and creatinine levels in Mukota and Mukota×Large White gilts fed a control and a high fiber diet with 20% corn cobs. Pond *et al*. (1980) observed that obese pigs had lower glucose levels than lean or contemporary pigs. Measurements of serum concentrations of metabolites and hormones including cholesterol, non-esterified fatty acids, leptin and insulin in pigs fed corn cob based diets need to be explored further.

2.13.5 APPROACHES TO IMPROVING CORN COB UTILIZATION BY PIGS

To take advantage of corn cobs efficiently as a feed ingredient, means to enhance their application in the diets of pig must be developed. This may be achieve via enhanced processing, and intensifying the preparation purposes to contain useful stuffs like prebiotic properties and their possible health values. One approach to improve utilization of corn cobs by pigs is through the disruption of their cellulose, hemicellulose and lignin matrices using biological, mechanical and chemical means rendering them more degradable. Limited data are available on the effect of mechanical or chemical processing on changes in fiber utilization in pigs (Kerr and Shurson, 2013). de Vries *et al*. (2012), reported that processing reduces particle size and solubilizes part of the non-starch polysaccharide (NSP) fraction, such that polysaccharides that are recovered in crude fiber (CF), NDF, and ADF fractions will differ before and after processing. This hampers the evaluation of effects of processing technologies on digestion of NSP. The reduction in particle size and increase in solubility of NSP from processing can also influence site of digestion or fermentation with significant nutritional impact given that the efficiency of energy utilization after hindgut fermentation is generally accepted to be lower. Huang *et al*. (2015) however concluded that digestible energy content of wheat bran was better fermented in the large intestine at higher inclusion levels. They argued that high inclusion levels reduce the risk of calculation errors in determining nutrient and energy digestibility of fibrous ingredients often encountered with low inclusion levels. Fiber from distilled dried grains with solubles in the ethanol production process is modified by grinding, heating and fermentation of the feedstock making it more digestible than fiber from corn cobs (Le Gall *et al*., 2009; Urriola *et al*., 2010). Mechanical processing, use of chemicals and exogenous enzymes, and ensiling have been investigated to improve digestibility of corn cobs.

2.13.5.1 MECHANICAL PROCESSING

Corn cobs are commonly processed by either simply grinding using a hammer mill or through a complex process involving various steps of pre- milling (coarse crushing), separation (into hard or woody and soft or chaffy fractions on air separator), pulverization and granulating (of woody fraction) (Božović *et al*., 2004). According to de Vries *et al*. (2012), a decrease in unit size of a feedstuff such as corn cobs improves the available surface area for interaction with the GIT digestive enzymes, thus stimulating their break down and also upsetting their physicochemical features such as their hydration features. de Vries *et al*. (2012) reviewed numerous work and established that, modification of feed ingredients mechanically using hammer and roller milling enhance the dissolving ability of the non-starch polysaccharides portion causing an improvement in apparent total tract digestibility of the fibre portion by up to 6 or 7% in monogastrics. However a study by de Vries *et al*. (2014), demonstrated that processing alone did not improve total tract apparent digestibility of solubilized rape seed meal NSP in broilers indicating that the structures could still not be degraded by cecal microbiota.

2.13.5.2 USE OF CHEMICALS

Using alkali, acid, or organic acids to upset fibre conditions in lignocellulose biomasses was reported by Menon and Rao (2012). Intense and weak acids disrupt the firm architecture of the lignocellulosic compound. Alkali destroys the side chains of ester and glycosidic causing structural changes of lignin, cellulose enlargement and incomplete decrystallization of fibre. Intense bases or acids break the bond of lignocellulosic in the cobs corn and improve the consequent degradation (Latif and Rajoka, 2001; Zhang *et al*., 2010). According to Božović *et al*. (2004), corn cobs can be dissolved extremely in sodium hydroxide. Tuah and Orskov (1989) reported that treating corn cobs with sodium hydroxide and ammonia considerably decreased the levels of fibre content. Nevertheless, interest on using harsh materials and the hazards related with managing chemicals restrict their use. In place of this, scientist are delving into the processes of bio-fermentation and exogenous enzymes usage.

2.13.5.3 USE OF EXOGENOUS ENZYMES

According to Jones *et al*. (2010) and Omogbenigun *et al*. (2004), exogenous enzymes are progressively used in the diet pigs to balance anti-nutritional factors such as fibre due to lack the suitable digestive enzymes by pigs. The enormous variety and amount of chemical characteristics present among feedstuffs that are of plant origin, along with interactions between components within feedstuffs and diets compel the use of exogenous enzymes to enhance usage (Barletta, 2010; Kerr and Shurson, 2013). Enhancements in the digestibility of nutrient and the performance of pigs from including enzymes to the diets of growing pig are influenced by the understanding of these features in relation to the activity of the enzyme. de Vries *et al*. (2012) reported that technologies for processing and enzymes that degrade the cell wall for example pectinases, may be used to change the structure of the cell wall and enhance the degradation of non-starch polysaccarides. de Vries *et al*. (2014) reported that, mechanical method of processing breaks down the cell wall architecture and decreases the unit size, therefore there will be an increment in the surface area accessibility for enzymes (that is both enzymes included in the diet and microbial enzymes existing in the GIT). Research on the use of corn cobs with added exogenous enzymes are rare, it is therefore important to find or develop new enzymes that meaningfully decrease the levels of fibre content in corn cobs. According to Appeldoorn *et al*. (2013), thorough enzymatic degradation of the soluble hemicellulose attained from fibre component monosaccharides of corn cob that is pre-treated by mild acid might not be influenced. This proposes that application of only one enzyme will not digest the unmanageable part of corn cobs fiber. In a subsequent study, Appeldoorn *et al*. (2013) used a cocktail of hemicellulolytic enzymes, endo- (1-4)-β-xylanase, β-xylosidase, and α-L-arabinofuranosidases for saccharification to remove arabinose and degrade the xylan backbone and further incubated a fraction with apolar oligosaccharides which had not been hydrolyzed with Ultraflo L and AG-II- Hydrolase which contain ferulolyl esterase activity to successfully remove some ferulolyl groups. They then demonstrated for the first time that corn cob hemicelluloses contain a series of feruloylated oligosaccharides containing an acetyl group attached to the same xylose to which the oligomeric side chain was attached to. They proposed that it was critical to find enzymes able to remove the acetyl groups directly located on the same residue as the oligomeric side chains or enzymes able to hydrolyze the oligomeric side chains. Breaking down the corn fiber glucuronoxylan will be improved by this.

2.13.5.4 ENSILING

Though ensiling is essentially the use of controlled fermentation to preserve a crop or material of high moisture by creating anaerobic conditions (McDonald *et al*., 1991), it can also reduce the levels of the fibre in the corn cobs (Khan *et al*., 2006; Rezaei *et al*., 2009). Silage fermentation is a dynamic process that requires good anaerobiosis and a low pH; conditions which are unfortunately difficult to attain with corn cobs. A low pH is normally obtained by the rapid metabolism of water soluble carbohydrates to lactic acid by lactic acid bacteria (LAB)

(McDonald *et al*., 1991). Rapid removal of air and a low pH prevents the growth of unwanted aerobic bacteria, yeasts and molds that compete with beneficial bacteria for substrates (Bolsen *et al*., 1996; Kung *et al*., 1998). Drier feedstock such as corn cobs have poor compaction and retain air pockets. In addition, as the DM content of the feedstock increases, growth of LAB is curtailed and the rate and extent of fermentation is reduced, because acidification occurs at a slower rate and the amount of total acid produced is less (Ashbell *et al*., 1991). Prolonged heating and high temperature are usually seen when the removal of air is delayed. Adding enzymes that degrade cell wall to forage of maize during ensiling enhanced the chemical characteristics of the silages produced and decreased the content of fibre (Colombatto *et al*., 2004; Sheperd and Kung, 1996; Meeske *et al*., 1999). It is necessary to research more on the use of exogenous enzymes during ensiling with the idea of decreasing the content of fibre. Ascertaining the right enzymes efficient during silage and have a high specified components of fibre related with corn cob and can determine the best environments for ensiling of corn cobs as well as likely additives and inoculants are crucial areas that must be researched on.

2.14 INFERENCES FROM THE LITERATURE REVIEWED

Pig production is highly influenced by feed cost and level of nutrition to satisfy the requirement of the animal. Feed cost constitutes 70 – 80% of the pig's production cost (Okai *et al*., 2000). For maximum growth and development, pigs must be supplied with the nutrients such as carbohydrates, fat and oils; protein, minerals, vitamins and clean and fresh water in their correct proportion and quantities

These nutrients are present in plant leaves, legumes and some AIBPs and serve as important sources of feed for monogastric animals such as pigs and poultry. However, due to the presence of anti-nutritive factors and high moisture content as well as presence of toxins and low palatability in some of them, care must be taken in their usage in order to minimize the adverse effects on the animal. From the literature, it is possible to formulate pig diets to achieve the required nutrients levels using non-conventional feedstuffs to either completely or partly replace some of the conventional feedstuffs and at a decreased cost. Two important factors need to be considered before the use of these NCFR. One has to do with the establishment of their nutrient composition, and the other has to do with the optimum inclusion levels. Furthermore, treating them further is necessary in order to make them safe and edible for feeding. Several studies have suggested that the use of non-conventional feedstuffs is aimed at reducing feed cost and consequently reduce production cost. More research is on-going with other AIBPs not yet used in animal feeding trials and corncob is one of such unexploited non-conventional feed ingredients. This experiment was carried out to determine the effect of graded levels of corncob with or without enzyme on the growth performance, carcass characteristics and blood traits of growing pigs as well as to evaluate the economy of gain of corn cobs as a feed ingredient.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 LOCATION AND DURATION OF EXPERIMENT

The trial was conducted at the Piggery Section of the Council for Scientific and Industrial Research-Animal Research Institute (CSIR-ARI), Katamanso, in the Adenta Municipality, Accra, Ghana from August 2015 to February 2016.

The rainfall pattern is bi-modal (major and minor season). The major season is from April to July and the minor season is from August to October. The average annual rainfall is about 800mm on the coast to about 1270mm.

Rainfall is usually characterized by thick cloud conditions and high intensive storms. The yearly normal temperature ranges from 25.1^{o}C in August to 28.4^{o}C in February and March which is the warmest month (http://www.ama.ghanadistricts.gov.gh).

3.2 FEED INGREDIENTS

The corn cobs were obtained from Ejura in the Ashanti Region mainly from farmers who cultivate maize. The collection, drying and milling of the cob started on the 5th of June 2015 and ended on the 20th of July 2015.

The rest of the ingredients; i.e. maize, maize bran, palm kernel cake, wheat bran, rice bran, soybean meal, fishmeal, as well as the micro ingredients; i.e. oyster shells, common salt and vitamin-trace mineral premix were purchased from shops within the Accra Metropolis.

3.3 EXPERIMENTAL DIET

Five (5) iso-nitrogenous (17% CP) diets were formulated to contain 0% corncob, 15% corncob without enzyme, 15% corncob with enzyme, 25% corncob without enzyme and 25% corncob with enzyme. These were labelled A, B, C, D and E, respectively. Batches of the diets were compounded to last for at most 10 days. The maize and the cob were milled using a hammer mill with a 2mm diameter sieve. The rest of the feed ingredients were not ground. The maize, corn cob, wheat bran, palm kernel cake, maize bran, rice bran, soybean meal and fishmeal were weighed using a hanging scale[1], while the oyster shell, common salt and the vitamin and trace mineral premix were weighed using an electronic scale[2]. Each formulated diet was then put in sacks and labeled properly

3.4 ENZYME USED

The enzyme used is Indigenous Micro Organisms (IMO), which is bacteria based. The Indigenous Micro Organisms were grown from the soils on the farm using local carbohydrate foods (cassava) to produce a concentrate. The concentrate was then diluted with water for use. The corn cob was soaked in the IMO solution over-night. The microorganisms break down the cellulose locked up in fibre and avail nutrients to the animals

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[1] HGM hanging scale. 5kg-150kg capacity. Model: ZZG-101, made by ATICO Medical Pvt. Ltd. China

[2] Wagtech electronic scale 1g -1000g capacity, made by Wagtech International Ltd. 10 Thatcham House, Turners Drive, Thatcham, Berkshire RG134QD UK

TABLE 3: PERCENTAGE COMPOSITION OF EXPERIMENTAL DIETS

Ingredient (KG)	Dietary Treatment				
	A-0% corn cobs	B-15% corn cobs	C-15% corn cobs + Enzyme	D-25% corn cobs	E-25% corn cobs + Enzyme
Corn cobs	0	15	15	25	25
Wheat bran	9	8	8	10	10
Soybean meal	10.5	14	14	16.25	16.25
Maize bran	12.75	9.25	9.25	7	7
Maize	26	19	19	14	14
Palm kernel cake	29	24	24	20	20
Rice bran	8	6	6	3	3
Fish meal	3	3	3	3	3
Oyster shell	1	1	1	1	1
Salt	0.5	0.5	0.5	0.5	0.5
Premix	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100
Feed cost/kg (GHS)	1.25	1.06	1.07	1.03	1.04
Calculated composition %					
Crude protein	16.91	16.77	16.77	16.80	16.80
Ether extract	6.19	5.10	5.10	4.38	4.38
Crude fibre	9.45	12.99	12.99	15.25	15.25
ME (MJ/KG)	13.67	14.12	14.12	14.24	14.24
Lysine	0.98	1.15	1.15	1.24	1.24
Methionine	0.34	0.36	0.36	0.36	0.36

Vitamin and TMP (Trace Mineral Premix): Inclusion rate is 25 kg/tonne to supply the following per tonne of feed: Vit.A, 2,000,000 IU; Vit.E, 15000 mg; Vit.B1, 1500 mg; Niacin 30,000 mg; Vit.B6, 1500 mg; Vit.D3, 4500,000 mg; Vit. K3, 3,000 mg; Pantothenic acid,12000 mg; Vit.B12, 10,000 mg; Vit. B2,6000 mg; Folic acid, 800 mg, Iron, 60,000 mg; Copper 75,00 mg; Iodine, 750 mg; Manganese, 130,000 mg; zinc, 70,000 mg; Selenium, 300mg. calcium,17.50%, Lysine,1,330 mg; Methionine, 1,075 mg; B-Corotenic acid, 350 mg.

Table 4: COST OF INGREDIENTS USED TO COMPOUND THE DIET.

Feed ingredient	PRICE/kg(GH₵)
Corn cobs	0.27
Wheat bran	0.60
Soybean meal	2.60
Maize bran	1.00
Maize	1.40
Palm kernel cake	0.38
Rice bran	0.50
Fish meal	3.2
Oyster shell	0.24
Salt	2.00
Vitamin-trace mineral premix	6.00
Enzyme	

3.5 FEEDING MANAGEMENT

Pigs were fed a daily amount of feed equal to 5% of the individual live weight. Water was provided *ad libitum.* The pigs were weighed separately every week and the daily feed portion were adjusted. The pigs were fed till they reached an average live weight of 70 ± 5 kg.

3.6 EXPERIMENTAL ANIMALS, DESIGN AND TREATMENT

Forty (40) Large White grower pigs (20 males and 20 females) ranging from 20kg to 35kg, with an average live weight of 27kg ± 5, were selected at the Piggery Unit of the Council for Scientific and Industrial Research-Animal Research Institute (CSIR-ARI), Accra for the feeding trial. The weights of the 40 pigs were equalized among the five dietary treatments. Each treatment consisted of four females and four males with four replicates per treatment and two animals per replicate in a completely randomized design. The two animals in each replicate were of the same sex.

3.7 MANAGEMENT OF EXPERIMENTAL ANIMALS

A thorough cleaning of the pens including the feed and water troughs with a disinfectant prior to the start of the trial was done. The water troughs and floors were also cleaned every morning during the experiment. Each pen contained a concrete feed and watering trough. Feed was provided every morning while fresh clean tap water was provided every morning and evening as a daily routine. Pigs were also washed with water every morning and kept clean and cool. On the day of the start of the feeding trial the experimental pigs were weighed individually with a Gascoigne weighing scale[3] to obtain the initial weights. Ear tagging was done for easy identification of pigs.

[3] GASCOIGNE, GUSH & DENT. 150kg capacity, made by precision Weighters, Reading,England

3.8 PARAMETERS MEASURED

3.8.1 FEED INTAKE

The determination of weekly feed intake (WFI) was done every Monday throughout the experimental period. The WFI was obtained by summing the quantities of feed allocated to each pig during the week. Feed was weighed using a table top weighing scale[4]. The summation of WFI for the period a particular pig stayed on the experiment was described as the total feed intake (TFI) for that pig. Average Daily Feed Intake (ADFI) was established by dividing TFI by the number of days the pig remained on the experiment.

3.8.2 LIVE WEIGHTS AND LIVE WEIGHT GAINS

The initial weight of each replicate was taken at the beginning of the experiment. Afterwards, pigs were weighed every week specifically on Mondays before feeding to determine body weight changes for the week using the Gascoigne weighing scale[3]. The Average Daily Gain (ADG) was then determined by dividing the weekly gain by seven (days).The live weight gained for the week was the differences between the previous week's recorded weight and the current weight. The difference between the final weight (70± 5kg) and the initial weight of each pig was the total weight gain (TWG).

3.8.3 FEED CONVERSION RATIO, FEED COST, AND FEED COST PER KG GAIN

Feed conversion ratio, defined as the quantity of feed (kg) consumed to gain a unit of live weight (kg), was calculated as the ratio of total feed consumed to total weight gain for each pig. The cost of feed was the sum total of the cost of each ingredient used in compounding 100 kg of a diet; from this the cost per kg was calculated. The economy of gain for each pig was calculated as the feed cost/kg live weight gain, i.e. the cost of feed required to produce a kg of weight and was computed as the product of feed cost (per kg) and the feed conversion ratio.

3.9 CARCASS EVALUATION

3.9.1 SLAUGHTERING OF PIGS

Each experimental pig was slaughtered when it attained the target weight of 70±5kg on the weighing day. The slaughtering was done at the Meat Processing Unit of the Council for Scientific and Industrial Research-Animal Research Institute (CSIR-ARI). An electric stunner was used to stun the pigs, they were then slaughtered and allowed to bleed. Pigs were scalded with hot water (80^0C) immediately after bleeding and the remaining hairs were singed with a gas burner. The carcasses were then hang, washed and eviscerated.

3.9.2 WARM CARCASS PARAMETERS

(i) Dressed Weight: Warm dressed weight was determined as the whole carcass weight after the removal of the viscera. The viscera (internal organs) were collected into a bucket and after washing off the clots of blood and fluids, the weight was determined and recorded using a table top scale[4].

[4] CAMRY Scale of 441bs x 202/20kg x 50g capacity made in China.

The liver, kidneys, heart, spleen, thymus gland and respiratory tract were separated and weighed individually as described by Bridi and Silva (2007).

The weights of the full GIT and then the empty GIT were taken after which the empty stomach was weighed.

3.9.3 CHILLED CARCASS PARAMETERS

The following parameters were taken after 24 hours chilling of each carcass in a cold room (4^0C):

(i) Chilled dressed carcass weight was the weight of the whole carcass (without the viscera). Each chilled carcass was then divided into two equal halves along the vertebral column and the left half was then used to determine the following parameters:

(a) Carcass length-this was determined from the left half of a hanging carcass and it was the distance between the anterior edge of the first rib and the anterior edge of the aitch bone (Merkel *et al.*, 1993).

(b) Weights of thigh, shoulder, hand, rip back, rip streak, rump back, rump streak and fillet. The absolute weights were measured on a table top scale as described by Bridi and Silva (2007).

(ii) Back fat thickness

The average of the thickness of the back-fat was measured from three points, the first rib, the last rib and rump and the P2 value was assessed by measuring the depth of back-fat at the P2 position which was taken 6.5cm from the dorsal midline and at the head of the last rib and recorded according to the methodology proposed by Merkel *et al*. (1993).

3.10 HAEMATOLOGICAL AND SERUM BIOCHEMICAL STUDIES

3.10.1 SAMPLE COLLECTION

Twenty (20) experimental animals, i.e., four pigs per treatment (2 males and 2 females) were bled via the anterior vena cava to collect about 4ml of blood into a labeled sterile vacutainer tubes which contained 1.0mg/ml of ethylene diamine tetra acetic acid (EDTA) and 0.1mg/ml heparin and was used for haematological analysis. All the forty experimental animals, i.e., eight pig per treatment (4 males and 4 females) were also bled through the anterior vena cava to collect about 4ml of blood into a labeled sterile vacutainer tubes without the EDTA (anticoagulant) for the blood biochemical studies.

3.10.2 HAEMATOLOGICAL EXAMINATION

The SysmexHaematological Auto-Analyser[5] was used for the analysis of haematological indices. The parameters measured were; Red (RBC) and White Blood Cells (WBC) counts, Haematocrit (HCT) or Packed Cell Value (PCV), Haemoglobin (Hb), as well as Mean Cell Haemoglobin (MCH), Mean Cell Haemoglobin Concentration (MCHC) and Platelets (PLTS) number.

[5] Mindray, Auto HaematologyAnalyser. ShenzhenMindray Bio-medical Electronics Co. Ltd. Mindray Building, Kej. 12th Road South, Hi- tech IindustriesPark Nanshan, Shenzhen, 5780, 57. P – R China.

3.10.3 SERUM BIOCHEMICAL INDICES

The goal of analyzing the serum biochemical was to determine the levels of cholesterol, high density lipoprotein, low density lipoprotein, total protein, globulin, albumin and triglycerides. The blood samples for the biochemistry analysis was allowed to clot at room temperature. The clotted blood samples were then centrifuged for 2500 rpm for 5 minutes at room temperature to separate the serum from the blood cells. The serum was then used for the analysis as follows; the total protein (TP) was determined using Biuret method as described by Kohn and Allen (1995). Albumin was determined using the Bromocresol Green (BCG) method. Total cholesterol (TC), high density lipoprotein and low density lipoprotein were estimated using the CHOP-PAP method. The globulin content was determined by subtracting albumin from the total protein.

3.10 STATISTICAL ANALYSIS

All data collected were subjected to analysis of variance (ANOVA) using Genstat Statistical software (Discovery Edition 3). The 5% probability level was used for determining significance among treatments.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 CHEMICAL COMPOSITION OF CORN COBS

The chemical composition of the corn cob is shown in Table 5. The crude protein, ether extract and dry matter values of 2.42%, 3.96% and 85.81%, respectively were slightly lower than those recorded by Rajmane and Deshmukh (2000) who recorded 4.4% crude protein, 4.2% ether extract and 91.5% dry matter whiles the crude fibre value 39.89% was higher than that of Rajmane and Deshmukh (2000) who recorded 34.9%. The changes in the values could be attributed to differences in production methods, climate, stage of maturity, soils, variety of maize and harvesting time, cultivar and perhaps drying methods employed (Szyszkowska *et al*., 2007).

Table 5: CHEMICAL COMPOSITION OF CORN COBS

Parameters	Values (%)
Crude Protein	2.42
Crude Fibre	39.89
Ether Extract	3.96
Dry Matter	85.81
Ash	2.16

4.2 PERFORMANCE CHARACTERISTICS

4.2.1 HEALTH AND MORTALITY OF PIGS

All the animals on the experiment did not show any visible external signs of ill health during the period of the experiment and willingly consumed their allowances of the experimental diets. No mortalities were recorded in the study. Okyere (1994) also recorded no mortalities when he fed broiler chickens with diet containing up to 40% wheat bran which is high in fibre but with different levels and type of OPTIZYME™. Again in a similar work done by Boateng *et al*. (2013), they recorded no mortalities when grower pigs were fed diets containing up to 60% of rice bran supplemented with Xzyme™ (25g per 100kg of feed). Len *et al*. (2008) also recorded no mortality when they fed different breeds of pigs diets containing high quality fibre.

4.2.2 GROWTH PERFORMANCE OF PIGS

A summary of the growth performance of pigs fed graded levels of corn cob with or without enzyme is presented in Table 6. Initial live weight (ILW), average daily feed intake (ADFI) and total feed intake (TFI) did not manifest dietary influences.

TABLE 6: GROWTH PERFORMANCE OF THE PIGS FED CORN COB BASED DIET

	Dietary treatment							
Parameters	A-0% CC	B-15% CC	C-15% CC + Enzyme	D-25% CC	E-25% CC + Enzyme	LSD	SEM	P - Values
Number of pigs (kg)	8	8	8	8	8			
Initial Live Weight (kg)	28.62	29.25	29.25	28.38	29.62	1.753	0.605	0.590
Final Live Weight (kg)	72.31[a]	70.44[b]	70.50[b]	69.12[b]	70.06[b]	1.708	0.589	0.013
Average Daily Weight Gain (kg)	0.56[a]	0.50[ab]	0.50[ab]	0.45[b]	0.49[ab]	0.066	0.023	0.049
Total Weight Gain (kg)	43.69[a]	41.19[b]	41.25[b]	40.75[b]	40.44[b]	2.054	0.709	0.025
Average Daily Feed Intake (kg)	2.53	2.47	2.51	2.48	2.50	0.101	0.035	0.721
Total Feed Intake (kg)	179.37	182.01	192.95	205.86	187.73	27.408	9.461	0.320
Feed Conversion Ratio (feed/gain)	4.12[a]	4.44[ab]	4.70[ab]	5.10[b]	4.67[ab]	0.742	0.256	0.034
Feed cost/kg Gain, GHS	5.15	4.70	5.03	5.25	4.86	0.784	0.382	0.299
Days to slaughter	79.6[a]	82.2[ab]	85.8[ab]	91.9[b]	83.1[ab]	10.83	3.74	0.021

LSD - Least Significant Difference **SEM** – Standard Errors of Mean **a, ab** - means in the same row with different superscripts differ significantly ($p < 0.05$) **CC** – Corn Cobs

4.2.2.1 LIVE WEIGHT CHANGES

The initial live weight was similar ($p < 0.05$) across dietary treatments (Table 6). However, final live weight and total weight gain of pigs fed the control diet were significantly higher ($p < 0.05$) than that of the pigs fed the tested diets but there were no significant difference among the tested diets. Pigs were slaughtered when they attained a live weight of 70+5kg. The average daily weight gain (ADWG) values were 0.56, 0.50, 0.50, 0.45 and 0.49 for the corresponding dietary treatments A, B, C, D and E respectively. Although the daily feed intake of the animals did not record any significant ($p > 0.05$) differences, there were significant ($p < 0.05$) differences in the average daily weight gains. Treatment A which is the control diet was significantly ($p < 0.05$) higher than treatment D i.e. 25% corn cob without enzyme. Each of them was however similar to the rest of the treatments.

These results suggest that, the pigs were able to effectively and efficiently digest the corn cob used in the tested diets probably due to the addition of enzyme. The pigs on tested diets except treatment D (25% corn cobs without enzyme) were similar to the control diet. With an addition of enzymes, fibre digestion is increased and an increase in animal performance is expected. Kerr and Shurson (2013) reported that, the inclusion level of enzymes for a range of diet increased the digestion and absorption of nutrient and therefore the rate of growth. Report by Choct (1997) showed that cell walls of legumes, cereal grains, and oil seed meals contained complex carbohydrates usually known as non-starch polysaccharides (NSP) which are not easily digested due to inadequate amount of degradable endogenous enzymes produced by pigs usually at the pre weaning stage and therefore supplementation with an enzyme is imperative. The days to slaughter of pigs on the five dietary treatments were 79.6, 82.2, 85.2, 91.9 and 83.1 for treatments A, B, C, D and E respectively. The control diet was significantly ($p <0.05$) lower than treatment D (25% corn cobs without enzyme) but each of them was similar to the rest of the treatments. This could be due to the high ADWG of pigs on dietary treatment A.

4.2.2.2 TOTAL FEED INTAKE

The total feed intake (TFI) of the pigs on the five diets did not show any significant ($p > 0.05$) differences (Table 6). The similar TFI among treatments suggest that the corn cob based diet was acceptable to the pigs. This shows that, unless prevented by bulk, or possibly palatability, a pig is likely to eat until its energy requirement is fulfilled, since energy is the first limiting nutrient in a pig diet (Coffey *et al.*, 1982). These results agree with the findings of Ndindana *et al.* (2002) and Kanengoni *et al*. (2004). They reported that provided energy density is sufficient, the pig can tolerate a wide range of crude fibre in the diet. This result also agrees with that of Anyika *et al*. (2009), who had earlier stated that feed intake can be influenced by level of palatability.

4.2.2.3 AVERAGE DAILY FEED INTAKE

The different dietary treatments did not impact significantly ($p > 0.05$) on the daily feed intake suggesting that pigs will readily consume diets containing up to 25% Corn Cobs. However, pigs fed with the enzyme added diets had numerically higher feed intake than their counterparts fed diets without enzyme. In agreement with previous work reported by Beauchemin *et al*. (1995), supplementation of feed with enzyme improves feed intake hence growth rate. Pigs on the five treatments were fed 5% of their body weight and consumed similar amounts of feed on daily basis. There were no leftovers for all the dietary treatments. Table 3 indicates that the energy content of the experimental diets were similar. Pigs, like other monogastric animals, generally eat to satisfy an inner metabolic need for energy and will therefore eat similar amount of diets containing similar levels of energy.

4.2.2.4 FEED CONVERSION RATIO (FCR), FEED COST AND ECONOMY OF GAIN

With the mean FCR values recorded, there was a significant difference ($p < 0.05$) between treatment A (0% corn cob) and D (25% corn cob without enzyme). Each of them was however similar ($p > 0.05$) to the rest of the treatments. Pigs on diet A utilized the diet efficiently followed by treatment B, then E and C and treatment D which was the least efficient. This result could be due to decreased ADG with increasing feed intake as the corn cob increased in the diets because FCR is a measure of how well an animal converts feed intake into live weight gain (Amoah *et al.*, 2017). A similar trial by Boateng *et al.* (2013), observed an improvement in FCR at every level of rice bran with addition of the XZYME.

The feed cost per kg for the dietary treatments decreased with increasing levels of corn cobs. Treatment A had the highest feed cost per kg and this can be attributed to the kg price of maize which from Table 4, is GHS 1.40 and its 26% inclusion in the diet as compared to GHS 1.06 for 15% inclusion of corn cob and GHS 1.03 for 25% inclusion of corn cob. Although the feed cost/kg of the control diet was higher than that of tested diets, the feed cost/kg gain were similar ($p > 0.05$) among the dietary treatments. This could be due to the better FCR of pigs on the control diet. However the feed cost/kg gain was numerically higher for treatment D (25% corn cobs without enzyme) and the control diet but was lowest for diet B (15 % corn cobs without enzyme), a difference of 55 and 45 pesewas per kg for treatments D and A respectively. Therefore 45pesewas x 41.19 kg weight gain will save GHS 18.54 per animal for treatment B when compared to the control. This implies that including 15% corn cobs without enzyme in diet of grower pigs was more profitable compared to the control diet. Therefore producing more pigs at a reduced cost as observed in this study, is likely to result in decreased cost of production. Corn cobs are relatively cheaper and might be responsible for the decrease cost/kg gain.

4.3 CARCASS CHARACTERISTICS

TABLE 7: CARCASS CHARACTERISTICS OF THE PIGS FED THE FIVE DIFFERENT EXPERIMENTAL DIETS.

Parameters	Dietary treatment							
	A-0% CC	B-15% CC	C-15% CC + Enzyme	D-25% CC	E-25% CC + Enzyme	LSD	SEM	P Value
Physical measurements								
Live weight (kg)	72.31[a]	70.44[ab]	70.50[ab]	69.57[b]	70.06[b]	1.842	0.636	0.053
Warm weight (kg)	48.12	47.19	47.31	46.29	46.69	2.408	0.831	0.598
Chilled weight (kg)	46.81	45.62	45.81	44.86	45.31	2.334	0.806	0.527
Carcass length (cm)	72.31	69.81	70.00	69.21	70.94	3.442	1.188	0.407
Measurement of Fat								
Backfat average (cm)	2.00[a]	1.63[ab]	1.58[ab]	1.27[b]	1.25[b]	0.474	0.164	0.019
P2 measurement (cm)	1.35[a]	0.95[ab]	0.83[b]	0.66[b]	0.53[b]	0.464	0.160	0.012
Exposed surface								
Lion eye area (cm^2)	24.87	26.09	26.17	25.45	24.98	3.752	1.295	0.925
Weight of major joints								
Shoulder (kg)	3.27	3.11	3.27	3.11	3.29	0.355	0.123	0.701
Hand (kg)	3.02	3.36	2.98	3.46	3.09	0.460	0.159	0.158
Head (kg)	5.42	5.36	5.44	5.26	5.42	0.341	0.118	0.834
Rip Streak (kg)	1.82	1.64	1.54	1.69	1.55	0.302	0.104	0.343
Rip back (kg)	3.37	3.13	3.17	3.01	3.07	0.371	0.128	0.370
Rump back (kg)	2.99	2.91	2.76	2.68	2.59	0.469	0.162	0.428
Rump streak (kg)	1.34[a]	1.27[ab]	1.21[ab]	1.01[b]	0.97[b]	0.303	0.105	0.044
Thigh (kg)	4.74	5.13	5.01	4.84	5.06	0.420	0.145	0.323
Trotters (kg)	0.86	0.93	0.87	0.92	0.91	0.110	0.038	0.659

TABLE 7 continued

Weight of organs								
Viscera (kg)	13.38	14.63	13.83	13.94	14.01	1.593	0.550	0.621
Full GIT (kg)	7.64^{a}	9.28^{b}	8.14^{ab}	8.49^{ab}	8.74^{ab}	1.182	0.408	0.045
Empty GIT (kg)	2.76	2.83	2.64	2.66	2.94	0.316	0.109	0.293
Empty stomach (kg)	0.58	0.64	0.65	0.64	0.66	0.080	0.027	0.267
Liver (kg)	1.14^{ab}	1.23^{a}	1.08^{bc}	0.99^{c}	1.09^{bc}	0.117	0.041	0.005
Respiratory tract (kg)	0.72^{b}	0.75^{b}	0.68^{b}	0.59^{a}	0.69^{b}	0.075	0.026	0.003
Fillet (kg)	0.26	0.27	0.27	0.27	0.29	0.045	0.016	0.845
Thymus gland (g)	17.25	16.78	17.29	17.29	16.73	3.280	1.132	0.992
Kidney (g)	206.60^{a}	193.87^{ab}	189.52^{ab}	189.69^{ab}	177.59^{b}	25.817	8.912	0.027
Heart (g)	203.91	210.15	199.90	195.65	216.24	20.989	7.245	0.304
Spleen (g)	103.31	90.97	93.39	103.58	102.26	17.992	6.211	0.453
Mesenteric lymph (g)	491.87^{a}	391.50^{b}	434.63^{ab}	399.38^{b}	369.51^{b}	64.510	22.269	0.006

LSD – Least Significant Difference **SEM**– Standard Error of Mean **a, ab**- means in the same row with different superscripts differ significantly ($p < 0.05$) **CC** – Corn Cobs

4.3.1 ABSOLUTE CARCASS PARAMETERS

4.3.1.1 PHYSICAL MEASUREMENT

Fig. 1. Carcass length

Table 7 shows that the carcass parameters measured; warm weight, chilled weight as well as carcass length were statistically ($p > 0.05$) similar. Treatment A had the highest warm and chilled weight and carcass length but was not significantly ($p > 0.05$) different from those on the corn cob with or without enzyme. Probably this was as a result of the termination criteria used, i.e., all pigs were slaughtered when they attained the stipulated live weights of 70 ± 5 kg. It also suggests that the test diets had the same nutritional effects as that of the control diet. Numerically, pigs on the control diet were longer than their counterparts on the tested diets. This result contradicts the findings of Adusah (2009), who found out that carcass of pigs on high fibre with probiotic diets were longer than those on the control diet. It also agrees with an earlier work done by Chimonyo *et al*. (2001), they reported that increasing the level of corn cob from 0 to 200g/kg did not influence chilled weight and carcass length. They did not observed any significant ($p > 0.05$) differences among the treatment means.

There was no significant ($p > 0.05$) difference in live weight at slaughter for pigs that were on corn cobs with or without enzyme; i.e. treatment B, C, D and E. The values of live weight at slaughter recorded for pigs on the control diet and 15% corn cob with or without enzyme i.e. A, B and C were also similar ($p > 0.05$) but were significantly higher ($p < 0.05$) than that of the pigs that were on 25% corn cob with or without enzyme i.e. treatment D and E. These results are contrary to those of Chimonyo *et al*. (2001), who recorded similar ($p > 0.05$) values in live weight at slaughter when pigs were fed up to 20 % corn cobs.

4.3.1.2 WEIGHTS OF MAJOR JOINTS

Fig. 2. Major joints

Fig. 3. Head

The mean values obtained for the other carcass measurements; i.e. weight of thigh, shoulder, fillet, hand, head, trotters, rip back, rip streak and rump back were also similar ($p > 0.05$) among the five dietary treatment except rump streak. The similarities observed on the major joints are probably due to the similarities observed for warm weight, chilled weight and carcass length. This is consistent with the report of Okai *et al*. (2000), who found no significant ($p > 0.05$) differences in the relative and absolute weights of these parameters when they fed diets containing varying levels (20, 30 and 40%) of higher fibre diets plus an exogenous enzymes to grower -finisher pigs. Saka (1984) also suggested that these body components (thigh, head, hand, trotters, rip back, rip streak, rump back, rump streak and shoulder) will only differ under extreme situations of malnutrition. This suggest that the pigs on this experiment were well fed and also, farmers would have alternatives in considering feedstuff for compounding diets at a reduced cost without compromising on final output and quality of carcass produced. Though the mean values obtained for the major joints were similar among the dietary treatments, pork from pigs on the tested diets will be more accepted by consumers because pig on the tested diets had leaner carcasses compared to pigs on the control diet. High levels of cholesterol and fat from animal products have been associated with coronary heart diseases and stroke and fear of this has had negative impact on acceptance of pork. Pork from pigs on the corn cobs diet may be sold at premium price which will greatly benefit the farmers.

4.3.1.3 BACK FAT AND P2 MEASUREMENT

Fig. 4. P2 measurement

Fig. 5. Back fat (control diet)

Fig. 6. Back fat (15% corn cobs without enzyme)

Fig. 7. Back fat (15% corn cobs with enzyme)

Fig. 8. Back fat (25% corn cobs without enzyme)

Fig. 9. Back fat (25% corn cobs with enzyme)

Back fat and P2 are the main determinants of the fat content of pork. The mean values obtained as shown in table 8 were significantly ($p < 0.05$) different. However there was no significant ($p > 0.05$) difference among pigs that were on the tested diets i.e. treatment B, C, D and E for both back fat and P2 measurement. Pigs on the control diet recorded the highest values 2.00 and 1.35 for back fat and P2 respectively. Pigs fed the corn cob diets with or without enzyme had lower values than the pigs fed the control diet. The values of back fat and P2 measurement decreased as the level of corn cob increased. The values obtained show that pigs fed corncob with or without enzyme had leaner carcasses than the pigs that were on the control diet. Generally, consumers prefer lean meat and tend to discriminate against high fat meat due to health risk involved. These findings are in agreement with the work of Fombad and Maffeja (2000), who reported that the production of lean pork carcasses can be attained by replacing feeds that are high in energy with bulky low energy feeds that are high in crude fibre or by the inclusion of inert materials such as polyethylene, corncob cellulose and sand in diet of pigs. It also agrees with Whitney *et al*. (2006), who reported that when dietary fibre was increased through the addition of distiller's dried grains with solubles at 10, 20 and 30% of the diet, the belly primal thickness was significantly decreased from 3.15 to 3.00cm, 2.84 and 2.71cm, respectively, indicating reduced fatness. The findings also agree with the work of Partanen *et al*. (2002), who reported lower side-fat depth (15.6 vs. 14.3 mm) when grower and finisher pigs were fed diets that are high in fibre.

4.3.1.4 EXPOSED SURFACE

Fig. 10. Loin eye area

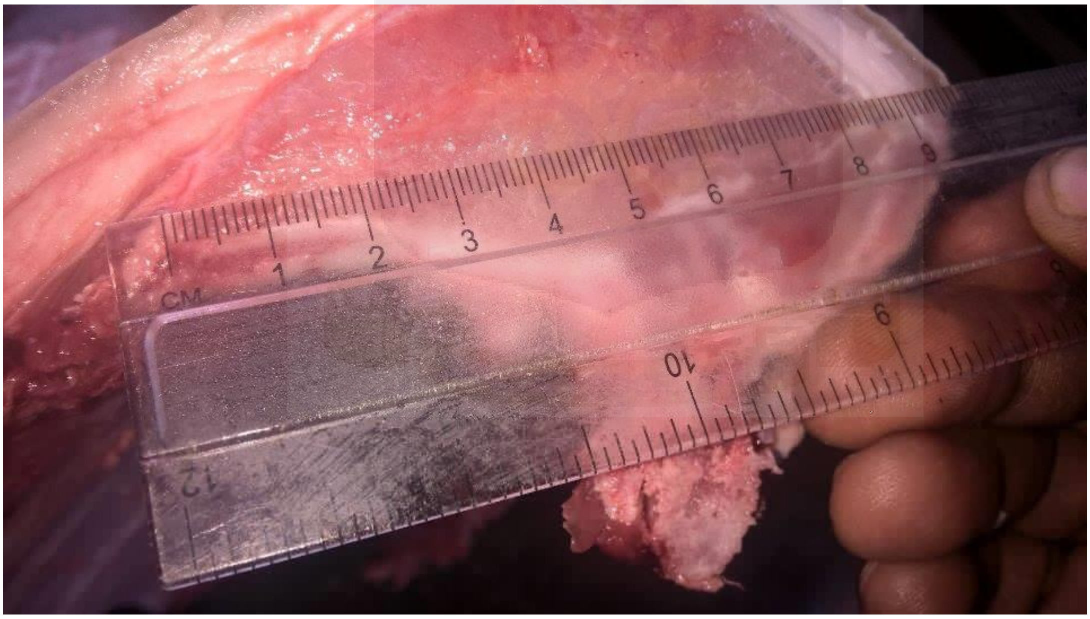

Fig. 11. Loin eye area

The mean values obtained for loin eye area were not influenced significantly ($p > 0.05$) by the dietary treatments. However, pigs on the control diet recorded the least value for loin eye area.

4.3.1.5 WEIGHT OF INTERNAL ORGANS

The values for the internal organs, i.e. heart, spleen, empty stomach, thymus gland, empty GIT, full GIT, liver, respiratory tract, kidney and mesenteric lymph are also shown in Table 7. Heart, spleen, empty stomach, thymus gland and empty GIT were not influenced significantly ($p > 0.05$) by the dietary treatments. Tengan *et al*. (2012) observed a similar pattern when they fed varying levels of African Locust Bean Fruit Pulp which is high in fibre to growing pigs. Similar work by Boateng *et al*. (2013), indicated no significant differences in the absolute weight of the various organs. The weight of viscera as shown in Table 7 were not significantly ($p > 0.05$) different. The mean values for dietary treatment A, B, C, D and E were 13.38, 14.63, 13.83, 13.94 and 14.01kg respectively. Though there was no significant ($p > 0.05$) difference among treatments, pigs on the corn cob diets with or without enzyme recorded higher values than the pigs on the cob-free diet. The results contradicts Montagne *et al*. (2003), who stated that high fibre diets increase the size of visceral organs in pigs depending on the fibre's physico-chemical characteristics and fibre level. The difference between the current study and Montagne *et al*. (2003) could be due to the type of fibre and level used. The mean values recorded for mesenteric lymph, full GIT, liver, kidney and respiratory tract as shown in Table 7 were significantly ($p < 0.05$) different. The mesenteric lymph of treatment A (control) was significantly ($P < 0.05$) higher than treatments B (15% corn cob without enzyme), D (25% corn cob without enzyme) and E (25% corn cob with enzyme) but was similar ($p > 0.05$) to treatment C (15% corn cob with enzyme). The results agree with Stanogias and Pearce (1985b), they reported that prolonged intake of corn cob supplemented diets by growing pigs led to an increase in weight of the gastrointestinal tract. Respiratory tract of pigs on the control diet was significantly ($p < 0.05$) higher compared to pigs on treatment D but was similar to the rest of the treatments. In terms of full GIT, treatment A was significantly lower ($p < 0.05$) compared to treatment B but each of them was similar to the rest of the treatments. Again, the kidney of pigs on the control diet was significantly ($p < 0.05$) higher than their counterparts on treatment E (25% corn cobs with enzyme) but was similar to treatments B (15% corn cobs without enzyme), C (15% corn cobs with enzyme) and D (25% corn cobs without enzyme).

4.4 HAEMATOLOGICAL AND SERUM BIOCHEMICAL STUDIES

4.4.1 HAEMATOLOGICAL ANALYSIS

Haematological profiles are good indicators of disease and health conditions in farm animals. These are good indicators of the status of an animal physiologically and its changes are important in evaluating the response of animals to numerous physiological situations (Khan and Zafar, 2005). Also Esonu *et al*. (2001) stated that haematological components reflect how an animal respond physiologically to its environment external and internal, which include feeding and feed. Blood samples were analyzed to determine whether the dietary treatments had any effects on the blood profile of the pigs.

Tables 8 shows the haematological profile of the pigs on the five dietary treatments. The haematological analysis on the pigs' blood did not show any significant ($p > 0.05$) differences among the dietary treatments in any of the parameters measured.

The results of the haematological characteristics of pigs fed diets containing graded levels of corn cob with or without enzyme showed no significant ($p > 0.05$) effects on the Haemoglobin (HB), red blood cell (RBC), haematocrit (HCT), mean cell haemoglobin (MCH), mean cell volume (MCV), white blood cell (WBC), platelet (PLT) and mean cell haemoglobin concentration (MCHC) of the experimental animals. The non-significant ($p > 0.05$) influence of the experimental diets on the RBC and WBC showed that the experimental diets had no harmful effects on the health status of the pigs. The mean values obtained were within the normal range for pigs as reported by Etim *et al.* (2014). These values were also similar to those reported by Tengan *et al*. (2012), who fed high fibre diets to growing pigs. The WBC values were not significantly different ($p > 0.05$) among the five dietary treatments studied. However, white blood cells (WBC), which assist in fighting diseases, were high in B (15% corn cobs without enzyme), C (15% corn cobs with enzyme), and D (25% corn cobs without enzyme). Also, treatment E (25% corn cobs without enzyme) recorded the highest mean value (13.80) of Haemoglobin (Hb) and treatment A recorded the least (11.12). The main functions of the white blood cell is to fight infections, to produce and transport antibodies in immune response and to protect the body against attack by foreign organisms (Isaac *et al*., 2013). Thus, animals that are not within the normal range of white blood cells are exposed to high risk of disease infection and also have the ability to generate antibodies and have high degree of resistance to diseases and enhance adaptability to local environmental prevalent disease conditions (Isaac *et al*., 2013).

The results show that platelets levels were also not significantly ($p > 0.05$) influenced by the five dietary treatments. Tengan *et al*. (2012) obtained 144.20, 155.20, 159.80,138.50 and 157.50×109/L as blood platelets values, but the values obtained in this current study were higher i.e. 314, 209, 310, 212 and 308×109L for A, B, C, D and E respectively. However, in spite of the higher figures recorded in this current study the test material did not seem to have any negative effects on the pigs. Blood platelets are associated with blood clotting. Low platelet concentration suggests that the process of clot-formation will be prolonged which will result in excessive loss of blood in the case of injury. The differences in the values could be attributed to state of the animal, time of day when blood samples were taken, and other factors relating to the environment. Esonu *et al*. (2001) reported that among other things, excitement, time of day, exercise, stage of estrus cycle, environmental temperature and other factors could bring about differences in haematological profile of pigs.

TABLE 8: HAEMATOLOGICAL PARAMETERS OF THE PIGS

Parameters	Dietary treatment							
	A-0% CC	B-15% CC	C-15% CC + Enzyme	D-25% CC	E-25% CC + Enzyme	LSD	SEM	P-Values
HCT (pg)	34.2	35.4	37.4	37.7	42.4	10.57	3.43	0.532
HB (g/dl)	11.12	11.52	12.47	12.75	13.80	3.111	1.010	0.403
MCH (pg)	19.96	19.64	20.10	20.35	20.64	2.372	0.770	0.907
MCHC (g/dl)	32.62	32.51	33.41	33.93	32.63	1.580	0.513	0.270
MPV ()	12.44	12.43	12.05	9.73	12.11	3.283	1.065	0.380
MCV (fl)	61.4	60.4	60.4	60.3	63.2	9.04	2.93	0.943
PCT ()	0.378	0.263	0.375	0.205	0.375	0.2067	0.067	0.281
PLT ($x10^9$/l)	314	209	310	212	308	135.5	44.0	0.252
RBC ($x10^{12}$/l)	5.55	5.84	6.19	6.25	6.57	1.002	0.325	0.277
WBC ($x10^9$/l)	15.35	17.67	18.33	18.07	15.82	6.686	2.170	0.808

LSD – Least Significant Difference **SEM** – Standard Error of Mean **a, ab**- means in the same row with different superscripts differ significantly ($p < 0.05$) **CC** – Corn Cobs

The mean values obtained for HCT, MCH and MCV in Table 8 again recorded no significant ($p > 0.05$) differences. These findings are in agreement with those reported by Angaeline and Madubuike (2004) and Alu *et al*. (2011).

Also there were no significant differences ($p > 0.05$) among the treatment means for mean cell haemoglobin concentration (MCHC). The MCHC values were within the normal ranges for pigs as stated by Eze *et al*. (2010), but lower than those reported by Frienship *et al*. (1984) and higher than those recorded by Rispat *et al*. (1993). The differences could be as a result of the diet, environmental, seasonal and other factors (Harapin *et al*., 2003).

According to Togun *et al*. (2007), when haematological values are within the standard range reported for the animal, it is an indication that diets did not show any negative influence on haematological indices during the period of the experimental but when the values are below the standard range then it is a sign of anaemia. Bawala *et al*. (2007) also reported that low values for haematological parameters could be due to the negative influence of high dietary fibre contents.

4.4.2 SERUM BIOCHEMICAL ASSAY

The results for the serum biochemical assay for total protein, globulin, albumen, total cholesterol, triglycerides and high and low lipoproteins are shown in table 9.

Table 9: SERUM BIOCHEMICAL PARAMETERS OF THE PIGS

	Dietary treatment							
Parameters	A-0% CC	B-15% CC	C-15% CC + Enzyme	D-25% CC	E-25% CC + Enzyme	LSD	SEM	P Values
Total Protein (g/l)	56.40	56.40	59.50	59.20	60.30	6.97	2.40	0.699
Albumin (g/l)	35.16^{ab}	32.45^{b}	35.85^{ab}	33.71^{b}	39.33^{a}	5.104	1.762	0.046
Globulin (g/l)	23.10	24.00	29.40	26.20	20.40	8.28	2.86	0.254
Total Cholesterol (mmol/l)	5.70^{a}	4.47^{b}	3.94^{bc}	3.20^{c}	3.87^{bc}	1.024	0.354	0.001
H D L (mmol/l)	1.684^{a}	1.748^{a}	1.756^{a}	1.509^{ab}	1.232^{ab}	0.4064	0.1403	0.047
L D L (mm0l/l)	3.02^{a}	2.02^{ab}	1.40^{b}	0.87^{b}	1.74^{b}	1.070	0.369	0.005
Triglycerides (mmol/l)	2.139^{ab}	2.296^{a}	1.647^{b}	1.829^{ab}	1.984^{ab}	0.5503	0.1899	0.015

LSD – Least Significant Difference **SEM** – Standard Errors of Means **a, ab**- means in the same row with different superscripts differ significantly ($p < 0.05$) **CC** – Corn Cobs

4.4.2.1 TOTAL PROTEIN, GLOBULIN AND ALBUMIN

The serum total protein and globulin levels were similar ($p > 0.05$) among the treatment means as those on the cob-free diet did not differ much from those on the corn cob based diets with or without enzyme. Even though total protein levels were not significantly different ($p > 0.05$)

among treatments, there was an increasing trend as the level of corn cob increased and this could suggest a dietary influence. However, significant ($p < 0.05$) differences were observed in albumin. Pigs on treatment E (25% corn cobs with enzyme) had significantly ($p < 0.05$) higher values compared to their counterparts on treatments B (15% corn cobs without enzyme) and D (25% corn cobs without enzyme) but similar to treatments A (control) and C (15% corn cobs with enzyme).

4.4.2.2 HIGH DENSITY LIPOPROTEIN (HDL), LOW DENSITY LIPOPROTEIN (LDL), TOTAL CHOLESTEROL AND TRIGLYCERIDES

The results obtained for high-density lipoprotein, low-density lipoprotein, total cholesterol and triglycerides are shown in Table 9. The results obtained for the above parameters indicated significant ($p < 0.05$) differences among treatment means. The total cholesterol for the animals on treatment A were significantly ($p < 0.05$) higher than the animals on the tested diet i.e. treatments B, C, D and E. There was no significant difference ($p > 0.05$) in total cholesterol of pigs fed corn cob with or without enzyme but the total cholesterol for the four treatments were significantly lower ($p < 0.05$) than that of the pigs fed the cob-free diet. There was a decreasing trend in the mean values as the level of corn cobs increased and this could suggest the corn cobs can be used to produce pork with reduced blood cholesterol. This also means that coronary artery diseases which are associated with high levels of blood cholesterol and fat from animal products may be reduced. In an earlier study by (Hundemer *et al*., 1991), rice bran which is high in fibre was found to be an effective supplement in reducing liver and plasma total cholesterol compared to the control diet. There was a significant difference ($p < 0.05$) in the mean values obtained for high density lipoprotein which is also known as good cholesterol. Treatment E i.e. 25% corn cobs with enzyme recorded the least mean value with treatment C i.e. 15% corn cobs with enzyme recording the highest mean value. The values obtained in this experiment were far below those reported by Tengan *et al*. (2012), but were within the range recorded by Rispat *et al*. (1993). The differences could be as a result of the environmental, seasonal, diet and other factors (Harapin *et al*., 2003). Pigs on 15% corn cobs with or without enzyme (treatments B and C) recorded the highest values. According to Lewis *et al*. (2002), having bigger numbers of high density lipoprotein is associated with better health. There was no significant difference ($p > 0.05$) in low density lipoprotein among pigs fed corn cob with or without enzyme but the low density lipoprotein for treatments C, D and E were significantly lower ($p < 0.05$) than that of the pigs fed the cob-free diet. The mean values obtained for low density lipoprotein and triglycerides was not within the range recorded by Rispat *et al*. (1993). Topping (1991) stated that high fibre diet increased LDL receptor activity in the liver hence, effectively lowering plasma cholesterol levels. The result of the study agrees with Topping (1991), as the corncob diets recorded lower levels of LDL and was able to lower the plasma cholesterol levels.

The ratio of high density lipoprotein and low density lipoprotein is more important compared to the absolute concentration. Though 25% corn cobs with or without enzyme (treatments D and E) recorded the lowest values (1.509 and 1.232 for treatments D and E respectively) in the absolute concentration compared to the control diet (1.684 treatment A), the cholesterol to high density lipoprotein ratio was better because their ratios (0.47 and 0.32 for treatments D and E respectively) were higher than that of the control diet (0.29 for treatment A). The cholesterol to low density lipoprotein ratio was lower for the pigs on the corn cobs diets with or without enzyme compared to the control diet. Low density lipoprotein cholesterol (bad cholesterol) is related with the cause of strokes, heart attacks, and other severe medical problems and high density lipoprotein is believed to transport cholesterol back to the liver for excretion or to other tissues that use cholesterol to synthesize hormones in a reverse cholesterol transport

(Tymoczko *et al*., 2002). Therefore higher numbers for high density lipoprotein and lower values for low density lipoprotein are associated with better health outcomes (Lewis *et al*., 2002).

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

The study was undertaken to establish the influence of corn cobs inclusion in pig diets on growth performance, carcass characteristics and blood parameters. The study revealed that corn cobs contains 2.42% crude protein, 39.89% crude fibre, 3.96% ether extract, 85.81% dry matter and 2.16% ash. The corn cobs was readily acceptable to pigs and they consumed their allocation of the five diets. Pigs on the control diet (0% corn cobs) gave the optimum growth performance. However pigs on all the dietary treatments; 0% corn cobs, 15% corn cobs without enzyme, 15% corn cobs with enzyme, 25% corn cobs without enzyme and 25% corn cobs with enzyme were statistically similar in terms of initial live weight, total feed intake and average daily feed intake. Also in terms of final weight and total weight, there were significant ($p < 0.05$) difference between the control diet (A) and the corn cobs containing diets (B, C, D, and E) but statistically similar among the corn cobs containing deits; B (15% corn cobs without enzyme), C (15% corn cobs with enzyme), D (25% corn cobs without enzyme) and E (25% corn cobs with enzyme).

From economic point of view, dietary treatments D and E were relatively cheaper to feed. Though FCR was significantly ($p < 0.05$) different among treatments, with treatment A being the most efficient, it was not significantly ($p > 0.05$) different from treatments B (15% corn cobs without enzyme), C (15% corn cobs with enzyme), and E (25% corn cobs with enzyme). The corn cobs inclusion had influence on the carcass characteristics. The values of back fat and P2 decreased as the level of corn cobs increased. There was a significant ($p < 0.05$) difference between the control diet (A-0% CC) and the corn cobs containing diets (B-15% CC, C-15% CC + enzyme, D-25% CC, and E-25% + enzyme) for both back fat and P2. Pigs on the corn cobs diets with or without enzyme had lower back fat and P2 measurement compared to those on the control diet. However there was no significant ($p > 0.05$) difference among pigs that were on the tested diets i.e. treatment B, C, D and E. The values obtained for the measurement of the major joints were not significantly ($p > 0.05$) different among treatments except rump streak.

There was no statistical difference among treatments for haematological profile. However there was a significant ($p > 0.05$) difference among treatments for blood biochemistry except total protein and globulin. The total cholesterol of pigs on the tested diets were significantly ($p < 0.05$) lower than that of the pigs fed the cob-free diet.

5.2 CONCLUSION

The result of this study therefore indicates that, corn cob which is economically cheaper and regarded as waste in some areas of Ghana can be used successfully as a feed ingredient in conventional pig feed without any adverse effect on the growth performance, health status and carcass characteristics of grower pigs.

Pork from pigs fed diets with added corn cobs had lower fat and lower cholesterol levels compared to pork from pigs fed diets without corn cobs. From economic point of view, dietary treatments B and E were relatively cheaper to feed.

5.3 RECOMMENDATION

1. Corn cobs is recommended as an alternative feed ingredient in pig diets for pig farmers in Ghana and wherever corn cobs are available worldwide and can be included up to 25% in pig diets without any adverse effect on pigs.

2. Further studies must be carried out to determine the digestibility of the corn cob using pigs.

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