

**PERFORMANCE, CARCASS AND MEAT QUALITY CHARACTERISTICS OF  
BROILERS AND PIGS FED DIETS CONTAINING FERMENTED PALM KERNEL  
CAKE**

**BY**

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**CERTIFICATION**


We certify that this work on “**Performance, carcass and meat quality characteristics of broilers and pigs fed diets containing fermented palm kernel cake**” was carried out by Ikpamezie, Linda Chidinma, (20104739228) in partial fulfillment for the award of the degree of Master of Science in Animal Products Technology in the Department of Animal Science and Technology of the Federal University of Technology, Owerri. Nigeria.

  
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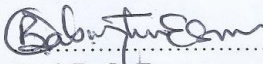
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## **DEDICATION**

This work is dedicated to my late father Mr. Frank Ejiogu), my mother Mrs. MargaretMary Ejiogu and my husband Hon. Engr. I.I. Ikpamezie).

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## TABLE OF CONTENTS

Title page	i
Certification	ii
Dedication	iii
Acknowledgement	iv
Table of Contents	v
Lists of Tables	ix
Abstract	x

### CHAPTER ONE:INTRODUCTION

1.1	Background Information	1
1.2	Problem Statement	4
1.3	Objectives of the Study	4
1.4	Justification of the Study	4

### CHAPTER TWO: LITERATURE REVIEW

2.1	Livestock Production in Global Industry	6
2.2	Contributions of Pigs and Poultry to World Meat Supply	7
2.3	Feeds and Feeding in Poultry Production	11
2.4	Feeds and Feeding in Pig Production	14
2.5	Non-conventional Feed Resources in Poultry and Pig Production	15
2.5.1	Characteristics of Non-conventional Feed Resources	18
2.5.2	Techniques for Improving the Utilization of Non-conventional Feedstuff	19
2.6	Palm Kernel Cake	21
2.6.1	Source and Distribution	21
2.6.2	Nutritive Value of Palm Kernel Cake	22
2.6.3	Performance of Broilers Fed Diets Containing PKC	28

2.6.4	Effects of PKC Diets on Performance and Carcass Characteristics of Pigs	30
2.7	Improving Nutritive Value of PKC	31

### **CHAPTER THREE: MATERIALS AND METHODS**

3.1	Experimental Site	35
3.2	Overview of the Experiments	35
3.3	Source and Processing of Experimental Materials	35
3.4	Proximate Composition of the Fermented PKC	36
3.4.1	Proximate Composition	36
3.4.1.1	Moisture content determination	36
3.4.1.2	Ash content determination	36
3.4.1.3	Crude protein determination	37
3.4.1.4	Determination of crude fibre	38
3.4.1.5	Ether extract (EE) determination	39
3.4.1.6	Nitrogen Free Extract Determination	39
3.4.1.7	Metabolizable energy	39
3.5	Experiment 1: Performance, Carcass and Meat Quality Characteristics of Broilers Fed Fermented Palm Kernel Cake	40
3.5.1	Management of Experimental Birds	40
3.5.2	Experimental Diets for Birds	40
3.5.3	Data Collection	43
3.5.3.1	Performance of Experimental Birds	43
3.5.3.2	Carcass and Organ Characteristics	43
3.5.3.3	Meat Quality Assessment	44
3.5.3.3.1	Drip Loss	44
3.5.3.3.2	Water Holding Capacity	44
3.5.3.3.3	Cooking Loss	44
3.5.3.4	Organoleptic Assessment	45
3.5.3.5	Haematology	45

3.5.3.5.1	Blood Sampling and Analysis	45
3.5.3.5.2	Total White Cell Count	45
3.5.3.5.3	Differential White Cell Count	46
3.5.3.5.4	Red Blood Cell Count	46
3.5.3.5.5	Haemoglobin Concentration	46
3.5.3.5.6	Packed Cell Volume	47
3.5.3.5.7	Red Cell Indices	47
3.6	Experimental Design and Analysis	48
3.7	Experiment 2: Performance, Carcass and Meat Quality of Pigs Fed Diets Containing Fermented Palm Kernel Cake	48
3.7.1	Experimental Animals	48
3.7.2	Experimental Diets	48
3.7.3	Data Collection	49
3.7.3.1	Performance of Experimental Pigs	49
3.7.3.2	Carcass Characteristics	49
3.7.3.3	Meat Quality Assessment	51
3.7.3.3.1	Drip Loss	51
3.7.3.3.2	Water Holding Capacity	51
3.7.3.3.3	Cooking Loss	51
3.7.4	Organoleptic Assessment	52
3.8	Experimental Design and Data Analysis of Experimental Pigs	52

#### **CHAPTER FOUR: RESULTS AND DISCUSSION**

4.1	Proximate Composition of Fermented PKC	53
4.2	Growth Performance of Broilers (Finisher Phase) Fed Fermented Palm Cake	55
4.3	Carcass and Internal Organ Characteristics of Broilers	57
4.4	Meat Quality of Broilers	57
4.5	Haematological Indices of Broilers Fed Fermented Palm Kernel Cake	60

4.6	Performance of Grower Pigs fed Experimental Diets	
4.7	Carcass Characteristics of Pigs	62
4.7.1	Effects of Treatment Diets on Carcass and Internal Organ Characteristics	62
4.7.2	Sex Effects on Carcass and Organ Characteristics of Pigs Fed Fermented Palm Kernel Cake	65
4.8	Meat Quality of Pigs	67

## **CHAPTER FIVE: CONCLUSION AND RECOMMENDATION**

5.1	Conclusion	69
5.2	Recommendations	69
5.3	Contribution to Knowledge	70
	References	71
	Appendix	87

## LIST OF TABLES

Table	Description	Page
2.1	Contributions of major livestock species to world meat production	8
2.2	The minimum requirements for protein, calcium and phosphorus in poultry feeds	12
2.3	Nutrient requirement of breeding stock	16
2.4	Nutrient requirement of growing stock	17
2.5	Proximate composition of palm kernel cake	24
2.6	Amino acid composition of palm kernel cake	25
2.7	Mineral composition of palm kernel cake	26
3.1	Ingredients and calculated chemical composition of the experimental diets	42
3.2	Ingredients and calculated chemical composition of the experimental diets	50
4.1	Proximate Composition of Fermented PKC	54
4.2	Growth performance of broilers (finisher phase) fed fermented palm kernel cake	56
4.3	Carcass characteristics and organ content of broiler (finisher phase) fed fermented palm kernel cake diets	58
4.4	Meat quality of fed fermented palm kernel cake diets	59
4.5	Haematological indices of broilers fed fermented palm kernel cake	61
4.6	Performance of experimental pigs fed fermented palm kernel cake diets	63
4.7	Effect of fermented PKC on carcass and organ characteristics of grower pigs	64
4.8	Effect of sex on carcass and organ characteristics of grower pigs	66
4.9	Meat quality and organoleptic assessment of grower pigs fed fermented Palm kernel cake	68

## ABSTRACT

Two experiments were carried out to evaluate the growth performance, carcass and meat quality of broilers and pigs fed diets containing fermented palm kernel cake (PKC). PKC weighing about 50kg was divided into 3 parts (Samples A, B and C). Sample A was kept in a plastic container to serve as control, B was weighed and mixed thoroughly with equivalent weight of water while sample C was mixed with equivalent weight of 2% sugar (sucrose) solution. The three samples were spread out on a mat under shade at room temperature. The following morning, sample A was transferred to its original container while samples B and C were packed and compressed into a polyethene bag and tied. Samples B and C were left to ferment for 6 days under room temperature. Each differently processed PKC was used to formulate one of three broiler finisher and pig grower diets at 30% and 40% levels of inclusion, respectively. Broiler feeding trial was from 5<sup>th</sup> - 8<sup>th</sup> weeks of age where as the pig grower trial was from 12<sup>th</sup> – 20<sup>th</sup> weeks of age. Feed intake, live weight gain, carcass traits, haematological profile and organoleptic quality were determined. Results from the two studies showed that fermentation significantly reduced crude fibre and ether extract content of PKC but did not lead to improvements in performance, carcass and meat quality characteristics of broiler finisher and pigs. However, percentage loin content was higher and connective tissue content in the meat lower in pigs fed 2% sugar fermented PKC diet compared to pigs fed unfermented PKC diet ( $p < 0.05$ ). Broilers fed 2% sugar fermented diets were higher in cooking loss and juiciness compared to counterparts fed unfermented PKC ( $p < 0.05$ ). There were no significant differences in haematological profile of broilers ( $p > 0.05$ ). In pigs, sex-related differences were observed in live weight, dressing percentage and percentages of ham, shoulder and belly contents ( $p < 0.05$ ). The similarity in feed intake and live weight gain across the three dietary treatments in broilers and pigs suggested that the fermentation technique adopted in this study significantly reduced crude fibre and ether extract but did not improve the nutritive value of PKC.

***Keywords: Broiler, pig, solid state fermentation, PKC, carcass characteristics, meat quality***

## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background Information

Animal products make an important contribution to nutrient supply in human diets which include energy, high quality protein and most of the important minerals and vitamins needed for the normal functioning of the body. These products have high biological values because of high contents of essential amino acids, minerals, vitamins and essential fatty acids. In addition they make up for the bland taste of starchy foods that form the bulk of human diets. In Nigeria, meat is a principal source of animal protein. A significant proportion of meat consumed in Nigeria comes from monogastric animals, namely poultry and pigs. The production of these animals also hold the higher potential for bridging the deficit in meat consumption not only in Nigeria but in most developing countries of the sub-Saharan region (Aladi, 2016). However, pig and poultry production has been known to face numerous challenges in Nigeria such as high cost of feed materials, diseases, poor technological knowhow, religious and cultural bias, increasing cost of veterinary care, ineffective storage facilities and unorganized market arrangements (Eko, 2009).

Prime among these constraints is the high cost of feed. Pigs and poultry depend largely on maize as the major source of energy (McDonald *et al.*, 2010). In Nigeria and most developing countries of the world, maize is an important staple food for humans. The resultant demand pressure has greatly increased the cost of maize as food for humans, feed for livestock and poultry and raw materials for some industries (Udedibie, 2002). The rise in price is majorly responsible for the high cost of pork and poultry meats. In order to sustain production at competitive prices, farmers have often resorted to inclusion of alternative feed ingredients as

substitutes for conventional feedstuffs (Okeudo *et al.*, 2005; Obun, 2013; Okah *et al.*, 2013; Okoli *et al.*, 2013). In addition, the seasonality of grain production in predominantly rain fed agrarian systems, and inadequate storage technology made their availability unreliable for livestock production. As a result, research attention has been focused on cheaper and readily available bio-materials to replace maize. These materials are generally referred to as non conventional feed resources (NCFR). Unfortunately, many of these non conventional feed resources replaced maize and other grains only on a marginal level (Udedibie *et al.*, 2004, Esonu *et al.*, 2005). The reasons have been conflicting due to variations in composition of the NCFR and other factors (Adebowale & Ademosun, 1985, Sonaiya, 1995; Ravindran, 1995; Chikwanha *et al.*, 2007). One of the commonest NCFRs used by poultry and pig farmers in Nigeria is palm kernel cake (PKC).

PKC has been reported to be a cost effective ingredient that can be utilized in ration formulation in livestock feeding (Zahan and Alimon, 2006., Adesehinwa, 2007; Okeudo *et al.*, 2005; Egenuka *et al.*, 2013). PKC does not serve as food for man or have any other industrial use at the present. It is easily available and can be obtained at a relatively cheap price. The global production of PKC is increasing as oil palm industries expand in many parts of Nigeria, Africa and Asia in recent years. More than four million metric tons of PKC was produced globally in the year 2002 (FAO, 2002) and most of them were utilized in to animal feeding (FAO, 2002). The use of this by-product in monogastric nutrition is however limited. The high fiber content of 13% and low metabolizable energy value (Ariff Omer *et al.*, 1998) have been identified as major limitations to its utilization in the feeding of non ruminants. It is reported to contain 30%  $\beta$ -mannan which is an anti-nutritional factor capable of causing depression in feed conversion efficiency and reduction in weight gain by 20% - 25% in poultry (Ariff Omer *et al.*, 1998). It is gritty and requires further processing such as grinding

or milling, addition of exogenous enzymes containing cellulases and mannanases (Sundu *et al.*, 2003) as well as solid state fermentation (Sukaryana, 2001).

Aladi *et al.* (2013) demonstrated that a blend of palm kernel cake with cassava root pulp in the ratio of 1:3 (w:w) would yield a product similar to maize in chemical composition. When the product was subjected to a solid state fermentation using *Aspergillus niger* or spontaneous inoculation, a product with superior physicochemical characteristics for poultry and pig feeding was derived. Other experiments have demonstrated that fungi such as *Rhizopus oligosporus* (Siregar *et al.*, 2003), *Aspergillus niger* (Iyayi *et al.*, 2001) and *Trichoderma viride* (Sukaryana, 2001) improved nutritive value of PKC under solid state fermentation. However the supply of strains of fungi with consistent quality and characteristics has remained a limiting factor to the transfer of these technologies to farmers (Aladi, 2016).

The isolation, purification and multiplication of fungi cultures require specialized techniques far out of reach of most farmers and farm environment. There is therefore need to evaluate spontaneous inoculation processes in which isolation and purification fungi species would not be necessary. Such fermentation will depend on the natural flora of farm and most importantly, the operations can be handled at low operational costs. Since PKC is low in moisture content (<9%) and fermentable sugars (<2%), moisture (water activity) and available fermentable sugars are critical factors to its successful solid state fermentation. To achieve adequate fermentation, moisture content of palm kernel cake needs to be increased to about 50% (Ramin *et al.*, 2005; Saw *et al.*, 2008) and supply of fermentable sugars would be required (Manpreet *et al.*, 2005)

## **1.2 Problem Statement**

The use of the common grain (maize) as feed for human, poultry and livestock has led to the high cost of animal products. The use of PKC as substitute is limited by its content of non starch polysaccharides (NSP) especially mannan. Solid state fermentation using fungi such as *A. niger*, *A. oryzae*, *T. resei* etc. has improved utilization of PKC. However supply and maintenance of pure cultures of these fungi strains have been difficult especially on farm situations. The development and implementation of spontaneous fermentation techniques is therefore a worthwhile alternative to be evaluated.

## **1.3 Objectives of the Study**

This research study was designed:

- To determine the growth performance, carcass characteristics and meat quality of broilers fed PKC fermented in water or sugar solution.
- To determine the growth performance , carcass characteristics and meat quality of pigs fed PKC fermented in water or sugar solution .
- To develop a package of findings that could be extended to practicing farmers in order to enhance animal productivity.

## **1.4 Justification of the Study**

The successful outcome of this work is expected to provide poultry and pig farmers with a viable technology that will improve the nutritive value of palm kernel cake. This would result to reduced cost of production and increased farmer's income. Consumers will benefit from cheaper and regular supply of their choice products (meat and eggs). It is expected to increase

demand for palm kernel cake at the expense of maize, leading to reduced cost of grains due to reduced pressure and stiff competition for the grain between man and livestock. A reasonable body of literature and data will be generated for further research.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1. Livestock Production in Global Industry

Livestock production systems occupy about 30 per cent of the planet's ice-free terrestrial surface area (Steinfeld *et al.*, 2006) and are a significant global asset with a value of at least \$1.4 trillion (Thornton, 2010). The livestock sector is increasingly organized in long market chains that employs at least 1.3 billion people globally and directly supports the livelihoods of 600 million poor smallholder farmers in the developing world (Thornton & Herrero, 2006). Keeping livestock is an important risk reduction strategy for vulnerable communities (Aladi, 2016; Randolph *et al.*, 2014; Thornton, 2010; Naess & Birdsén 2000) and also are important providers of nutrients and traction for growing crops in smallholder systems. Livestock products contribute 17% to calorie consumption and 33% to protein consumption globally, but with large differences between rich and poor countries (Rosegrant *et al.*, 2009). Currently, livestock is one of the fastest growing agricultural subsectors in developing countries. Its share of agricultural GDP is already 33% and is quickly increasing. This growth is driven by the rapidly increasing demand for livestock products, due to the accelerating increase in population growth, urbanization, education and increasing incomes in developing countries (Delgado, 2005). The global livestock sector is characterized by a dichotomy between developing and developed countries. Total meat production in the developing world tripled between 1980 and 2002, from 45 to 134 million tons (World Bank, 2009). Much of this growth was concentrated in countries that experienced rapid economic growth, particularly in East Asia, and revolved around poultry and pigs. On the other hand, in developed countries, production and consumption of livestock products is at high levels, and growth is slowing or stagnating. Furthermore, livestock production and merchandizing in

industrialized countries account for 53% of agricultural GDP (World Bank, 2009). This combination of growing demand in the developing world and stagnant demand in industrialized countries represents a major opportunity for livestock keepers in developing countries, where most demand is met by local production, and this is likely to continue well into the foreseeable future. Livestock systems have both positive and negative effects on natural resource base, public health, social equity and economic growth (World Bank, 2009). In recent years however, growing concern now exist over the impact of livestock production systems on the environment (Gerber *et al.*, 2013). Some of these concerns include air pollution (Cambra-Lopez *et al.*, 2010), biosafety (Martinez, 2009), green house gas emission (Webb *et al.*, 2005) and soil and underground water pollution (Malin *et al.*, 2003).

## **2.2 Contributions of Pigs and Poultry to World Meat Supply**

The contributions of the major livestock species to world meat supply is shown in Table 2.1 and indicates that while the contributions of the pig and poultry industries have been increasing in recent years, those of the ruminant species have been on the decline. At present, pork meat production represents the highest contribution to world meat supply. The table also shows that it increased from 90.14 million metric tons in 1999 to 110.27 metric tons in 2011. This represents an increase of 22.35 %. Within the same period, the contribution of poultry to world meat supply rose from 58.02 million metric tons to 102.25 million metric tons representing an increase of nearly 100 %. As at 2011, pig and poultry meat controlled over 70 % of meat consumption globally (FAOSTAT, 2014). However, global poultry production is expected to overtake pig meat in 2020 (Evans, 2014). According to the Food and Agriculture Organisation of the United Nations (FAO, 2014), poultry meat production will grow at around 2.3% per year to around 134.5 million tonnes over the next 10 years to 2023 making it the largest meat sector from 2020 onwards (FAO, 2014).

Table 2.1 Contributions of the major livestock and poultry species to world meat production  
(million metric tons)

	1999-2001	2003-2005	2007	2008	2009	2010	2011
Cattle	55.82	58.14	61.87	61.67	61.84	67.78	66.33
Sheep and Goats	11.33	12.13	13.14	13.12	13.05	13.46	13.41
Pigs	90.14	97.11	100.17	103.98	106.07	109.37	110.27
Poultry	58.02	67.00	75.08	78.16	79.60	99.05	102.25
Total	215.30	234.38	250.24	256.93	260.55	289.66	292.26
<b>Percentages</b>							
Cattle	25.93	24.81	24.72	24.00	23.73	23.40	22.70
Sheep and Goats	5.26	5.18	5.25	5.11	5.01	4.65	4.59
Pigs	41.86	41.43	40.03	40.47	40.71	37.75	37.73
Poultry	26.95	28.58	30.00	30.42	30.55	34.20	34.98

Source: FAO (2014)

Several reasons have been postulated for this trend. Ruminant animals require large expanse of land for grazing and are rarely raised completely indoors unlike pigs and poultry. Pigs are physiologically well adapted for meat production. They grow and mature rapidly, have short gestation period of about 114 days and produce large litters. They are omnivorous and can subsist on wide varieties of feeding regimens. Pigs efficiently convert cereals, legumes, tubers, sugar beets and a variety of industrial by-products such as molasses, brewers spent grains, cereals offal etc into high quality meat (Aladi, 2016). The products have excellent organoleptic quality and can be processed into a variety of products (Ikeme, 1990). According to Okoli *et al.* (2012), poultry production is attractive because birds are able to adapt easily with rapid generation time and high rate of productivity. Although pig meat makes the highest contribution to world meat production, it suffers the highest prejudice globally. Pork and pork products are not consumed by Muslims, Jews and some Christian fundamentalist groups (Aladi, 2016). The animal is regarded as dirty by many cultures and tribes. Pork is very high in energy because of high fat levels and this makes it to suffer discrimination by health dieticians who link meat consumption to the development of atherosclerosis and related problems (Aladi, 2016; Hu *et al.*, 1999). In most production systems, broiler diets are corn-soy based, where most of the carbohydrates and hence energy comes from corn while soybean is the principal source of proteins (McDonald *et al.*, 2010). Fish meals and/or blood meals provide supplemental protein (amino acids). Commercially available synthetic methionine and lysine are included as supplements (Chiba, 2009) since these essential amino acids are likely to be limiting in corn-soy based diets (McDonald *et al.*, 2010). Supplesmental micronutrients are provided via commercial premixed preparations known as mineral and vitamin premixes. To enhance performance and health of birds, feed additives such antibiotics (Dibner *et al.*, 2005; Yang *et al.*, 2007; Kocher, 2006) and emulsifiers (McDonald *et al.*, 2010) may also be included. In recent times however,

increasing concerns for the environment (Saitoh, 2001; Carter *et al.*, 2013; Liu *et al.*, 2005; Bolan *et al.*, 2005) and the need to minimize cost of production has led to formulation of diets with increasingly lower contents of protein and minerals (NRC, 1994). Emphasis is now laid on digestibility and utilization rather than content or nutrient levels in the diets of poultry. This has led to development and use of enzymes and feed treatment options which could enhance nutrient digestibility and uptake by poultry and hence reduce excretion and pollution of environment. Some of these enzymes include pectinases (Igbasan *et al.*, 1997; Cowieson *et al.*, 2006), hemicellulases (Saleh *et al.*, 2005; Tahir *et al.*, 2005), xylases (Choct *et al.*, 2004), xylases (Choct *et al.*, 2004), mannanases (Wu *et al.*, 2005; Jackson *et al.*, 2004; Daskiran *et al.*, 2004), proteases (Angel *et al.*, 2011; Ghazi *et al.*, 2002; de Barros Soares *et al.*, 2000) and phytases (Acousta & Cardenas, 2006). In developing countries such as Nigeria, scarcity of maize and soybean for poultry feeding due to their increasing demands as human food and raw materials for several industries led to increased use of non conventional feed and often less digestible materials at high levels (Aladi, 2016). Some of these by-products include maize offals, brewers dried grains, palm kernel cake, cassava processing by-products (baggase) etc. These have all resulted to lower performance and are likely to lead to increased nutrient excretion and environment.

Nevertheless, the per caput consumption of beef in Nigeria is 10 g against 40 g global mean, sheep and goat meat is 10 g against 11 g global mean while pork and poultry stand at 12 g and 4 g against the global means of 117 g and 48 g, respectively (FAOSTAT, 2012). This large difference in consumption of poultry and pig meats underscore the potentials of these livestock sectors and that they are largely underdeveloped and unexploited in this region. The problems of these livestock sectors have been reported to include but not limited to inadequate supply of inputs such as feeds and weaner crops, poor management due to lack of

expertise, low level technology leading to the production of pork of unpredictable quality and hence consumer resistance, poor investment climate tending to put pig production at a disadvantage in the competition for capital, poor marketing arrangement and adverse socio-cultural factors inhibiting the sale of poultry and pig products (FMANR, 1978). Among these challenges provision of adequate feed has been reported as the most limiting as it usually account for over 70 % of cost of production (Udedibie *et al.*, 2002, 2004; Esonu *et al.*, 2001; Uchegbu *et al.*, 2005).

### **2.3 Feeds and Feeding in Poultry Production.**

Poultry refers to any of the domesticated and commercialized types of birds used for production of eggs and/or human food (Chiba, 2009). They include chickens, turkeys, pigeons, peafowl, duck, geese, quail, pheasants, partridges and ratites (ostriches and emu). For most of these species, nutrient requirement guides have been published by the National Research Council (NRC, 1994). Requirements vary because of differences in type of poultry, age of birds, purpose, environment and management conditions (NRC, 1994). In tropical environments, it has become conventional to feed higher crude protein and lower metabolizable energy rations compared to those found in these international reference guides. According to Larbier & Leclereq (1992), it has become impracticable to set energy requirements in terms of unit/ kg diet because birds adjust their feed intake to achieve daily energy intake. Proper protein and energy balance is essentially to ensure birds consume adequate amount of protein. Poultry feeds are referred to as complete feeds, because they are designed to contain all the protein, energy, vitamins, minerals, and other nutrients necessary for proper growth, egg production and health of the birds. Broiler chicks are fed starter diet soon after

**Table 2.2: The Minimum Requirements for Protein, Calcium, and Phosphorus  
in Poultry Feeds**

	<b>Minimum Requirement</b>		
	<b>Protein (%)</b>	<b>Calcium (%)</b>	<b>Phosphorus (%)</b>
<b>Broiler</b>			
Starter (0-6 weeks)	23	0.9	0.5
Finisher (6weeks –market)	10	0.8	0.5
<b>Pullets</b>			
Starter (0-8 weeks)	20	0.9	0.5
Developer (8- 20weeks)	8-14	0.8	0.5
<b>Laying Hens</b>			
Layers	16	3.0	0.5

Source: National Bank for Agriculture and Rural Development (1993)

hatching till 3-4 weeks of age. The starter diet has the highest level of protein a chicken receives during its lifetime. As the chick matures, it requires a lower percentage of dietary protein and a higher level of energy. After the chicks reach 4<sup>th</sup> week of age, a finisher diet is fed till slaughter weight is attained at about 6-8 weeks of age. However, NRC (1994) recommended a three phase feeding program for broilers: 0-3 weeks (starter feed), 4-5 weeks (grower feed), and 6-8 weeks (finisher feed). Pullets and cockerels are fed a developer diet until they are at least 18 weeks of age. When egg production starts, a layer ration is given until egg production ends. The minimum requirements for protein, calcium, and phosphorus in poultry feeds are shown in Table 2.2. In most production systems, broiler diets are corn-soy based, where most of the carbohydrates and hence energy comes from corn while soybean is the principal source of proteins (McDonald *et al.*, 2010). Fish meals and/or blood meals provide supplemental protein (amino acids). Commercially available synthetic methionine and lysine are included as supplements (Chiba, 2009) since these essential amino acids are likely to be limiting in corn-soy based diets (McDonald *et al.*, 2010). Supplemental micronutrients are provided via commercial premixed preparations known as mineral and vitamin premixes. To enhance performance and health of birds, feed additives such antibiotics (Dibner *et al.*, 2005; Yang *et al.*, 2007; Kocher, 2006) and emulsifiers (McDonald *et al.*, 2010) may also be included. In recent times however, increasing concerns for the environment (Saitoh, 2001; Carter *et al.*, 2013; Liu *et al.*, 2005; Bolan *et al.*, 2005) and the need to minimize cost of production has led to formulation of diets with increasingly lower contents of protein and minerals

(NRC, 1994). Emphasis is now laid on digestibility and utilization rather than content or nutrient levels in the diets of poultry. This has led to development and use of enzymes and feed treatment options which could enhance nutrient digestibility and uptake by poultry and hence reduce excretion and pollution of environment. Some of these enzymes include pectinases (Igbasan *et al.*, 1997; Cowieson *et al.*, 2006).

#### **2.4 Feeds and Feeding in Pig Production.**

Pigs are monogastric animals and so require concentrates for optimal growth and productivity (McDonald *et al.*, 2010). However, pig can utilize fibrous food only to a limited extent and adult pigs are more efficient than younger ones (Noblet *et al.*, 2001; Montagne *et al.*, 2003). The nutrient requirements of pigs have been published by several regulatory agencies and vary due to breed, age, physiological condition and environment (NRC, 1999). In pig diet formulation, similar feed materials as those used in poultry diets are used. According to Choct *et al.* (2000) and Jorgensen *et al.* (1996), pigs can utilize fibrous feeds better than poultry and this ability increases with age. Though the NRC requirements stipulate higher metabolizable energy levels for pigs over poultry (NRC, 1998,1999), it has become conventional to formulate diets of lower metabolizable energy for pigs using more readily available agro industrial by-product (Amata, 2010). Many researchers have reported comparable results to those fed control diets but their effects on nutrient excretion are not widely reported. The reason for this paucity of information is that in most of these cases, the primary concern of researchers is food production and availability. Common diets for pigs include weaners, growing and finishing rations for meat production stock while gilts, boars, gestating ad lactating rations are formulated for breeding stocks. The recommended nutrient

levels are shown in Tables 2.3 and 2.4. NRC (1998) however recommended that these levels should be adjusted to the live weight of pigs.

The nutrient need of the developing embryo and the need to conserve nutrients for ensuing lactation during the later stage of pregnancy placed the pregnant sow under a nutritional pressure (NRC, 1998). The increased needs are mainly for proteins, vitamins and minerals (Bracke *et al.*, 2002, Noblet *et al.*, 1990). Mature sows gain 30-35 kg and gilts 40-45 kg during pregnancy (Kranendonk *et al.*, 2007). It is however necessary to regulate feed intake in pregnant pigs so that sows and gilts are never over fat or thin (Noblet *et al.*, 1997; Burrin *et al.*, 2000).

## **2.5 Non-conventional Feed Resources (NCFR) in Poultry and Pig Production**

A huge gap exists between the demand and supply of conventional feed resources for feeding livestock in developing countries. In order to solve this problem, it is essential to increase the availability of conventional feed resources as well as exploit the use of non-conventional feed resources (NCFR) in livestock production systems (Salem *et al.*, 2004). Non-conventional feed resources (NCFR) generally refer to all those feeds that have not been traditionally used for feeding livestock and are not commercially used in the production of livestock feeds. Potentially available NCFR include crop residues, agro-industrial by-products and leaf and seed meals. Examples include leaves and seeds of the African pear (*Dacryodes edulis*), *Gliricidia sepium* leaf meal, the seeds and leaves of *Gmelina arborea*, the leaves of *Myrianthus arboreus*, browse foliage, slaughter house by-products, cassava leaf meal, tapioca waste, tea waste, mango seed kernels and animal organic wastes.

**Table 2.3 Nutrients requirement of breeding pigs**

Type/Breed	Gilts	Lactating Gilts & Sows	Young Boars & Adult Boars
Live Weight (kg)	110-250	140-250	110-250
Energy and protein			
DE (M cal/kg)	3.3	3.3	3.3
ME (M cal/kg)	3.17	3.17	3.17
Crude Protein (%)	14	15	14
Inorganic nutrients (%)			
Calcium	0.75	0.75	0.75
Phosphorus	0.5	0.5	0.5
Salt	0.5	0.5	0.5

Source: National Bank for Agriculture and Rural Development (1993)

**Table 2.4 Nutrient requirement of growing pigs**

Type	Weaning	Growing	Finishing
Live Weight (kg)	5-12	12-50	50-100
Daily Gain (kg)	0.3	0.5	0.6
Energy and Protein			
DE ( M cal/kg)	3.5	3.5	3.3
ME (M cal/kg)	3.36	3.36	3.17
Crude Protein (%)	22	18	14
Inorganic nutrients (%)			
Calcium	0.8	0.65	0.5
Phosphorus	0.6	0.5	0.4
Sodium	-	0.1	-
Chlorine	-	0.13	-

Source: National Bank for Agriculture and Rural Development (1993)



Most of these feed materials are low in energy, protein, minerals and contain high levels of anti-nutritional substances (Salem *et al.*, 2004).

The major constraints to the use of NCFR are collection, storage, high moisture content and need for detoxification. There is an urgent need for processing techniques that are economic and practicable. The availability of NCFR, especially of plant origin, is dependent to a large extent on the type of crop being cultivated and the prevailing degree of deployment of crop applicable technology (Younas and Yaqoob, 2005).

### **2.5.1 Characteristics of Non Conventional Feed Resource**

According to FAO (1985), non-conventional feed resources are usually organic by-products of production and processing which have not been recycled or salvaged. They are usually obtained either in solid, slurry or liquid form and their economic values are usually less than the cost of collection and transformation before use. Utilization in poultry and pig feeding is further limited by their bulkiness, high crude fibre content and low nitrogen content (Amata, 2010). Nutrient composition vary considerably and some NCFRs contain anti-nutritional components which have deleterious effects on animals. Presently, information about the nature of the activity of these components and means of detoxification is insufficient. However, bioprocessing techniques such as fermentation and pretreatment with live enzymes can convert these wastes into materials of potential value in livestock feed industry (Aladi, 2016).

Many NCFRs are utilized in feeding poultry and pigs especially where they are produced close to livestock farms. According to Amata (2010) nutritional value can be increased if there were economically viable technological means for converting them into some useable

products. To do this, a substantial information is required on chemical composition, nutritive value, the presence of anti-nutritional components and value in feeding systems (Soetan *et al.*, 2009, Aganga *et al.*, 2003).

The generation of non-conventional feed resources is essentially from agriculture and various agro-based industries and is a function of many factors. Such factors include the quantity and quality of the materials produced. These are in turn dependent on the prevailing agro-climatic conditions and cropping patterns, the type of raw materials, the production process, the production rate, the type of inputs used, the regulations affecting product quality and the constraints imposed upon effluent discharge (Devendra, 1985).

### **2.5.2 Techniques for Improving the Utilization of Non-conventional Feed Resources**

Different techniques have been investigated in Asia to improve the nutritive value of NCFR such as ammonia treatment of cereal straws (Schiere & Nell, 1993; Wannapat *et al.*, 2009; Joy *et al.*, 1992), mixing of several agro-industrial-by products (Uchegbu, *et al.*, 2005; Anyaegbu *et al.*, 2012), supplementation with deficient nutrients (Adesehinwa, 2009) inclusion enzymes (Cowieson *et al.*, 2006; Iyayi & Davies, 2005), ensiling (Hadjipanayiotiou, 1999), feed block technology (Ben Salem and Nefzoui, 2003). Adequate supply of nutrients is a major limiting factor in the use of NCFR (Neggesse *et al.*, 2009, Ayssiwede *et al.*, 2011) and hence, it is believed that supplementation with deficient nutrients will optimize their use as livestock feed material. Supplementation with grains and concentrates increase energy value (Adesehinwa, 2007) but paucity of reliable data on the

nutritive composition of the NCFR is a limiting factor to supplementation (Neggesse *et al.*, 2009, Ayssiwede *et al.*, 2011).

An alternative to the use of supplementation is to treat the NCFR with chemicals to improve their quality (Kumar *et al.*, 2008). Chemicals such as ammonia gas generated from urea under anaerobic conditions renders fibre more fragile and disrupt the bonds between lignin and other digestible components in fibrous feedstuff such as straws (Sreekrishnan *et al.*, 2004). Ammonia treatment increased crude protein content, feed intake and digestibility of treated straws thereby improving livestock productivity (Wanapat *et al.*, 2009; Schiere & Nell, 1993; Joy *et al.*, 1992). However, this requires additional labour and materials and these affect the flexibility of operation. The high cost of urea and to a lesser extent the plastic sheet cover are main factors limiting adoption by farmers (Amata, 2014). Studies have shown that mud could be used to cover urea-treated straw instead of plastic sheets (Salem *et al.* 1995).

Ensiling can be used to extend the storage period of NCFR such as tomato pulp, citrus pulp, olive cake etc (Salem *et al.*, 2008). This is particularly effective in recycling of protein and energy rich but moist farm or food wastes such as tomato and citrus pulp (Hadjipanayiotiou, 1999). These by-products if not ensiled become rancid and moldy. These by-products can be ensiled separately or combined with other by-products such as molasses or wheat bran. Hadjipanayiotiou (1999) observed that olive cake preserved well as silage, judging from its aroma, colour, pH and the absence of molds. Replacing parts of barley hay and straw with olive cake silage in the diets of lactating ewes, goats and cows did not have negative effects on milk yield and fat corrected milk yield (Hadjipanayiotiou, 1999). Incorporation of citrus pulp and wheat straw silage in lamb diets to replace oat hay and 30 commercial concentrates

revealed similarities in live weight and carcass weights among the treatment groups and lambs on silage produced carcasses with better muscular conformation and lower fatness score (Scerra *et al.*, 2000).

Agro-industrial by-products especially those with high moisture content can be efficiently used through feed block technology (Salem and Nefzoui, 2003). These blocks are solidified mixtures of agro-industrial by-products (such as olive cake, tomato pulp and molasses) urea, binders (such as cement and/or quicklime), minerals and vitamins. This technology has been reported to provide flexibility to extension workers and farmers to choose ingredients to be included in the feed block and its use as supplements in drought and other harsh conditions (Salem & Nefzoui, 2003). In addition, the blocks can be prepared when the cost of the ingredients' cost is low and stored for later use. Some blocks containing catalytic supplements are able to enhance digestion of low quality fibrous feedstuff through balanced, synchronized and fractional supply of main nutrients to the animal on poor diets (Salem *et al.*, 2008). Feed blocks may also be used as vehicles for several minerals such as copper and zinc and so improve reproduction performance of small ruminants (Al-Haboby *et al.*, 1999) and as carriers of several reagents mainly polyethylene glycol (PEG) used to deactivate tannins in fodder shrubs and trees (Salem *et al.*, 2000; Salem *et al.*, 2002). Feed blocks may also be used to provide antihelminthic medicines to control gastrointestinal parasites in browsing animals (Anindo *et al.*, 1998) and rumen modifiers such as saponins to decrease protozoa population in the rumen leading to higher efficiency of microbial protein production (Salem & Znaidi, 2008; Makkar, 2007).

## **2.6 Palm Kernel Cake**

### **2.6.1 Source and Distribution**

The African oil palm is one of the important economic crops in the tropics (Anyanwu *et al.*, 1982) and is believed to have originated from the tropical rainforest of West and Central Africa (Hartley, 1988) where it grows wild in secondary forests (Akinyosoye, 1976; Ugochukwu *et al.*, 1999). In Nigeria, oil palm cultivation is embedded in the culture of millions of people with the most extensive oil palm plantation in Africa of at least 350,000 hectares (Carrere, 2001). Nevertheless, 80% of production comes from dispersed small holders who use manual processing techniques. Oil palm is a major prospect as regards economic development due to the fact that every part of the tree is profitable (RMRDC, 2004). The leading world producers are Malaysia and Indonesia – whose production is based on large scale monoculture (Carrere, 2001).

The Oil palm tree produces fruits which are characterized by a fibrous and oil-rich mesocarp and a white opaque endocarp embedded in a brown casing which is referred to as the kernel. The oil palm produces two major commercial products, namely the palm oil and palm kernel oil which comprise 22 % and 4-6 % of the fresh fruit bunch respectively. The palm kernel oil and palm kernel cake are products from the processing of the nuts (Sundu *et al.*, 2006). Palm kernel cake (PKC) is the residue obtained after the extraction of palm kernel oil from the seeds of oil palm tree. Depending on the process of oil extraction, palm kernel cake or meal is obtained. Palm kernel cake is the product of mechanical expeller method while palm kernel meal result from solvent extraction (Chin, 2002; Okeudo *et al.*, 2005). Palm kernel cake is known to contain about four times as much residual oil as the meal (Chin, 2002). The global production of palm kernel cake continues to increase due to the tremendous growth of the oil

palm industry in many parts of Asia and Africa (Porla, 2000). Currently, Malaysia is the highest producer of palm kernel cake, most of which are exported to EU countries where they are used mainly as livestock feed (Saw *et al.*, 2008).

### **2.6.2 Nutritive Value of Palm Kernel Cake**

The nutrient composition of palm kernel cake is shown in Table 2.5. Palm kernel cake has been reported to serve as both energy and medium protein feed, but the proximate composition of palm kernel cake suggested that it be classified as an energy source. The mechanical and solvent extracted palm kernel cakes are of different quality depending on the extent and efficiency of oil extraction (Sundu *et al.*, 2006). The mechanically extracted palm kernel cake has higher level of oil than the solvent extracted palm kernel cakes. O'mara *et al.*, (1999) reported that mechanically extracted palm kernel cake has 5–12 % oil content whereas the solvent extracted has 0.5 - 3% oil content. Thus, the percentage of other nutrients such as crude protein and minerals are lower in expeller pressed palm kernel cake. Palm kernel cake has crude protein of 14-21 % and so is precluded as a protein source in most cases because the crude protein level is less than 20%. However, the crude protein content is enough to meet the requirement of most ruminants despite some negative attributes (Hair-Bejo & Alimon, 1995; Hassan & Yeong, 1999).

Ramachandran *et al.* (2007) reported that PKC has a good nutrient content with high quality amino acids, a total crude fibre content of 37 % and an average residual oil content of 10 %. However, reports by Yeong *et al.* (1983) and Hutagalung *et al.* (1982) suggested that the

amino acid composition of palm kernel cake is not very good. The amino acid composition of palm kernel cake is shown in Table 2.6 while the mineral composition is shown in Table 2.7.

**Table 2.5: Proximate composition of palm kernel cake (%)**

	O'mara <i>et al.</i> (1999)		Sundu <i>et al.</i> , (2005)
	Expeller	Solvent	
Protein	16.4	1.97	140 – 210
Ether extract	0.783	0.095	80 – 170
Crude fibre	2.38	2.68	210 – 230
Ash	0.495	0.488	30 – 60
Dry matter	-	-	940
Gross energy	-	-	4998

**Table 2.6: Amino acid composition of palm kernel cake (%)**

	Yeong <i>et al.</i> (1983)	Hutagalung <i>et al.</i> (1982)
Phenylalanine	0.73	0.74
Lysine	0.59	0.61
Histidine	0.29	0.34
Tyrosine	0.38	0.47
Glycine	0.82	0.84
Valine	0.93	0.80
Leucine	1.11	1.14
Isoleucine	0.62	0.61
Threonine	0.55	0.60
Serine	0.69	0.77
Methionine	0.30	0.34
Arginine	2.18	2.40
Crystine	0.20	-
Tryptophan	0.17	0.19



**Table 2.7: Mineral composition of palm kernel cake**

<b>Mineral</b>	<b>Percentage (%)</b>
Calcium	3.6
Phosphorus	8.0
Manganese	135mg
Magnesium	4.4
Sodium	-
Chlorine	-
Iron	356mg
Zinc	41mg
Copper	27mg
Potassium	0.4

Source: Adapted from Nwokolo *et al.* (1976).

Nwokolo *et al.* (1976) indicated that the availabilities of essential amino acids are in excess of 85 % except for valine which is only 68.4 %. Palm kernel cake has been reported to have 21-23 % crude fibre content which makes it resistant to monogastric enzymes (Sundu and Dingle, 2003). Analyses have also shown that about 49% of the dry matter in PKC is in the form of nitrogen free extractives (Sundu *et al.*, 2006). Palm kernel cake may also undergo Maillard reaction (the reaction of mannose with amino groups) leading to the formation of a brown complex due to heat application in the process leading to oil extraction (Sundu *et al.*, 2006). This would adversely affect digestibility of the feedstuff. The fibre content of palm kernel cake may not make it a first choice feedstuff for monogastric animals but ruminants are able to utilize the inherent nutrients considerably through degradation during rumen fermentation. Palm kernel cake has largely been used in sub-Saharan Africa in feeding cattle especially dairy animals where it can serve as the main protein source (Bedingar & Deyefa, 1990).

Jelan *et al.* (1986) reported that cattle fed PKC combined with small quantities of feed additives (e.g vitamins and minerals) produced approximate daily growth rates of 0.7- 1.0 kg/animal. PKC is useful in fattening cattle either as a single feed, with only mineral and vitamins supplementation or mixed with other feedstuffs. It has become the main ingredient in dairy cattle ration in Malaysia (Chin, 2002). In Nigeria, the use of palm kernel cake in feeding animals was developed since the 1940s (Onwudike, 1986a; Umunna,1980). According to FAO (2012), PKC has become a major feed ingredient in monogastric animal feeding and has a lot of potentials to aid sustainable livestock development.

Early studies with pigs (Oyenuga, 1968 and Babatunde *et al.*, 1975) did not highly recommend the use of PKC in non-ruminant (monogastric) feeding, it has been reported that with proper balancing of dietary ingredients, monogastric animals could tolerate high levels of PKC (Fetuga *et al.*, 1977; Yeong *et al.*, 1981). Nwokolo *et al.* (1977) indicated that up to 30% level of PKM could be incorporated into broiler starter ration without any adverse effects on growth rate, while Yeong *et al.* (1981) recommended 15% level of inclusion in broiler starter ration. Starter and grower pullets can be fed PKC diets at 34% and 38% inclusion levels respectively without any significant reduction in growth performance (Onwudike, 1986b). Prominent among its limitations in monogastric animal feeding is the high fibre content (13 %) and low metabolizable energy value for poultry (Ariff Omer *et al.*, 1998). Its non starch polysaccharide (NSP) fraction is reported to contain 30 % mannan which is a powerful anti-nutritive factor capable of depressing feed conversion efficiency and reduce weight gains by 20-25 % in poultry (Daud & Jarvis, 1992; Daud *et al.*, 1997; Hagglund, 2002). The value of PKC as feed is further reduced by the high shell content that accompanies local processing.

### **2.6.3 Performance of Broilers Fed Diets Containing PKC**

Onwudike (1986b) reported that PKC can be fed to starter and finisher broiler chicks at the 28 % and 35 % inclusion levels without any deleterious effect on production. Most authors seem to agree that optimal inclusion of PKC in broilers diets is 30 % especially among the finishers. Okeudo *et al.* (2005, 2006) reported that broilers fed a 30 % PKC diet during the finisher phase were similar in growth rate to counterparts fed a 0 % PKC diet. Panigrahi and Powell (1991) had shown that with methionine and lysine supplementation, broilers can be fed diets containing 40% PKC. Interestingly, studies have also shown that inclusion of PKC

in poultry diets improves the health and immunity of the birds (Allen *et al.*, 1997; Sundu *et al.*, 2006). However, the mechanism for this health promotion effect has not been clarified.

Shakila *et al.* (2012) found that enzyme supplementation of diets containing palm kernel cake did not improve efficiency of utilization at finisher phase but was effective at the starter phase. The inclusion of palm kernel up to 30 % with or without enzyme supplementation did not influence the carcass traits, total serum protein and serum alkaline phosphatase. According to Bello *et al.* (2011), feed intake and daily weight gain increased with increase in PKC inclusion up to 30% while the FCR were similar to the control. Similarly, the feed cost/kg weight gain was slightly better on the palm kernel meal (PKM) and no significant treatment effect on all the carcass and haematological parameters. These findings show that PKM can be included at 30% level in the diet of broilers without a negative effect on performance, carcass yield and blood constituents.

George and Ugwuja (2011) investigated the effects of replacing soybean meal with palm kernel cake and found that PKC can partially replace up to 30 % of soybean meal in the diets of broilers without adversely affecting growth performance and feed utilization. Anaeto *et al.* (2009) reported that 20 % inclusion of PKC in broilers diets decreased cost of production but did not have any significant effect on the internal organ weights except for the gizzard. The gizzard weight among birds that received diets containing 20% PKC was heavier ( $p < 0.05$ ) than other treatments. According to Kperegbeiyi and Ikperite (2011), due to the high cost of maize, PKC could be used to replace at least 50 % of the required amount of maize in broiler starter diets without compromising returns on investment. Okeudo *et al.* (2005) reported that 30 % inclusion level of PKC in broiler diet did not affect dressing percentage and carcass

weight but gizzard size increased. The authors also reported that meat tenderness and juiciness were not affected by dietary treatment but flavour and hedonic rating scores were higher in broilers fed diets containing PKC compared to counterparts fed 0 % PKC diets.

#### **2.6.4 Effect of PKC Diets on Performance and Carcass Characteristics of Pigs.**

Palm kernel cake has been found to reduce the cost of swine diets. Okai & Opoku-Mensah (1988) reported that feeding diets containing PKC at 0%, 10% and 20 % inclusion levels did not affect performance. However, back fat thickness decreased with higher inclusion level of the palm kernel cake. There was a decrease in the cost of feed with increasing levels of dietary palm kernel cake. Oluwafemi *et al.* (2012) reported that experimental diets containing up to 60% PKC with or without enzyme supplementation had no negative effect on the overall performance of finisher pigs. In a 42 days trial, Adesehinwa (2007) demonstrated that replacement of maize at 50 % and 100 % levels did not affect the average daily feed intake, daily weight gain and efficiencies of feed and protein utilization of pigs. The cost of feed consumed/day and the feed cost/kg live weight gain of the pigs decreased ( $P < 0.05$ ) with increasing levels of PKC in the diets while apparent digestibility of the nutrients contained in the diets and serum metabolites of the pigs were not affected.

Rhule (1996) evaluated performance and carcass characteristics of pigs fed with diets containing PKC at 0, 200, 300 and 400 g kg<sup>-1</sup> inclusion levels. The average daily gains (ADG) in live weight by the pigs during the grower phase were 0.47, 0.46, 0.39 and 0.40 kg on the 0, 200, 300 and 400 g kg<sup>-1</sup> PKC diets, respectively. These were significantly ( $P < 0.05$ ) different. The corresponding ADGs during the finisher phase were 0.45, 0.45, 0.46 and 0.42

kg. The differences were not statistically different. Feed conversion ratios were 3.84, 3.85, 4.32 and 4.50 kg feed kg<sup>-1</sup> weight gain on the 0, 200, 300 and 400 g kg<sup>-1</sup> PKC diets (grower phase) and 6.71, 6.21, 6.11 and 6.62 kg feed kg<sup>-1</sup> weight gain (finisher phase). Dressing percentage was significantly ( $P < 0.05$ ) reduced from 69.5 to 67.1 with increasing level of PKC in the diet while the back fat thickness was not affected by PKC inclusion. However, rib eye area was significantly ( $P < 0.05$ ) reduced from 43.3 cm<sup>2</sup> to 33.9 cm<sup>2</sup>. Shoulders & Stein (2008) found that among weanling pigs, body weight at day 10 showed a linear decrease ( $P < 0.05$ ) as the concentration of palm kernel meal in the diet was increased. However, by day 21, no significant difference in body weight was observed among pigs fed the same experimental diets. Daily weight gain and feed conversion ratio during the first ten days also showed a linear decrease ( $P < 0.05$ ) as the concentration of palm kernel meal in the diet was increased, whereas average daily gain and gain:feed from days 11 to 21 and from days 0 to 21 were not affected by increasing palm kernel meal level of inclusion. Average daily feed intake was not affected by the amount of palm kernel meal in the diet at either of the stages. This suggests that there were no palatability problems with the diets containing palm kernel meal rather lower concentration of metabolizable energy in palm kernel meal than in corn and soybean meal was responsible for reduced performance at earlier stage (Shoulders & Stein, 2008).

## **2.7 Improving nutritive value of PKC**

The anti-nutritional effect of the non starch polysaccharides (NSP) found in PKC is manifested by poor growth owing to reduced nutrient utilization (Annison & Choct, 1991). Incorporation of PKC in livestock and poultry diets is also limited by its gritty nature, unpalatability, relatively low availability of amino acids and high copper content (Onwudike, 1986; Hair-Bejo & Alimon 1995). These adverse effects can be overcome by dietary

supplementation of exogenous enzymes (Bedford 1995). In practical poultry feeding, the choice of appropriate enzymes for a particular diet is very important; but it is not definitely known which enzyme will be best for PKC based diets (Choct, 2001). The ability of exogenous enzymes to break down fibre in feedstuffs and improve the nutritive value has been reported by Ofuya & Nwajiuba (1990), Chen *et al.* (2000) and Iyayi & Davies (2005). Sundu & Dingle (2003) reported that there are basically three enzymes that are needed to improve the nutritive value of palm kernel meal, namely mannanase, cellulase, and  $\alpha$  galactosidase to digest the mannan, cellulose and the galactosidic side chains of the palm kernel cake, respectively. Enzyme supplementation of PKC to improve the utilization of nutrients in PKC by monogastric animals has been evaluated by many researchers (Oluwafemi, 2015). According to David *et al.* (1997), the degradation of  $\beta$ -mannan in PKC by an appropriate enzyme to mannose will release the sugar and other digestible sugars that can be absorbed and metabolized by monogastric animals. Bedford (1997) reported that addition of enzymes to the diets of chicks up to 42 days reduced the viscosity of the digesta with a resultant improvement in the feed conversion efficiency and fat digestibility in birds.

Use of feed additives (Lawal *et al.*, 2010) and /or modification of flora by incorporation of mannanase producing microbes (Ouhida *et al.* 2002) have been employed to make nutrients in PKC more available to monogastric animals. These have yielded marginal results due to factors intrinsic to the metabolism of farm animals (Ouhida *et al.*, 2002).

Solid state fermentation (SSF) has been recommended as a viable alternative to use of exogenous enzymes in diets of farm animals (Iluyemi *et al.*, 2006; Iyayi *et al.*, 2010; Mohd *et al.*, 2013). SSF is generally defined as the growth of microorganism on moist solid material in absence or near absence of free water (Pandey *et al.*, 2001). In SSF water may be added

but this must not exceed the saturation of the solid substrate without allowing the separation of the liquid from the solid phase (Raimbault, 1998). Solid state fermentation has become a method of preference for this purpose as it simulates the natural environment of most microorganisms, especially fungi (Iluyemi *et al.*, 2006). SSF is done on PKC to convert the  $\beta$ -mannan into mannose and also to increase the protein content and its nutritive value in general. According to Hagglund *et al.* (2003), mannase degradation improves the quality of animal feed. The peculiar advantage SSF over enzyme supplementation is that the system produces endogenous multi enzyme complexes which simultaneously or synergistically degrade the substrate (Lio & Wang, 2012; Yang *et al.*, 2012 ; Hagglund *et al.* 2001; Ademark *et al.*, 1999).

Iyayi *et al.* (2010) reported that PKC was used as a substrate for production of polysaccharidases from *Aspergillus niger*, *Trichoderma viride*, *Rhizopus stolonier* and *Mucor mucedo*. The extracted enzymes produced were purified and used to ferment PKC in solid state at the rate of 250ml/kg of the material for 7 days. Unbiodegraded and enzyme degraded PKC were used to formulate broiler starter and finisher diets at the rates of 70g/kg and 100g/kg respectively. Roxazyme® G2G, a commercial enzyme specific for cereal-based diets was used to supplement the unbiodegraded PKC at the recommended inclusion level of 0.15/kg. Results of the study showed that PKC can act as a substrate for the production of multienzyme complex from the 4 fungi. The enzyme complexes so produced were more efficacious in breaking down cellulose and hemicellulose compared to Roxazyme® G2G. Mohd *et al.* (2013) also reported that SSF of PKC with locally cultured *Rhizopus oryzae* in limited presence of oxygen, initial moisture content of 50% and at pH 5 for 10 days at ambient temperature was effective in improving the nutritive value of PKC for poultry feeding. Results revealed that ash and protein were increased by 18.26% and 4.03%

respectively while carbohydrate and fat contents were decreased by 2.32% and about 100%, respectively. In addition, the essential amino acid and non - essential amino acid composition were increased in the fermented PKC. During SSF, the microbes used PKC as growth substrate and subsequently degraded the fibrous material and secondly, the microbial growth contributed to the crude protein content of the biomass, thus increasing the nutritive value (Wong *et al.*, 2010). SSF of PKC has been reported to increase the level of unsaturated fatty acids while saturated fatty acid level decreased (Iluyemi *et al.*, 2006).

Swe (2004) examined the effects of SSF with *Aspergillus niger* on the nutrient value of (PKC) and found that the neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents of fermented substrate were decreased by 47.3 % and 22.6 %, respectively. The crude protein (CP) was increased by 28.7% after 8 days of fermentation and the mannanase activity was 109.7 IU/g after 6 days of fermentation. Puastuti *et al.* (2014) evaluated the nutritive value of PKC fermented with *Aspergillus niger*, *Trichoderma viride* and *Aspergillus oryzae* and reported that CP content of the PKC increased by 79.21% and the amount of water soluble DM increased by 46.7 %. Samaneh *et al.* (2012) conducted fermentation in a bioreactor in order to produce lipase from agricultural products/residues by *Aspergillus niger*. Several agricultural products and residues including rice bran and corn meal were tested. Results showed that rice bran produced the highest lipase content and showed the best result for enzyme production which obtained after 96 hours of incubation at temperature of 36 °C and cabin humidity of 90%. SSF offers numerous advantages, including lower energy requirements, produce less waste water and is environment friendly as well as solving the problem of solid wastes accumulation.

## **CHAPTER THREE**

### **MATERIALS AND METHODS**

#### **3.1 Experimental Site**

This study was carried out at the Teaching and Research Farm of the School of Agriculture and Agricultural Technology of the Federal University of Technology, Owerri, Imo state. Owerri is located in the south eastern part of Nigeria with an altitude, mean annual rainfall, temperature and humidity of 90 cm, 200-250 mm, 26.5-27.5 °C and 70 – 80 %, respectively Imo state lies between latitude 4°45'N and 7°15'N and Longitude 6°50'E and 7°25'E (Ministry of Lands and Survey,1984).

#### **3.2 Overview of the Experiments**

Two experiments were carried out to determine the effects of feeding solid state fermented palm kernel cake with water or sugar on the performance, carcass and meat quality of broilers and pigs.

#### **3.3 Source and Processing of Experimental Materials**

Expeller palm kernel cake used in the experiments were procured from local dealers in Owerri, Imo State. The PKC weighing 50kg was run in a hammer mill (0.2 mm sieve size) to homogenize the particle size. The palm kernel cake was divided into three equal parts labeled A, B, C. Sample A was kept, in a plastic container to serve as control. Sample B was weighed and mixed thoroughly with equivalent amount of water (w/w). Sample C was mixed with an equivalent weight of 2 % sugar(sucrose) solution. The sugar solution was prepared by

dissolving 2 kg granulated sugar in 100 kg of water. After mixing, the samples were spread out 2cm thick on a polyethylene mat under shade at room temperature. The following morning, sample A was transferred to its original container, while samples B and C were packed into polyethylene bags, compressed to remove excess air and then tied. They were kept inside plastic containers and covered to protect from rodents. Each of the two samples were allowed to stand and ferment under room temperature for 6 days before use.

### **3.4 Proximate Composition of the Fermented PKC**

#### **3.4.1 Proximate composition:**

The proximate compositions of the experimental materials (unfermented PKC, PKC fermented in sugar solution and PKC fermented in water) were measured using the procedures of AOAC (1995). The determinations were done in triplicates and the means recorded.

**3.4.1.1 Moisture content determination:** 1.0 g of each sample was placed in an oven and dried at 105 °C for three hours. The sample was allowed to cool in a dessicator and then re-weighed. The percentage moisture content was calculated by expressing the loss in weight on drying as a fraction of the initial weight of sample and multiplied by 100.

$$MC (\%) = W_0 / W_i \times 100$$

Where

MC = Moisture content,

$W_0$  = loss in weight (g) on drying and

$W_i$  = initial weight of sample (g).

**3.4.1.2 Ash content determination:** The ash content was determined using the ignition method. The crucibles used were thoroughly washed and pre-heated in a muffle furnace to about 500 °C. Samples weighing 1.0 g were used in moisture determination. There were weighed in triplicate and placed in weighed crucible and then re-weighed. The crucible was covered with its lid, the number noted and then placed in a cold muffle furnace. The temperature was allowed to rise to 500 °C and the ashing carried out for three hours at this temperature. The crucible was removed from the furnace, allowed to cool in a desiccator and re-weighed. The percentage ash content was calculated using the formula:

$$\text{Ash (\%)} = (M_a / M_s) \times 100$$

Where:

$M_a$  = Mass of ash (g)

$M_s$  = Mass of sample used (g)

**3.4.1.3 Crude protein (CP) determination:** Determination of crude protein was done by first determining the total nitrogen using the macro - Kjeldhal method. One gram of the sample was weighed in triplicate and placed in digestion flasks. Few granules of anti - bumps and about 3.0 g of copper catalyst mixture (96 % anhydrous sodium sulphate, 3.5% copper sulphate and 0.5% selenium dioxide) were added to each of the flasks. Digestion was then commenced by adding (to each flask) 20mls of concentrated sulphuric acid. Digestion was continued until a clear solution was obtained and then the flask was allowed to cool. The

digest was then filtered and made up to 100 cm<sup>3</sup> with distilled water. 20 cm<sup>3</sup> of the diluted digest was pipetted into round-bottomed flasks and used in the distillation step.

For distillation, the round-bottomed flask was set on a heating mantle and connected using a Liebig condenser to a beaker (receiver flask) containing 20 cm<sup>3</sup> of 2 % boric acid, with screened methyl red indicator. The condenser was submerged in the boric acid by the use of a Buchner funnel, 30 cm<sup>3</sup> of 40% sodium hydroxide was then injected into the flask and distillation of the ammonia formed commenced by heating the flask. The distillation was continued until the boric acid solution completely changed from purple to greenish – yellow. The boric acid mixture (containing the ammonium borate complex formed) was then titrated with 0.1M HCl to colourless end point and the titre noted. The total nitrogen was then calculated using the formula:

$$\% \text{ TON} = (\text{TV} \times \text{NE} \times \text{TV}_d) / \text{M}_s \times \text{V}_d \times 100$$

Where

TON = Total Nitrogen,

TV = Titre value,

NE = Nitrogen equivalent to molarity of acid,

TV<sub>d</sub> = Total volume to which digest was diluted,

M<sub>s</sub> = Mass of sample (g)

V<sub>d</sub> = Volume of digest distilled.

$$\% \text{ crude protein} = \% \text{ TON} \times 6.25$$

**3.4.1.4 Determination of Crude Fibre:** Fritted crucibles were dried at  $130 \pm 2^{\circ}\text{C}$  for 30 minutes and weighed. To simplify filtration, 1.0g of well-prepared sample was weighed into the crucible containing 1.000g of celite 545. The crucibles were positioned in the Fibertec Cold Extraction Unit and the valves were closed. 25 ml acetone was added to each crucible. The solvent was extracted and filtered by placing the valves in 'VACUUM' position. This was repeated three times. The crucibles were removed and kept at room temperature until the acetone has evaporated. Dry crucibles were then redried for at least 2 hours at  $130 \pm 2^{\circ}\text{C}$  and then cooled to room temperature in a desiccator and weighed. The samples were then ashed by heating the crucibles for at least 3 hours at  $525 \pm 15^{\circ}\text{C}$ . The crucibles were then cooled slowly to room temperature in a desiccator and weighed. The crude fibre content was then calculated as

$$\% \text{ Crude Fibre} = \frac{W_2 - (W_3 + C)}{W_1} \times 100$$

**3.4.1.5 Ether extract (EE) determination:** Determination of ether extract content of the samples was done using Soxhlet type of the direct solvent extraction method. The solvent used was petroleum ether (boiling range  $40 - 60^{\circ}\text{C}$ ). Three grams of the dried sample was weighed in triplicate and secured in Soxhlet extraction thimble. The thimble was then put into 20 cm<sup>3</sup> capacity soxhlet extractor. A washed, oven - dried 100 cm<sup>3</sup> round - bottomed flask was weighed and approximately 60 cm<sup>3</sup> of petroleum ether added to it. The flask was then mounted on the heating mantle activated and extraction carried on for four hours. At the end of extraction, the solvent was evaporated and the flask dried in the oven (at  $60^{\circ}\text{C}$ ). The flask was cooled and re - weighed. The percentage ether extract was calculated using the formula:

$$\% \text{ EE} = M_{\text{ex}} / M_{\text{s}} \times 100$$

Where

$M_{\text{ex}}$  = mass of extract (g)

$M_{\text{s}}$  = Mass of sample used (g)

**3.4.1.6 Nitrogen Free Extracts Determination:** Nitrogen free extracts of each sample was estimated by difference.

$$\text{Nitrogen free extract (\%)} = [100 - (\% \text{ moisture} + \% \text{ CP} + \% \text{ EE} + \% \text{ ash})].$$

**3.4.1.7 Metabolizable Energy:** This was calculated based on proximate composition using the prediction equation as described by Ponzenga (1985)

$$\text{ME} = 37 \times \text{CP \%} + 81.8 \times \text{EE\%} + 35.5 \times \text{NFE \%}.$$

Where; ME = metabolizable energy,

CP = crude protein,

EE = ether extract,

NFE = nitrogen free extract,

### **3.5 EXPERIMENT 1**

#### **Performance, carcass and meat quality characteristics of broiler finishers fed fermented palm kernel cake.**

##### **3.5.1 Management of Experimental Birds**

The total of one hundred and eight (108) day old Marshal broiler chicks were used for this experiment. They were raised on a deep litter system and were fed a commercial broiler starter diet. According to the label on the feed bags, it contained 2842 Kcal/kg metabolizable energy; 21.04%, crude protein; 2.7%, ether extract; 7.16%, crude fibre and 3.64% ash. The commercial feed was offered to the birds *ad libitum* for four (4) weeks. After this, the chicks were randomly allotted into nine (9) experimental units of twelve (12) birds each. Three units (replicates) were randomly allotted to one of the three (3) treatment diets giving three (3) replicates per treatment. Experimental diets were given for 28 days (from 5<sup>th</sup> – 8<sup>th</sup> weeks of age). All vaccinations and other management practices were observed according to the conventional procedures used by the University Farm.

##### **3.5.2 Experimental Diet for Birds**

Three (3) experimental diets A, B, C were formulated. Diet A contained 30 % unfermented palm kernel cake, diet B contained 30 % palm kernel cake fermented in portable water while diet C contained 30 % palm kernel cake fermented in 2 % sugar solution. The compositions of experimental diets are shown in Table 3.1.

**Table 3.1: Ingredients and calculated chemical composition of broiler finisher diets (%)**

<b>Ingredients</b>	<b>A</b>	<b>B</b>	<b>C</b>
Unfermented PKC	30.00	-	-
PKC fermented in water	-	30.00	-
PKC fermented in solution	-	-	30.00
Maize	46.00	46.00	46.00
Soybean meal	16.00	16.00	16.00
Fish meal	3.00	3.00	3.00
Bone meal	4.00	4.00	4.00
Lysine	0.25	0.25	0.25
Methionine	0.25	0.25	0.25
Salt	0.25	0.25	0.25
Vitamin/mineral premix*	0.25	0.25	0.25
Total	100	100	100
<b>Calculated Chemical Composition</b>			
Crude protein %	18.94	18.94	18.94
Crude fibre %	7.16	7.16	7.16
Ether extract %	2.71	2.71	2.71

Ash (%)	3.61	3.64	3.64
Metabolizable energy (Kcal/kg)	2842	2842	2842

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\*Formulated to provide per kg diet vitamin A-8,000,000 I.U; vit. D<sub>3</sub>, 1,600,000 I.U; vit E, 5,000 I.U; vit. K,2,000 mg; thiamine,1,500 mg; riboflavin, 4,000 mg; pyridoxine,1,500 mg; niacin , 15,000 mg; vit. B<sub>12</sub>, 10 mg; panthothenic. acid , 5,000mg; folic acid, 500mg; biotin, 20 mg; choline chloride, 200 g; antioxidant, 125g; manganese, 80g; zinc, 50g; iron, 20g; copper, 5g; iodine, 1.2g; selenium, 200 mg; cobalt, 200 mg.

### **3.5.3 Data collection**

#### **3.5.3.1 Performance of Experimental Birds**

The live weights of the birds were determined at the beginning and at the end of the experiment on replicate basis. The weight gained by each replicate was calculated as the difference between the final weight of the birds and their initial weight and divided by the number of birds in each duplicate. This was further divided 28 days to determine the average daily weight gain (ADWG). Daily feed intake was determined on replicate basis as the difference between feed given and the quantity left over the following morning. This was divided by the number of birds per replicate to get the average daily feed intake. The total feed consumed by the birds was divided by 28 days to get the average daily feed intake (ADFI). Feed conversion ratio was calculated as the ratio of ADFI to ADWG. Cost of feed was calculated based on prevailing market prices. Feed cost per kilogram weight gain was determined by multiplying the feed conversion ratio with feed cost per kg for each diet.

#### **3.5.3.2 Carcass and Organ Characteristics**

At the 56<sup>th</sup> day of the experiment, the birds were starved of only feed for 24 hours. The following morning, all birds were weighed on replicate basis and two birds whose weights were closest to the mean of each replicate were selected. These birds were labeled and bled to death by severing the jugular vein and blood was allowed to drain in vertical position (head down). They were scalded in hot water, defeathered and eviscerated. The carcasses were weighed and cut into different parts and offals such as head, neck, shank, wings, drumstick, thigh back, breast muscle following the guidelines described by USDA (1998). All the component parts were weighed and their individual weights expressed as percentage of the live weight of the chicken.

### **3.5.3.3 Meat Quality Assessment**

#### **3.5.3.3.1 Drip Loss**

Drip loss was determined following the method described by Honikel (1998). The left thighs of the birds from each treatment were deboned and split into two halves. One half was weighed and kept in an air-tight transparent polyethylene bag (Ziploc<sup>®</sup>), labeled and refrigerated at 7 °C for 24 hours. The following day, the samples were carefully removed and dried with filter paper and reweighed. The difference in weight was expressed as percentage of the initial weight and recorded as percentage drip loss.

#### **3.5.3.3.2 Water Holding Capacity**

Determination of water holding capacity was carried out as described by Kauffman *et al.* (1992). A 3.5g sample was cut out from the other half of the thigh and weighed. Each sample was wrapped in a serviette and compressed under a screw jack until all the free water was

expelled. The meat residues were recovered and weighed. The difference in weight was determined and represented the weight of the fluid expelled. This was expressed as percentage of the weight of the initial sample and recorded as the water holding capacity of the meat.

#### **3.5.3.3.3 Cooking Loss**

The remaining portion of the left drumsticks were individually weighed and wrapped in a transparent polyethylene bag, labeled and heated for 30 minutes under steam. They were allowed to cool, dried with absorbent paper towel and reweighed. The decrease in weight was expressed as percentage of the fresh weight and recorded as percentage cooking loss. This followed the guidelines of AMSA (1978).

#### **3.5.3.4 Organoleptic Assessment**

The right drumstick from each bird was packed in Ziploc polyethylene bag and kept in a refrigerator. After 48 hours of refrigerated storage, they were deboned and cut into portions weighting approximately 50g each. The samples were soaked in 2% saline solution for 30 seconds and wrapped in a transparent polyethylene bag. They were cooked for 30 minutes and thereafter cooled to ambient temperature. The samples were served to a panel of eighteen (18) trained assessors drawn from 500 level students of the Department of Animal Science and Technology, FUTU. The panellists were asked to wholly masticate the meat sample and evaluate it for tenderness, juiciness, flavour intensity, connective tissue content and hedonic rating using the eight point category rating scale as described by Miller (1998).

### **3.5.3.5 Haematology**

#### **3.5.3.5.1 Blood Sampling and Analysis**

As each bird was being bled, 5 ml of blood was collected into bijou bottles containing EDTA and stored under ice. These were later taken to the Haematology Laboratory of the Federal Medical Centre, Owerri for haematological analysis. The analysis took place within 12 hours of sampling. The samples were analyzed for total red blood cell count (RBC), haemoglobin concentration (Hb), packed cell volume (PCV), total white blood cell count (WBC) and percentages of heterophils, lymphocytes and eosinophils as described by Schalm *et al.* (1975). The mean corpuscular haemoglobin (MCH), mean corpuscular volume (MCV) and mean corpuscular haemoglobin concentration (MCHC) were calculated.

#### **3.5.3.5.2 Total White Cell Count (WBC)**

0.2 ml of blood sample was tinged with 0.38 ml of 1 % glacial acetic acid (1:20) to haemolyse the red blood cells. It was stained with Gentian violet before being dropped on the counting chamber (Haemocytometer) and viewed under x 10 lens magnification of an Olympus microscope as described by Schalm *et al.* (1975).

#### **3.5.3.5.3 Differential White Cell Count**

A blood smear was prepared by placing a drop of blood on a glass slide with a Pasteur pipette and neatly covered to make a thin film of the blood sample. After drying, the sample was stained with Leishman's stain and covered again to fix the stain. This was diluted with

phosphate buffer and allowed to stand for 8 to 10 minutes before washing off the stain. The sample was treated with cedar-wood oil before placing under x100 lens magnification of Olympus microscope. The number of heterophils, lymphocytes and eosinophils were determined and expressed as percentages of the total leukocyte count as described by Schalm (1975).

#### **3.5.3.5.4 Red Blood Cell counts (RBC)**

0.2 ml of blood sample was diluted with a solution of 3.0 g of sodium citrate in 100 ml of distilled water. 1.0 ml of formaldehyde was added to haemolyse the white blood cells on thorough mixing. A smear was prepared and RBC count was determined with the RBC Haemocytometer counting chamber under x10 lens magnification of the Olympus microscope as described by Schalm (1975).

#### **3.4.3.5.5 Haemoglobin Concentration (Hb)**

The Hb was determined with the cyanomethaemoglobin (CMH) method using the Gallen Kamp colorimeter. Blank solution count was determined by pipetting 4.0 ml of Drabkin's solution (mixture of potassium cyanide and potassium ferrocyanide) into a curvet, placed on the colorimeter and then read off at 540 nm. To determine the haemoglobin content of the blood samples, 4.0 ml of Drabkin's solution was pipetted into a vial containing 0.02 ml of blood. The mixture was thoroughly mixed and allowed to stand for 10 to 15 minutes before being read at 540 nm on the colorimeter as described by Schalm (1975).

### 3.5.4.3.5.6 Packed Cell Volume (PCV)

2.0 ml of blood containing EDTA was pipetted and placed in Hematocrit tubes. The Hematocrit tubes were arranged vertically in a normal blood sedimentation rack. The tip of the tubes was tightly embedded in the rubber support and allowed to stand for 45 minutes. The PCV was read off from the upper meniscus as described by Schalm (1975).

### 3.5.3.5.7 Red Cell Indices

The mean corpuscular haemoglobin (MCH), mean corpuscular volume (MCV) and the mean corpuscular haemoglobin concentration (MCHC) were expressed in pictogram (pg), fetolitre (fl) and grams/100ml respectively. The MCH, MCV and MCHC were determined from RBC, PCV and haemoglobin (Hb). The haematological constants were calculated using the appropriate formulae as described by Jain(1986).

$$MCV(fL) = \frac{PCV(L/L)}{RBC \times 10^{12} L}$$

$$MCH(Pg) = \frac{Hb \times 10(g/L)}{RBC \times 10^{12}} \text{ and}$$

$$MCHC(g/l) = \frac{Hb \times 10(g/L)}{PCV(L/L)}$$

## 3.6 Experimental Design and Data Analysis

Collected data were subjected to analysis of variance (ANOVA) using a completely randomized design (CRD). Significantly different means were separated using the least significantly difference (LSD) test as described by Snedecor and Cochran (1967).

## **3.7 EXPERIMENT 2**

### **Performance, Carcass and Meat Quality of Pigs Fed Diets Containing Fermented Palm Kernel Cake.**

#### **3.7.1 Experimental Animals**

Eighteen 12 week old grower pigs (9 males and 9 females) of mixed breed selected from the Piggery Unit of the Teaching and Research Farm of the Federal University of Technology, Owerri, were used for the study. They were assigned to one of three dietary groups comprising three boars and three gilts each. Each sex within a dietary group was kept in a separate pen of 2 × 4m each. The animals were dewormed with piperazine at the beginning of the experiment and also later administered with I-vermectin at 14 weeks of age to control ectoparasite especially mange. Animals in each pen were fed together and allowed a quantity of feed equal to 4 % of their total body weight throughout the experiment while water was provided *ad lib*. The feeding trial lasted for 8 weeks.

#### **3.7.2 Experimental Diets**

Three (3) experimental diets A, B, C were formulated. Diet A had unfermented palm kernel cake while diets B and C contained palm kernel cake fermented either in water or in 2% sugar solution, respectively, as described for the broiler study. The composition of the experimental diets is shown in Table 3.2.

#### **3.7.3 Data Collection**

##### **3.7.3.1 Performance of Experimental Pigs**

The live weights of the pigs were measured at the beginning of the experiment. They were also weighed every two weeks. The average daily weight gained by the animals was calculated as the difference between the final weight of the animal and their initial weight divided by the period of the experiment (days). The total quantity of feed consumed per animal in each treatment unit was determined and then divided by the period of the experiment to get average daily feed intake (ADFI). Feed conversion ratio was calculated as ADWG divided by ADFI. Cost of feed per kilogram was calculated using the dietary composition and prevailing market prices of the ingredients. Cost per kilogram weight gain was calculated as the feed conversion ratio multiplied by the feed cost.

### **3.7.3.2 Carcass Characteristics**

At the 8<sup>th</sup> of the feeding trial, all the 18 pigs were starved for 24 hours. They were weighed, stunned, shackled and slaughtered by the severance of the jugular vein. They were allowed to bleed to death in a vertical position (heads down). After bleeding, the kill out weights were determined. The pigs were then scalded in hot water and dehaired. They were eviscerated and the carcass weights were recorded. The carcasses were then cut into primal cuts such as the ham, shoulder, spare rib, belly, jowl meat, head, loin, trotter and tail following the methods described by FAO (1998). The internal organs such as heart, liver, lungs, spleen, kidney and GIT were carefully removed and weighed. The weight of each part was expressed as a percentage of the animal's live weight. The back fat (thickness) was measured at the

**Table 3.2: Ingredients and calculated chemical composition of the experimental diets.**

<b>Ingredients</b>	<b>A</b>	<b>B</b>	<b>C</b>
Maize	20.00	20.00	20.00
Palm kernel cake	40.00	-	-
Fermented palm kernel cake in water	-	40.00	-
Fermented palm kernel in sugar solution	-	-	40
Soya bean meal	8.00	8.00	8.00
Wheat offal	28.00	28.00	28.00
Bone meal	3.00	3.00	3.00
Lysine	0.25	0.25	0.25
Methionine	0.25	0.25	0.25
Salt	0.25	0.25	0.25
Additive*	0.25	0.25	0.25

Total	100.00	100.00	100.00
<b>Calculated Chemical Composition</b>			
Crude protein (%)	18.82	18.82	18.82
Crude fibre (%)	7.91	7.91	7.91
Ether extract (%)	4.39	4.39	4.39
Ash (%)			
Metabolizable energy (Kcal/kg)	2324.3	2324.3	2324.3

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\*Additive – 625 g, detoxizyme – 125 g, superliv -125 g, prebiotics and probiotics - 62.5g, herbo-methionine - 125g, limestone (carrier) - 187.5g.

10<sup>th</sup> rib using a transparent metric ruler while loin eye area was measured at the 10<sup>th</sup> rib by tracing on an acetate paper.

### **3.7.3.3 Meat Quality Assessment**

Meat quality assessments were carried out according to the same methods described in the broiler experiment.

#### **3.7.3.3.1 Drip Loss**

Samples of meat were collected from the *Semitendinosus* muscle of each animal. They were weighed and kept in an air-tight transparent polyethene bag, labelled and refrigerated at 7 °C for 24 hours. Determination of drip loss was carried out following the same method described in the broiler study.

### **3.7.3.3.2 Water Holding Capacity (WHC)**

An approximately 3.5 g sample was cut out from the loin of each animal between the 10<sup>th</sup> and 11<sup>th</sup> rib and weighed. WHC determination was same as the method used in the broiler study.

### **3.7.3.3.3 Cooking Loss**

Meat samples from the remaining portion of the *Semitendinosus* muscle were cut, weighed (approximately 3.5 g) and individually wrapped in a transparent polyethylene bag, labeled and heated for 30 minutes under steam. They were allowed to cool and then dried with absorbent paper towel and reweighed. The loss in weight was expressed as percentage of fresh weight and recorded as percentage cooking loss.

## **3.7.4 Organoleptic Assessment**

The other *Semitendinosus* muscle of each animal was carefully cut out and packed in a polyethylene bag (Ziploc<sup>®</sup>) and refrigerated at 7 °C for 48 hours. After this, they were cut into meat samples weighing approximately 50 g. The meat samples were soaked for 30 seconds in saline solution (30 g/l) and wrapped individually in transparent polyethylene bag. They were cooked under steam for 30 minutes, cooled to room temperature and kept in stainless steel flask until sensory evaluation. Trained meat assessors drawn from 500 level students of the Department of Animal Science and Technology, FUTO were used. The panelist were told to wholly masticate a meat sample and evaluate it for tenderness,

connective tissue amount, juiciness, flavor and hedonic rating using the eight points category rating scale as described by Miller (1998).

### **3.8 Experimental Design and Data Analysis.**

Data on performance, carcass characteristics and meat quality of pigs were subjected to analysis of variance (ANOVA) using a randomized complete block design (**RCBD**). Dietary treatment was the main effect while sex was the block effect. Significantly different means were separated using the least significant difference test as described by Snedecor and Cochran (1967).

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### 4.1 Proximate Composition of Fermented PKC

The proximate compositions of fermented PKC are shown in Table 4.1. There were significant differences ( $p>0.05$ ) in moisture content, crude fibre, ether extract, ash and nitrogen free extract. On air dry basis, the moisture contents of fermented PKC (12.60 in water and 11.70 in sugar solution) were significantly lower ( $p<0.05$ ) than the unfermented PKC. This drop in moisture content may have resulted to some physiochemical changes in the PKC during fermentation. These changes must have reduced the water binding capacity of molecules in PKC. Though the influence of fermentation on water binding capacities of molecules in PKC has not been reported, such changes have been reported for fermented cassava and cereal products (Aviara *et al.* 2010; SudhakarRao *et al.* 2014). The fermented samples had significantly lower crude fibre content when compared to the unfermented samples. Reduction could be as a result of fungi degradation during fermentation of PKC. The ability of SSF to degrade fibre has been reported by Ofuya & Nwajiuba (1990); Iyayi & Losel (2001). However this reduction of content did not influence the crude protein content of fermented samples significantly. The ether extract of fermented PKC (TB and TC) were significantly lower than that of unfermented PKC. Microbial activities during fermentation must have influenced this. This finding is also in agreement with those of Aladi *et al.* (2013) and Aladi, (2016) who fermented a mixture of cassava root pulp and PKC. Aladi (2016) attributed the changes to the ability of the implicated fungi to utilize lipids as carbon source during fermentation. The ash content of PKC fermented in water (8.56) was significantly ( $p<0.05$ ) lower than those of unfermented samples but was similar ( $p>0.05$ ) to those in sugar solution. On the other hand, samples fermented in sugar solution were similar to the

**Table 4.1 Proximate Composition of Fermented PKC**

Parameter (g/kgDM)	A	B	C	SEM
Moisture	17.00 <sup>a</sup>	12.60 <sup>b</sup>	11.70 <sup>b</sup>	0.660
Crude protein	19.10	19.13	20.99	2.060
Crude fibre	13.67 <sup>a</sup>	5.58 <sup>b</sup>	4.70 <sup>b</sup>	0.519
Ether extract	9.87 <sup>a</sup>	4.97 <sup>b</sup>	6.77 <sup>b</sup>	0.866
Ash	5.94 <sup>b</sup>	8.56 <sup>a</sup>	7.90 <sup>ab</sup>	0.847
Nitrogen free extract	37.17 <sup>b</sup>	49.15 <sup>a</sup>	47.92 <sup>a</sup>	2.844

A- (Unfermented palm kernel cake), B- (PKC fermented in water), C- (PKC fermented in 2% sugar solution)

unfermented samples in ash content. The reason for this discrepancy is not clear. The results are however in tandem with those of Marini *et al.* (2008) who reported that loss of organic matter during fermentation usually lead to increase in ash content. Chavez *et al.* (1995) also reported that SSF significantly increased ash content of PKC. Changes in NFE values followed trends found for CF, EE and moisture contents. This is expected since the values of NFE are calculated from them and so has additive effect.

#### **4.2 Growth Performance of Broilers Finisher Phase Fed Fermented Palm Kernel Cake**

The results of the growth performance of broilers (finisher phase) fed fermented palm kernel cake are shown in Table 4.1. No significant differences ( $p > 0.05$ ) were found in all the parameters studied. Apparently, the results of this study do not agree with the findings of Wong *et al.* (2010) who reported that during solid state fermentation (SSF), microbes use PKC as growth substrate and subsequently degrade the fibrous materials which in turn increase the protein content and nutritive value of PKC. Their report is supported by the findings of other authors including Marini *et al.* (2005), A'dilah *et al.* (2011) and Dairo and Fajuyi (2008). This suggests that the spontaneous inoculation technique used here was not effective in degrading neither the fibre nor increase protein content sufficiently to elicit significant improvement in the performance of the birds. Two factors may be responsible for this. First, PKC is very low in fermentable sugars and so normal SSF of PKC in water may not lead to any significant changes in the product since fermentative organisms rely largely on fermentable sugars for proliferation and action on the substrate (Fung, 2000). Secondly, the period of fermentation may not have been sufficient to produce a significant change in the

chemical composition of PKC. Although the periods of fermentation of PKC reported by the above authors were similar to the one used in this study, these authors used purified strains

**Table 4.2: Growth performance of broilers finisher phase fed fermented palm kernel cake based diets**

<b>Parameters (g)</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>SEM</b>
Initial live weight	511.40	513.75	512.13	10.233
Final live weight	1972.89	1984.29	2036.56	36.400
Average daily feed intake	118.76	115.86	121.96	9.620
Average daily weight gain	44.29	44.53	46.19	1.661
Feed conversion ratio	2.68	2.60	2.64	0.182
Feed cost	92.33	92.33	92.33	
Feed cost per kg weight gain	247.44	240.06	243.75	

A- Unfermented palm kernel cake, B- PKC fermented in water, C- PKC fermented in 2% sugar solution

such as *Aspergillus niger* (Marini *et al.*, 2005) and *Trichoderma resei* (Iyayi *et al.*, 2001; Jaelani *et al.*, 2008), and included nutrient broth during inoculation (Akinnyele *et al.*, 2013).

The aggregate performance of the birds is similar to those reported by other authors (Okeudo *et al.*, 2005; Bello *et al.*, 2011; Anaeto *et al.*, 2009 and Kperegbeji *et al.*, 2011). Several investigators (Graham *et al.*, 1986; Fernandez and Jorgensen, 1986; Graham & Aman, 1986a; 1986b; Fanimu *et al.*, 2003) have reported that addition of fibre to the diet can lead to a lower apparent digestibility of starch, fat, crude protein and peptides and hinder absorption. Moreover, the water binding capacity of fibre has been reported to reduce diffusion of the products of digestion towards mucosal surface (Dierrick *et al.*, 1989). Thus overall growth rate observed for the experimental birds might have been affected by a reduced availability of protein and other nutrients for growth.

#### **4.3 Carcass and Internal Organ Characteristics of Broilers**

The results of the carcass and internal organ characteristics of broiler (finisher phase) fed fermented and unfermented PKC are shown in Table 4.2. There were no significant differences ( $P > 0.05$ ) in all the parameters evaluated. This means that fermentation of PKC did not have any positive and negative effect on carcass and internal organ characteristics of broilers. The carcass weights were similar across the three different diets.

#### **4.4 Meat Quality of Broilers**

The result of meat quality assessment of broilers fed fermented and unfermented PKC are shown in Table 4.3. Significant differences were found in cooking loss but not in water holding capacity and drip loss. The results showed that birds fed unfermented PKC recorded the lowest cooking loss ( $p < 0.05$ ). Though there were no significant differences ( $p > 0.05$ ) in

**Table 4.3: Carcass characteristics and organ content of broiler (finisher phase) fed fermented palm kernel cake diets.**

<b>PARAMETERS</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>SEM</b>
Live weight(g)	1955.0	2071.0	1963.8	45.31
Defeathered weight (%)	90.34	83.85	88.84	2.852
Dressed weight (%)	64.44	70.26	64.81	5.131
<b>Carcass characteristics (% of live weight)</b>				
Head	2.61	2.22	2.45	0.331
Neck	4.57	4.48	3.85	0.977
Shank	0.36	0.33	0.38	0.815
Wings	0.43	0.38	0.40	0.091
Drumstick	10.49	10.01	10.60	0.078
Thigh	19.17	19.23	21.11	1.782
Back	5.68	5.37	5.53	0.350
Breast muscle	27.37	28.44	27.35	1.710
GIT	4.07	4.33	4.83	0.980
Heart	0.47	0.45	0.44	0.147

Liver	1.70	1.56	1.68	0.210
Gizzard (full)	3.11	3.13	3.12	0.370
Gizzard (empty)	2.48	2.22	2.081	0.150
Spleen	0.11	0.14	0.15	0.061
Abdominal fat	0.70	1.15	0.60	0.012

A – Unfermented PKC, B – Fermented PKC in H<sub>2</sub>O, C – Fermented PKC in sugar solution

**Table 4.4: Meat quality of broilers fed fermented palm kernel cake diets**

PARAMETERS	A	B	C	SEM
<b>Meat quality characteristics</b>				
Cooking loss	31.81 <sup>b</sup>	33.56 <sup>ab</sup>	37.28 <sup>a</sup>	2.41
Water holding capacity	42.72	40.01	43.38	4.25
Drip loss	1.90	2.81	2.34	0.51
<b>Organoleptic quality</b>				
Juiciness	5.75 <sup>a</sup>	6.75 <sup>b</sup>	6.38 <sup>ab</sup>	0.33
Tenderness	6.63	6.75	6.63	0.40

Connective tissue amount	6.38	6.25	5.13	0.64
Flavour intensity	5.75	5.75	4.88	0.87
Hedonic score	6.63	7.13	6.38	0.58

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<sup>a,b</sup> Means in the same row bearing different superscripts are significantly different (P<0.05)

A-Unfermented PKC, B- Fermented PKC in water, C- Fermented PKC in sugar solution

water holding capacity, it is likely that muscles from birds fed unfermented PKC retained less water and hence the reduced cooking loss. Cooking loss is known to be positively correlated with muscle moisture and negatively with intramuscular fat content (Okeudo and Moss, 2005) and intramuscular fat and moisture content are negatively correlated (Lawrie, 1991). From the foregoing, a reduction in cooking loss may be caused by increase in intramuscular fat. However, diet related differences in abdominal fat were not significant which suggests that they may not have been differences in intramuscular fat. This would make it difficult to relate the observed significant differences in cooking loss to fat content. A probable explanation may be found in the fact that fermented products would have higher acidity

levels. This would impact on the acidity level of the muscle resulting to lower muscle pH postmortem, a condition associated with higher drip loss and cooking loss.

There were no significant differences in tenderness, connective tissue amount, flavour intensity and hedonic rating ( $P>0.05$ ). However, diet related differences were significant for juiciness ( $P<0.05$ ). The juiciness of the birds on treatment A were similar to that of the birds on treatment C. Those of the birds on treatment B were similar ( $P>0.05$ ) to those of the birds on treatment C. The differences in juiciness must have been influenced partly by the fat content of the carcass and partly by fermentation of PKC. It is possible that fermentation released factors (eg.volatile fatty acids) which enhanced juiciness of birds fed fermented PKC.

#### **4.5 Haematological Indices of Broilers Fed Fermented Palm Kernel Cake.**

The results for haematological analysis of broilers fed fermented and unfermented palm kernel cake diets are shown in Table 4.5. There were no significant differences ( $p>0.05\%$ ) in all parameters evaluated. However, reports from Merck Veterinary Manual (1979) and Mitruka and Rawnsley (1977) indicate that these values are within the normal range for

**Table 4.5 Haematological indices of broilers fed fermented palm kernel cake.**

Parameters	A	B	C	SEM
Haemoglobin concentration (g/dL)	11.20	10.90	10.63	1.075
PCV (%)	35.43	32.50	34.23	3.560
RBC ( $\times 10^6/\mu\text{L}$ )	2.62	2.54	2.62	0.256
MCV (fL)	135.47	127.73	130.70	6.724

MCH (pg)	42.73			
MCHC (g/dL)	31.57	33.63	30.97	1.364
Platelets x 10 <sup>3</sup> /μL	67.33	121.33	59.33	58.380
White blood cells x 10 <sup>3</sup> /μL	67.43	68.00	70.70	4.818
Heterophils %	90.67	86.00	82.67	3.64
Neutrophils %	9.33	14.00	17.33	3.641

A (unfermented palm kernel cake), B (PKC fermented in water), C (PKC fermented in sugar solution)

PCV (packed cell volume), MCV (mean corpuscular volume), MCH (mean corpuscular haemoglobin), MCHC (mean corpuscular haemoglobin concentration)

a healthy broiler of similar age and environment. The normal haematological values show the nutritional healthy status of the broiler chicken, and thus indicate adequate nourishment of the birds (Church *et al.*, 1984). Nutrition, especially dietary protein intake is known to affect live weight and heamatological parameters of animals (Mafuvadze & Erlwanger, 2007). Esonu *et*

*al.* (2001) stated that haematological constituents reflect the physiological responsiveness of the animal to its external and internal environments which include feed and feeding. Some scientists have studied the effects of various feeds on the haematology and serum biochemistry of livestock and concluded that feed ingredients including unconventional feeds affect animal physiology. Awosanya *et al.* (1999) observed the dependence of blood protein and creatinine on the quality of dietary protein. Taken together, this means that these diets were similar nutritionally, and the fermentation process did not result in the elaboration of factors with adverse metabolic or physiological reactions.

#### **4.6 Performance of Grower Pigs**

The results of the performance of pigs fed fermented palm kernel cake diets are shown in Table 4.4. There were no significant differences found in the final live weight, daily feed intake, daily weight gain, feed conversion ratio and feed cost per kg live weight gain for the three different treatments. This shows that within this study, the fermentation process did not improve the nutritive value of PKC.

#### **4.7 Carcass Characteristics of Grower Pigs**

##### **4.7.1 Effect of treatment diets on carcass and internal organ characteristics**

Table 4.5 shows the effect of treatment diets on the carcass and internal organ characteristics of experimental pigs. No significant differences ( $p>0.05$ ) were found among treatment groups for all carcass parameters except for the size of the loin. The size of the loin in treatment A

**Table 4.6 Performance of the experimental pigs fed fermented PKC diets.**

<b>Parameters(kg)</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>SEM</b>
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Initial live weight	18.13	20.10	19.64	0.765
Final weight	34.70	36.34	36.67	1.220
Daily weight gain(g)	16.59	16.24	19.53	2.090
Feed conversion ratio	4.24	4.63	3.88	0.356
Feed cost(#/kg)	92.33	92.33	92.33	0.00
Cost of feed consumed (#)	4713.75	5061.90	5009.34	104.61
Feed cost/kg weight gain(#)	391.50	427.49	358.24	27.90

Note: A (Unfermented palm kernel cake), B (PKC fermented in water), C (PKC fermented in sugar solution)

**Table 4.7: Effect of fermented PKC on carcass and organ characteristics of grower pigs**

<b>Parameter (%)</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>SEM</b>
Live weight(kg)	34.70	36.33	33.78	1.907
Dressing (%)	60.73	59.02	63.56	1.487
Carcass length (cm)	78.17	76.50	77.17	1.253
Carcass characteristics (%)				
Ham	38.84	35.61	35.93	0.862
Loin	11.20 <sup>a</sup>	10.78 <sup>a</sup>	13.97 <sup>b</sup>	1.015
Shoulder	16.20	16.54	16.24	0.606
Spare rib	6.20	5.76	8.56	0.867
Belly	4.76	4.84	4.30	0.186
Jowl meat	4.92	5.46	5.64	0.419
Head	8.64	9.39	9.21	0.337
Tail	1.47	0.46	0.53	0.405
Trotters	1.45	1.32	3.35	0.832
Liver	1.33	1.25	2.03	0.350
Lungs	1.09	1.01	0.95	0.100
Heart	1.40	1.36	1.13	0.115

Kidney	1.38	1.07	1.56	0.802
Spleen	1.02	0.94	1.64	0.292

<sup>a,b,c</sup> Means within a row having different superscripts are significantly different ( $P < 0.05$ ). A (Unfermented palm kernel cake), B (PKC fermented in water), C (PKC fermented in sugar solution)

(Unfermented PKC) was similar ( $p > 0.05$ ) to those in treatment B (PKC fermented in water) and both were significantly lower than those in treatment C (PKC fermented in sugar solution). This would suggest that PKC fermented in sugar solution had effect on the size of muscles of the loin. The reason for this phenomenon is not clear. Whilst the acidity level of feeds may be suspected, it is also possible that genetic constitution of the animals was responsible for this difference. Breed differences in carcass composition of pigs have been reported (Lawrie, 1991; Mason, 1996; Payne, 1990). However, the size of the liver, kidney, lung, spleen and heart were not significantly ( $p > 0.05$ ) affected by the treatment diet suggesting that dietary differences may not have adversely affected the metabolic activities of the animals.

#### **4.7.2 Sex Effect on Carcass and Organ Characteristics of Pigs Fed Fermented Palm Kernel Cake**

The result of the effect of sex on carcass and organ characteristics of pigs fed fermented palm kernel cake are shown in Table 4.6. Significant sex differences ( $p < 0.05$ ) were found for the dressing percentage and proportions of shoulder and belly. Males had significantly higher ( $p < 0.05$ ) dressing percentage and proportion of shoulder cut. This could be due to the effect of male hormone (testosterone). Testosterone is androgenic and so stimulate higher muscle

development at the expense of fat (Lawrie, 1991). On the other hand female pigs had higher proportion of belly cut. The reason is obvious. The belly cut is largely made up mammary glands whose development is minimal in males. At the slaughter age of these animals (24 weeks and above), significant mammary development must have occurred in females to elicit this difference. The size of the heart among males was higher ( $p < 0.05$ ) than in females. The reason for this is not clear from this work, but may be related to higher metabolic activity of boars versus gilts.

**Table 4.8: Effect of sex on carcass and organ characteristics of grower pigs**

<b>Parameters (%)</b>	<b>Male</b>	<b>Female</b>	<b>SEM</b>
Live weight(kg)	31.32 <sup>a</sup>	38.55 <sup>b</sup>	1.907
Dressing %	64.93 <sup>a</sup>	57.27 <sup>b</sup>	1.487
Ham	19.09 <sup>a</sup>	15.70 <sup>b</sup>	0.862
Loin	12.28	11.68	1.015
Shoulder	18.27 <sup>a</sup>	14.63 <sup>b</sup>	0.606
Spare rib	6.54	7.14	0.867
Belly	4.04 <sup>a</sup>	5.23 <sup>b</sup>	0.186
Jowl meat	5.56	5.10	0.419
Head	9.70	8.45	0.337
Tail	1.03	0.61	0.405
Trotters	2.34	1.73	0.832

Liver	2.20	0.87	0.350
Lungs	1.47	1.77	0.100
Heart	1.56	0.83	0.115
Kidney	1.49	1.77	0.802
Spleen	1.56	0.83	0.292

<sup>a,b,c</sup> Means within a row having different superscripts are significantly different (P < 0.05)

#### **4.8 Meat Quality of Pigs**

The result of the meat quality including organoleptic quality assessment of experimental pigs are shown in Table 4.7 .No significant differences were found in cooking loss, water holding capacity and drip loss. There were as well no significant differences (P>0.05) in tenderness, flavour intensity and hedonic rating. However, pigs fed unfermented PKC had significantly higher (P<0.05) amount of connective tissue (5.33) than those fed PKC fermented in 2% sugar solution and PKC fermented in water.

**Table 4.9 Meat quality and organoleptic traits of grower pigs fed differently fermented palm kernel cake**

<b>PARAMETER</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>SEM</b>
<b>Meat quality characteristics</b>				
Cooking loss	39.273	40.413	41.347	4.51
Water holding capacity	48.397	51.260	49.883	5.35
Drip loss	2.650	4.390	3.590	1.21

### Organoleptic assessment

Juiciness	3.168	3.665	3.740	0.648
Tenderness	3.415	2.750	3.665	0.465
Connective tissue	5.330 <sup>a</sup>	4.082 <sup>ab</sup>	4.415 <sup>b</sup>	0.681
Flavour intensity	2.753	3.500	3.750	0.741
Hedonic rating	2.998	2.920	2.918	0.796
Off – flavour	1.667	1.667	3.00	1.067

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<sup>a,b,c</sup> Means within a row having different superscripts are significantly different ( $P < 0.05$ ). A (unfermented palm kernel cake), B (PKC fermented in water), C (PKC fermented in sugar solution)

## CHAPTER FIVE

### CONCLUSION, RECOMMENDATION AND CONTRIBUTION TO KNOWLEDGE

#### 5.1 Conclusion

In this study the results of the experiment showed that the fermentation technique (fermentation in water or with sugar solution) did not significantly improve the nutritive value of PKC. The experimental diets however did not exert any adverse effects on performance, carcass characteristics and haematological indices of broiler (finisher phase) and pigs. However sizes of loin of pigs fed diet C (PKC fermented in sugar solution) were superior to those fed diets of A and B (unfermented PKC and PKC fermented in water).

Results from the effects of sex on pigs showed that the live weight, dressing percentages and proportions of shoulder and belly were significantly different ( $p < 0.05$ ). The live weight and proportions of the belly of the female pigs were higher compared to those of the males whilst the dressing percentages and proportions of the shoulder of the males were higher compared to those of the females. Juiciness of meat from broilers fed fermented PKC was significantly higher whereas the connective tissues of the pigs fed fermented PKC was lower than in birds or pigs fed unfermented PKC diets. Results from haematological analysis of the birds showed that fermentation had no adverse effects on the birds.

#### 5.2 Recommendation

- In this study, solid state fermentation of PKC in water or 2% sugar solution produced little improvement in aggregate performance. Therefore it is not recommended.

- However, further studies need to be carried out to investigate the effect of higher sugar concentration and longer periods of fermentation on the nutritive value of PKC as animal feed for monogastric animals.

### **5.3 Contribution to Knowledge**

Within the circumstances of this study, results established that though solid state fermentation of PKC in water or sugar solution significantly reduced fibre and ether extract content of palm kernel cake, this did not lead to improvements in performance, carcass and meat quality characteristics of broiler finisher and pigs.

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## APPENDIX 1

### ORGANOLEPTIC ASSESSMENT

#### A. TENDERNESS SCORE

Extremely tender	=1
Very tender`	=2
Moderately tender	=3
Slightly tender	=4
Slightly tough	=5
Moderately tough	=6
Very tough	=7
Extremely tough	=8

#### B. JUICINESS SCORE

Extremely juicy	=1
Very juicy	=2
Moderately juicy	=3
Slightly juicy	=4
Slightly dry	=5
Moderately dry	=6
Very dry	=7
Extremely dry	=8

#### C. FLAVOUR

Extremely flavoured	=1
Very flavoured`	=2
Moderately flavoured	=3
Slightly flavoured	=4
Slightly unflavoured	=5
Moderately unflavoured	=6
Very unflavoured	=7
Extremely unflavoured	=8

#### D. CONNECTIVE TISSUE AMOUNT

Extremely low	=1
Very low	=2
Moderately low	=3
Slightly low	=4
Slightly high	=5
Moderately high	=6
Very high	=7
Extremely high	=8

## APPENDIX 2

### NORMAL HAEMATOLOGY OF BROILERS

Erythrocytes (/μL) × 10	2.5-3.5
Haemoglobin (g/	7-13
Packed cell volume (PCV) %	22-35
Mean corpuscular volume (MCV) fL	90-140
Mean corpuscular haemoglobin concentration(MCHC)%	26-35
Mean corpuscular haemoglobin(MCH)pg	33-47
Reticulocytes (%)	0-0.6
Leukocytes (/μL)	12,000-30,000
Heterophils (band)	rare
Hererophils	3,000-6,000
Lymphocytes	7,000-17,500
Monocytes	150-2,000
Eosinophil	0-1,000
Basophil	rare

Adapted from, Wakenell, P.S. (2010).

### APPENDIX 3

#### NORMAL HAEMATOLOGY OF PIGS

Erythrocyte $\times 10^6 / \mu\text{L}$	5.0-8.0	6.5
Haemoglobin (g/dL)	10.0-16.0	13.0
PCV (%)	32-50	42.0
MCV (fL)	50-68	60.0
MCH (pg)	17.0-21	19.0
WBC ( $/\mu\text{L}$ )	11,000-22,000	16,000
Neutrophil (band)	0.4	1.0
Neutrophil (mature)	28-47	37.0
Lymphocyte	39-62	53.0
Monocytes	2- 10	5.0
Eosonophil	0.5-11	3.5
Basophil	0-2	0.55
Thrombocytes ( $\times 10^6 / \mu\text{L}$ )	5.2 $\pm$ 1.95	
Plasma protein (g/dL)		
6.0-8.0		
Fibrinogen (g/dL)	0.1-0.5	

Source: Thorn (2010)