

**FEEDING POTENTIALS OF STAR APPLE (*CHRYSOPHYLLUM ALBIDUM*)
KERNEL IN BROILER CHICKENS**

BY

AJIDE, SOLOMON OLUSOJI

(13/68AH001)

B.AGRIC, MSc ANIMAL SCIENCE (ABU, Zaria)

**A thesis submitted to the Department of Animal Production
Faculty of Agriculture in partial fulfilment of the requirement for the award of
the degree of Doctor of Philosophy (Ph.D.) Animal Production,
University of Ilorin, Ilorin Nigeria.**

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CERTIFICATION

We the undersigned Internal Examiners hereby certify that Ajide, Solomon Olusoji (13/68AH001) has satisfactorily effected all the necessary corrections pointed out to him during the Oral Examination of his thesis entitled; Feeding Potentials of Star Apple (*Chrysophyllum albidum*) Kernel in Broiler Chickens held on xx/xx/18 and recommended that he be awarded the degree of Doctor of Philosophy (Ph.D.) in Animal Production.

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Dr. A.A. Annongu Head of Department		

DECLARATION

I, Ajide, Solomon Olusoji hereby declare that this thesis entitled ‘Feeding Potentials of Star Apple (*Chrysophyllum albidum*) Kernel in Broiler Chickens’ is a record of my research work. It has neither been presented nor accepted in any previous application for a higher degree. All sources of information have being specifically acknowledged.

In addition, the research work has been ethically approved by the University Ethical Review Committee.

.....

Ajide, S.O.

.....

Date

DEDICATION

This thesis is dedicated to the Omnipotent Almighty God for the Grace He bestowed on me in the course of my Doctoral of Philosophy programme in University of Ilorin, to my Heart rob-my darling wife; Olayinka, my miracle Son; Daniel and siblings, my dear parents, Chief & Mrs T.S. Ajide and my loving siblings, Wole, Femi, Funmi and Rotimi for their financial support, incessant prayers, encouragement and moral support.

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LIST OF ABBREVIATIONS

CKM:	<i>Chrysophyllum albidum</i> Kernel Meal
RCKM:	Raw <i>Chrysophyllum albidum</i> Kernel Meal
ASAK:	African star apple kernel
ASAK ^{AC} :	African star apple kernel using activated charcoal
ASAK ^{BN} :	African star apple kernel using bentonite
ASAK ^P :	African star apple kernel using phytase
ASAK ^{PEG} :	African star apple kernel using polyethylene glycol
ANFs:	Antinutritional factors
PEG:	Polyethylene glycol
AST:	Aspartate Aminotransaminase
ALT	Alanine Aminotransaminase
ALP:	Alkaline phosphate Aminotransaminase

ABSTRACT

Maize constitutes the highest proportion of energy source in poultry diets. It is costly due to competition by man, industry and livestock. High rate of maize inclusion in diets translates to high cost of feed and reduce profit for livestock farmers. African Star Apple (*Chrysophyllum albidum*) Kernel (ASAK) is a potential alternative to maize because of its high energy content. The objectives of this study were to: (i) determine the proximate composition and phytochemicals of raw and processed ASAK; (ii) determine the optimum dietary inclusion level of raw ASAK; (iii) determine the effects of selected processing methods on the antinutritional contents and feeding value of ASAK; and (iv) determine the profitability of using ASAK meal in broiler diets.

Five experiments were conducted. Experiment 1 investigated the proximate composition, phytochemicals and inclusion levels of raw ASAK in broiler diets. Experiment 2-5 examined the effects of processing ASAK meal with activated charcoal, bentonite, phytase or polyethylene glycol (PEG) on the antinutritional contents, growth performance, serum biochemistry, haematology, liver histology and profitability of broilers. Data collected on the response variables were subjected to analyses of variance as appropriate for a Completely Randomized Design ($p < 0.05$).

The findings of the study were:

- (i) energy and crude protein obtained for raw ASAK were 3.93 kcal/g and 8.71%, while phytate, tannins and saponins were 1,308.70, 1,037.47 and 12.15mg/kg, respectively;
- (ii) broilers fed graded levels of raw ASAK meal had a significantly ($p < 0.05$) lower Weight Gain (WG), Feed Intake (FI) and Feed Conversion Ratio (FCR) compared with the control. The haematology and serum biochemistry were also significantly ($p < 0.05$) different across the dietary treatments, 10-30% Dietary Level (DL) showed abnormal AST, ALT, ALP, creatinine, urea with severe liver degeneration;
- (iii) Activated charcoal and bentonite increased the energy and crude protein contents of ASAK by 0.01kcal/g and 7.80%, 0.07 kcal/g and 2.62%, respectively. Phytase and PEG reduced the energy of ASAK by 0.08 and 0.14kcal/g and increased the crude protein by 2.73 and 2.41%, respectively, residual saponins, phytate and tannin content reduced significantly across the processing methods;

- (iv) broilers fed ASAK meal processed with activated charcoal, bentonite, phytase and PEG had significantly ($p<0.05$) poorer WG, FI, and FCR than the control at all dietary levels;
- (v) AST, ALT and ALP were abnormal with severe deposition of tars in the central vein of the liver in broilers fed activated charcoal processed ASAK and severe hepatocyte perturbation occurred in those fed PEG processed ASAK from 25-30% DL; and
- (vi) abnormal AST, ALT, ALP and severe liver degeneration occurred from 15 to 30% when bentonite and phytase processed ASAK were fed, while 20-30% DL of the later led to severe hepatocyte perturbation.

In conclusion, broilers fed processed ASAK meal performed better than those fed raw ASAK, while those fed the control diet performed significantly better than those fed raw and processed ASAK. This study therefore recommends further studies that will unravel the best method to enhance the nutritive value of the ASAK meal in broilers diet.

Word Count: 495.

CHAPTER ONE

1.0 Introduction

The human population is increasing at a very fast rate necessitating an increased need for animal protein which could only be met via abundant livestock production. Development of cheap alternative feeding materials is currently receiving immense attention by entrepreneurs, nutrition scientists and other researchers through evaluation of novel or unconventional feed resources like agro-industrial by-products. These approaches are to reduce the cost of production and competition among animals, industries and humans for conventional foods/feeds without affecting the dietary and reproductive performance of the livestock. Amaefule *et al.* (2006) reported their successes in the use of novel feed resources for feeding swine. The poultry industry in Nigeria has the potentials of meeting the supply of animal protein in the short time basis (Ilo *et al.*, 2011). The major constrain to the expansion of the poultry sector is feed, it accounts for about 70% of the cost of production (Ukachukwu and Osuagwu 2006). In any poultry diet, maize has the highest inclusion rate. This high inclusion level of maize causes an increase in the price of feed due to the increasing demand and seasonality in its availability for man and livestock (Agbede *et al.* 2002). Preston (1995) reported that the limiting factor to researchers in the tropics is inability to proffer novel feed resources for monogastric animals. Okoye (2002) reported that the poultry industry in Nigeria is challenged by exorbitant prices of feed ingredients. Some alternative novel feed resources are available but their nutritional composition are yet to be ascertained for animal feeding (Shittu *et al.*, 2006). African star apple seed kernels are a potential alternative novel

feed. There seems to be no reports using African star apple seed kernels in broiler nutrition.

African Star apple (*Chrysophyllum albidum*) originated from the Greater Antilles and the West Indies. It belongs to the sapotaceae family with a wide spread throughout the lowlands of Central America and cultivated in the entire Tropical world together with Southeast Asia. In Nigeria, *Chrysophyllum albidum* is known as Agbalumo, Agwaluma, Udara among the Yorubas, Hausas, and Ibos respectively. It is a natural indigenous wild fruit tree, its potentials for plantation establishment gives it relevance in Nigeria, Uganda, Niger Republic, Cameroon, Ivory Coast (Adewusi and Bada, 1997).

African star apple is a fruit tree mostly found in the southern part of Nigeria. The fruit is available in the urban and rural areas from December to April and cultivated in plantations. The fruits are not harvested on the trees but allowed to freely fall to the ground and subsequently gathered. The fruit has about five flat seeds which are enclosed in a milky pulp. An asterisk star like shape appears in the central core when sliced transversely from which the name “star apple” was coined (CENRED, 1999).

The African star apple fruit has earned its relevance as a commercial tree in Nigeria. The pulp could be used for the production of soft drinks and the residual cake for animal feeding (Ajewole and Adeyeye, 1991). Ukana *et al.* (2012) reported that the pulp contains valuable amount of crude fibre, fat, mineral matter and caloric value. Carbohydrate and crude protein in the fruit are higher in the seeds. Early reports (Ajewole and Adeyeye, 1991) found the crude protein, carbohydrate, crude fat, crude

fibre, total ash contents in seeds as 8.75, 83.38, 3.45, 2.42 and 2.00% respectively warranting the seeds as a good novel feed stuff in animal feed. Mineral elements analyses revealed that the pulp has greater amount of sodium and iron while the peels contain greater amount of potassium and zinc. Calcium and magnesium were higher in the seeds (Ukana *et al.*, 2012). The fruit has been found to contain high content of ascorbic acid with 1000 to 3,300mg Vitamin-C per 1000gram of edible fruit or about 100times that of oranges and 10 times that of guava or cashew (Adisa, 2000). The fruit contains about 90% anacardic acid which is industrially used for wood preservation. The roots and leaves are used for medicinal purposes (Adewusi, 1997).

The tree together with the fruit seeds contains phytochemicals or antinutritional factors such as saponin, cyanogenic glycoside, oxalate, phytate, tannin. These phytochemicals diminish the availability of nutrients at high concentrations (Ojako and Igwe, 2008). The antinutritional factors elicit toxic biological responses with possible physiological implications (Igile, 1996). Saponins inhibit nutrient uptake (carbohydrate, proteins) hence decreases growth rate and feed efficiency in monogastric animals. It influences the absorption of lipids, vitamins A and E and predisposes the animals to hypocholesterolaemia by binding cholesterol making it unavailable for absorption. Saponin also causes haemolysis of the red blood cells and has been demonstrated to have anti-spermal effects (Su and Guo, 1986; Pant *et al.*, 1989). Oxalates limit the metabolism of calcium and magnesium by binding with these minerals. It causes muscular weakness, paralysis, gastrointestinal tract irritation and blockage of the renal tubules by calcium oxalate crystals, development of urinary calculi and hypocalcaemia (Blood and Radostits, 1989). Oxalates is found to cause

nephritic lesions in the kidneys (Jones *et al.*, 1997). Phytates interfere with the digestion of protein by forming complexes with it. Tannins are plant polyphenols which have ability to form complexes with metal ions and with macro-molecules such as proteins and polysaccharides. Tannins decrease feed intake in animals especially monogastrics, bind dietary proteins including digestive enzymes to form complexes that are not readily digestible (Aletor, 1993). They also cause decreased palatability and reduced growth rate in animals (Roeder, 1995).

Preliminary evaluations of proximate, minerals and vitamin contents (Edem *et al.* 2011; Ukana *et al.* 2012) of star apple showed that it is very high in energy and other nutrients. Considering the nutrient composition of star apple seed kernels, there is need for research on the kernels for use in nutrition of poultry. Hence the need to investigate optimum inclusion level of the kernel meal in diets and proffer method(s) for detoxification in case of toxicity or antinutrient effects at higher inclusion in diets.

1.2 Significance of the Study

Chrysophyllum albidum is an important economic tree in Nigeria grown in plantations for its fruits. The fruits are harvested and consumed by man while the seeds generated in tons are discarded. The fruit kernel, if found useful by experiment, could be used as a cheap alternative energy nutrients source for feeding animals.

1.3 OBJECTIVES OF THE STUDY

- i. To determine the proximate composition and phytochemicals of raw and processed African star apple kernel.

- ii. To determine the optimum level at which the raw African star apple kernel meal could replace maize in diets of broilers.
- iii. To determine the effect of selected processing methods on the antinutritional contents and feeding value of African star apple kernel in broilers.
- iv. To determine the profitability of using processed African star apple kernel meal in the diet of broilers.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1.1 Description of the star apple tree

African star apple (*Chrysophyllum albidum*) is an economic tree in the forest, it belongs to the sapotaceae family. The fruit originates from different ecological zones in Nigeria, Uganda, Niger Republic, Cameroon and Coted' Ivorie. It has a height of 36.5m and atimes smaller (Bada, 1997). The fruit has about 4 to 5 seeds. It is a crop of commercial relevance in Nigeria. The fruit has a fleshy pulp that is consumed by children and adult (Cenred, 1999). It has a high vitamin C level in the range of 1000 to 3,300mg per 1000gm of edible fruit. The vitamin C content is 10 and 100 times that of orange and guava/cahew respectively (Adisa, 2000). In the industries, anacardic acid is extracted from the fruit for wood preservation. The roots and leaves also serve as medicinal purposes (Adewusi, 1997).

Scientific classification

Kingdom: Plantae

Phylum: Angiosperm

Unmarked: Eudicots

Unmarked: Asterids

Order: Ericales

Family: Sapotaceae

Sub-family: Chrysophyllorideae

Genus: *Chrysophyllum*

Specie: *albidum*

2.1.2 Description of star apple seed

Chrysophyllum albidum seeds are shiny and have a bean like shape. The colour of the seed is brown with a hard shell. The kernels of the seeds are processed for treatment of skin and vagina infection in the western part of Nigeria (Adewusi, 1997; Adisa, 2000; Madubuike and Ogbonnaya, 2000). The seeds of *Chrysophyllum albidum* are processed as tonic for ameliorating diarrhea in Venezuela (Julia, 1987).

2.2 Origin of Star Apple

The debate on the origin of the star apple remains unresolved with some botanist claiming that it originated from Central America and others of the view that it is from the West Indies. The Jamaicans, Haitians, Puerto Ricans use it for production of drinks. The fruit is well adapted to the low to medium altitudes in Mexico and Panama. Reports revealed that the Indians began the cultivation of the seeds in 1802 in the southern states close to Srilanka. The fruit trees is being cultivated in other countries involving Zanzibar, Cuba, Vietnam, the Philippines, Benin, Nigeria, Peru, and Argentina. The fruit tree is grown in Florida and Hawaii on a limited scale in the United States. Records show that, it was a Spanish explorer (Cniezadeteon) who made the first documentation in the 1500 when he found it growing in Peru (Julia, 2013).

The fruit was subsequently found to be growing in the Philippines, Panama, Guatemala, the Caribbean Islands, Zanzibar and the warmer parts of India. The United States Department of Agriculture obtained some seeds from Jamaica in the late 1800's and cultivated it in Florida and Hawaii respectively. The warm to hot

tropical climate is found to be approximately suitable for growing the star apple tree. It cannot tolerate cold especially the young trees. The trees are usually grown on small scales or by the road sides (Julia, 2013).

2.3 Varieties of Star apple

The African star apple (*Chrysophyllum albidum*) is reported to be present in different ecological zones of Nigeria, Uganda, Niger, Cameroon, and Cote d'Ivoire (Bada, 1997). The varieties of *Chrysophyllum albidum* available in the West and Central Africa include *Chrysophyllum africanum*, *Chrysophyllum giganteum*, *Chrysophyllum akusae*, *Chrysophyllum pruniforme*, *Chrysophyllum ubangiense* (Wikipedia, 2016).

2.3.1 The plates below present the varieties of *Chrysophyllum albidum*



Plate 2.3.1.1: *Chrysophyllum acrocarpum*



Plate 2.3.1.2: *Chrysophyllum africanum*

Source of varieties of *Chrysophyllum albidum*: Adepoju and Adeniji (2012).



Plate: 2.3.1.3: *Chrysophyllum akusae*



Plate: 2.3.1.4: Cross section *C. albidum* fruit



Plate 2.3.1.5: *C. albidum* seeds



Plate 2.3.1.6: *C. albidum* seed kernels

2.4 Utilization of *Chrysophyllum albidum*

In republic of Benin, Laurent *et al.* (2012) reported three main uses of the fruit which include food, medicinal and fire wood. In Nigeria, the tree is highly regarded in Traditional medicine (Odugbemi *et al.*, 2007). The fruit is processed and used for drinks, jelly and other purposes (Oyelade *et al.*, 2005). The fruit pulp could be useful for the production of wine and alcohol. It is rich in unsaturated fatty acids which could be used in reducing the incidence of heart disease in humans. The seed could be processed for animal feeding (Ajewole and Adeyeye, 1991). The leaves of

Chrysophyllum albidum is used for nutrient recycling by enhancing the top soil (Adesina, 2005). The rich linoleic (38.4%) and oleic acid (29.6%) makes it useful for free fatty acid production (Akubugwo and Ugbogu 2007). The seeds are discarded due to paucity of information on it and unavailability of facilities to process it in southern Benin, Ghana and Nigeria which may be responsible for the minimal cultivation of it on commercial basis (Edem *et al.*, 2011).

The bark of *Chrysophyllum albidum* tree is used for the treatment of yellow fever and malaria while the leaves are processed as emollients. The cotyledon of the seed is used for the production of eleagnine. Eleagnine is an alkaloid that has anti-inflammatory and antioxidant activities (Idowu *et al.*, 2006). The fruit pulp are consumed and other components of the trees are used for treating several diseases. The fruit contributes to food security and income for rural dwellers. The *Chrysophyllum albidum* presently faces extinction, therefore the need to protect the existing trees and also encourage its cultivation in the urban areas is important. In achieving this goal, proper agronomic practices and development of improved varieties will need to be in place where the fruit trees is gradually facing extinction due to urban expansion (Laurent *et al.* 2012).

2.5 Nutrient composition of African star apple and their relevance

The biological, chemical and physical scores are useful in the assessment of any feedstuff. Chemical score is vital in assessing the nutrient composition of any feed because it takes cognizance of the proximate composition which includes protein, carbohydrate, lipid, moisture, ash and dietary fibre (Eddy and Udo, 2004).

2.5.1 Moisture level of African star apple

Moisture contents of the star apple peel, pulp and seed were 47.95%, 32.65% and 26.55% respectively with an average of 35.76%, these clearly shows that peel contain much moisture. The moisture content is the most vital index used in food processing, the seeds of *Chrysophyllum albidum* could be easily preserved due to the low moisture content of the seed (Ukana *et al.*, 2012). Edem *et al.* (2011) reported the moisture content of *C. africanum* as 66.67% and higher than the value of 42.10% reported by Amusa *et al.* (2003). This implies that *C. africanum* fruits may have a short shelf life due to its high moisture content.

2.5.2 Carbohydrate Content of African star apple

Ukana *et al.* (2012) reported the carbohydrate levels in the African star apple peel, pulp and seed as 79.39%, 79.03% and 83.38% respectively. The carbohydrate level of 78.34% reported by Edem *et al.* (2011) in the seed is also similar to the value reported by Ukana *et al.* (2012). The values reported by these authors are higher than the value of 67.60% earlier reported by Amusa *et al.* (2003). However the range in the values reported by the above authors attests to the high carbohydrate content of the African star apple. The range in the soluble carbohydrate of 44.8- 69.6% reported by Sule *et al.* (2014) for maize gives credence to the high carbohydrate content of African star apple seed kernels.

2.5.3 Crude protein content of African star apple

Ukana *et al.* (2012) reported the crude protein contents of star apple peel, pulp and seed as 6.68%, 4.73% and 8.75% respectively with an average of 6.73%. Edem *et al.* (2011) reported the average crude protein of 5.66% for *C. africanum*. The value is

lower than 8.75% earlier reported by Amusa *et al.* (2003). The crude protein could be enhanced by dehydration of the fruits (Igboh *et al.*, 2009). Agbabiaka *et al.* (2013) reported the crude protein content of the raw and fermented star apple kernels as 10.13% and 14.49 % respectively. The increase in the crude protein value of the fermented kernel could be as a result of the microbial activities via fermentation. The author attested to the similarity in the crude protein content of the African star apple seed kernels with some conventional energy feedstuff (maize and millet) with a crude protein of 9-10%.

2.5.4 Crude fat of African star apple

Ukana *et al.* (2012) reported the ether extract levels in the African star apple peel, pulp and seed as 8.94%, 10.00% and 3.45% respectively with an average of 7.46%. Amusa *et al.* (2003) earlier reported the ether extract level of the African star apple as 16.20% and higher than the values reported by Edem *et al.* (2011) as 9.38% and 7.46% by Ukana *et al.* (2012), respectively. Agbabiaka *et al.* (2013) reported the crude fat content of the raw and fermented African star apple seed kernels as 9.72% and 4.94% respectively. The crude fat was higher than the value of 3.9% obtained for sweet maize (Cortez, 1999).

2.5.5 Crude fibre of African star apple

Ukana *et al.* (2012) reported the values of 1.83%, 3.0% and 2.42% for the star apple peel, pulp and seed respectively with an average of 2.41%. The crude fibre content was higher in the pulp and lower in the peel. Previous authors (Amusa *et al.*, 2003; Edem *et al.*, 2011) reported the crude fibre content of *C. africanum* fruit to be 4.50%.

2.5.6 Ash Contents of African star apple

Ash content indicates the amount of inorganic matter and oxides present in the sample. It is the determinant factor of the mineral constituents in the sample. The ash content was reported to be 3.15%, 3.25% and 2.00% for the peel, pulp and seed respectively with 2.80% as the average ash content of the fruit according to the report of Ukana *et al.* (2012).

2.5.7 Mineral composition of African star apple and their importance

The sodium content of the star apple peel, pulp and seed were 43.858, 69.382 and 37.516 mg/kg respectively with an average of 50.25mg/kg (Ukana *et al.*,2012). Sodium is the principal extracellular cation and is used for acid base balance and osmoregulation in inter modular fluid. Ukana *et al.* (2012) reported the potassium contents of 62.262, 5.965, and 41.416mg/kg for the star apple peel, pulp and seed respectively with an average of 36.72mg/kg. Potassium content of the peel is the highest while that of the pulp is the least. Potassium is an essential cation in the intracellular fluid, it functions in acid base balance, conduction of nerve impulse and in cell membrane function, its deficiency results in muscular weakness, paralysis and mental confusion (Murray *et al.*, 2000).

Calcium contents in the star apple peel, pulp and seed were 8.25, 40.99 and 71.52mg/kg respectively with an average of 40.56mg/kg. That of the peel was very low as compared to that of the pulp and seed (Ukana *et al.* 2012). Calcium is essential in enzyme activation, membrane permeability and also involved in normal transmission of nerve impulses (Murray *et al.*, 2000). The magnesium content in the star apple peel, pulp and seed were 6.16, 3.52, and 29.49mg/kg respectively with an

average of 13.02mg/kg (Ukana *et al.* 2012). Magnesium is vital in many enzyme activities such as oxidative phosphorylation. Oxidative phosphorylation is inhibited in the absence of magnesium (Murray *et al.*, 2000).

The iron level obtained in the star apple peel, pulp and seed were 37.33, 40.11 and 6.22 mg/kg respectively with an average of 27.89 mg/kg (Ukana *et al.* 2012). Iron functions in the transport of oxygen, it is a vital component of the haemoglobin. Its deficiency causes anaemia which is more severe in pigs (Murray *et al.*, 2000). The values of zinc reported by Ukana *et al.* (2012) for the star apple peel, pulp and seed were 13.46, 6.83 and 1.76mg/kg respectively. The average zinc content was 7.35mg/kg. Zinc is present in many plant and animal tissues, it is involved in cell replication (Arinola, 2008).

2.6 Importance of Tree crops to Animal Feeding

Tree crops are vital for food security, health, social and economic welfare of rural communities (FAO, 1989). These tree crops contribute significantly to the nutritional needs of humans and animals. Adequate information of these trees will enhance their conservation, contribution to food and increased productivity (Adepoju and Adeniji, 2012). The fruits from these trees directly contribute to food security, although the quantity may be small but they are relevant in certain periods of the year especially during the dry season (Holskins, 1985). There is an increasing awareness about the relevance of these wild fruit trees in localities where found with regard to the nutritional demands of the people (Melgarejo *et al.*, 1995). *Chrysophyllum albidum* is a tree crop mostly grown in the south western region of Nigeria. It belongs to the sapotaceae family. The fruit is available between December and April. The pulp is

consumed while the seeds are peels are discarded. Its contribution to animal feeding is yet to be fully investigated (Adepoju and Adeniji, 2012).

2.7 Phytochemicals in novel feedstuff and their effect on the animals

There is an array of plants with active biological constituents used for feeding animals and humans. The compounds in these plants exhibit toxic and positive physiological implications (Igile, 1996). Some of these plants contain antinutrients obtained either via fertilizer, pesticides while some are intrinsic (Igile, 1996). The phytochemicals in these plants could have deleterious effects on the health or confer some benefits to humans and animals if consumed moderately (Kersten *et al.*, 1991; Sugano *et al.*, 1993). The presence of antinutritional factors in the animal's ration diminishes the animal's productivity incases where the animals are confined and during off seasons when the conventional feed resources are not readily available (Kumar, 1992). The common phytochemicals mostly present in novel feedstuff include saponins, tannins, flavonoids, alkaloids, trypsin inhibitors, oxalates, phytates, haemagglutinins (lectins), cyanogenic glycosides and gossypol etc.

2.7.1 Saponins

Saponins are a heterogeneous group of foam-producing triterpene or steroidal glycosides that occur in an array of plants such as oilseeds and pulses involving cowpea, chickpea, soybean, groundnut, lupin and sunflower (Jenkins and Atwal, 1994). Saponins inhibit the permeability of the cell wall and exhibit some side effects when consumed (Belmar *et al.*, 1999). Annongu, (2012) reported that saponins affects the absorption of nutrients across the intestinal wall by binding to the cells of

the small intestine. Saponins have being shown to reduce growth rate, feed efficiency and affects the absorption of lipids, cholesterol, bile acid, vitamins A and E in chicks (Jenkins and Atwal, 1994). Nkwocha, (2014) reported that saponins assert physiological effect in lowering the level of plasma cholesterol concentration in albino rats. Reports revealed that saponin from *Bulbostemma paniculatum* and *Pentapamox leschenaultii* have effects on semen quality in man (Su and Guo, 1986; Pant *et al.*, 1989).

2.7.2 Tannins

Tannin is an anti-nutritional factor mostly found in cereal and legumes. It binds protein and impairs the digestion of protein (Olomu, 1995). Elkin *et al.* (1990) and Douglas *et al.* (1993) reported depressed growth rate and reduced feed efficiency in poultry fed diets containing tannins. Tannin causes the astringent taste of feed which inturn causes decreased feed intake due to reduced palatability (Tapiers *et al.*, 2002). The presence of tannins in poultry ration reduce dry matter intake, body weight gain, feed efficiency and nutrient digestibility (Hassan *et al.*, 2003; Ravindran *et al.*, 2006). Ortiz *et al.* (1994) reported that chicks fed diets containing tannin revealed histological changes in the ileal mucosa and hydropic degeneration of the liver hepatocytes. Inclusion of mucuna seed meal at 15% containing tannins was reported to have a deleterious effect on the blood parameters (Esonu *et al.*, 2001). However, Medugu *et al.* (2010) was of a contrary opinion that replacement of maize with sorghum having high and low tannin content had no adverse effect on the blood parameters and carcass components of broiler chickens. Tannins interfere with digestion by altering trypsin and amylase activities (Akande *et al.* 2010). Complexes

are formed between tannins with proteins, carbohydrates and minerals preventing their bioavailability to the animals (Waghorn *et al.*, 1994; Hagerman *et al.*, 1998; Parr and Bolwell, 2000).

2.7.3 Phytate

Adequate information on the effect of phytate on animals is important as it affects digestibility adversely. Availability of calcium, zinc, iron and other minerals are inhibited in the animal's body due to the binding effect from phytic acid (FAO, 1990). Phytic acid is present in reasonable levels in virtually all plants especially the legumes and oil seeds which include rape seed, cotton seed and soyabeans. In cereals and legumes seeds, about 62-73% and 46-73% are organically bound phytin phosphorus respectively (Matyka *et al.*, 1993). The absence of phytase enzymes in the digestive tract of monogastrics makes the phosphorus bound in phytic acid unavailable to the animals. Chelates are formed when phytic acid forms complexes with protein and minerals, thereby reducing the bioavailability of protein and minerals to the animals (Khare, 2000). Akande *et al.* (2010) reported that insoluble complexes are formed when phytic acid chelates with metal ions which include calcium, magnesium, zinc, copper, iron and molybdenum preventing their absorption in the gastrointestinal tract of the birds.

2.7.4 Oxalate

The metabolism of calcium and magnesium is affected when oxalates binds with protein thereby forming complexes that inhibit digestion. Calcium oxalates are formed when oxalic acid binds with calcium making it insoluble. The absorption and utilization of calcium in the animal's body is adversely affected by calcium oxalate

(Olomu, 1995). Substantial amount of soluble oxalate in the body inhibits the absorption of soluble calcium ions which in turn forms a complex of calcium oxalate that is insoluble thereby causing kidney stones (Adeniyi *et al.*, 2009).

2.7.5 Cyanogenic glycoside

Many plants and seeds contain cyanogenic glycosides. Hydrogen cyanide is usually formed when animals macerate fresh plants during chewing thereby making the enzymes and cyanogenic glycosides release hydrogen cyanide (cyanogenesis). The process through which plants produce hydrogen cyanide gas (HCN) so as to defend themselves against herbivores is known as cyanogenesis (Feedstuff database, 2007). The primary symptom of hydrogen cyanide poisoning involves intensive breathing, tetany, convulsions, paralysis and death. Pigs fed raw cassava containing 500mg/kg hydrogen cyanide suffered from chronic intoxicification (Feedstuff database, 2007).

2.8 Different processing methods for alleviating the toxic effect of the antinutritional factors in the animals

The antinutritional factors in plants have different biochemical effects on animals and man. Substantial levels of these phytochemicals in the plants can be eliminated by different methods such as boiling, soaking, germination, autoclaving, fermentation, genetic manipulation and other processing methods (Soetan, 2008). Some processing methods have been proffered to eliminate the phytochemicals in novel feedstuff. They are grouped into physical and chemical methods.

2.8.1 Some physical methods for removing antinutritional factors in feedstuff include:

2.8.1.1 Cooking

Bressani (2002) reported that cooking reduces antinutritional factors in non conventional feedstuff by 15%. The nutritional values of root and tuber crops were improved via cooking and useful in the elimination of antinutritional factors (Agwunobi *et al.*, 2002). Ogundipe *et al.* (2008) reported a decrease in the tannin content after 30 minutes of cooking. Thirty minutes of cooking reasonably eliminated the antinutritional factors in most legume seeds (Balogun *et al.*, 2001). Buba *et al.* (2010) reported a decrease in the antinutritional factors of sickle pod (*Cassia tora*) seed after cooking for 45 minutes. There was a detrimental effect on the performance of broiler chickens fed cooked *Napoleona imperialis* meal (Uchegbu *et al.*, 2008). Bressani (1993) had earlier reported that cooking for 60 minutes at 100°C may denature the protein resulting in loss of vitamins and minerals in legume seeds. Trugo *et al.* (1990) reported 90% decrease in the trypsin inhibitor of *phaseolus vulgaris* after cooking for 60 minutes at 100°C.

2.8.1.2 Soaking

Soaking is a physical method that is employed for the removal of soluble antinutritional factors. It is accompanied by metabolic reactions that alters some of the components of the feed ingredient (Vidal-Valverde *et al.*, 1992). Soaking of feedstuff for 24 hours was found useful in the reduction of tannins and cyanide in non conventional feedstuff (Ahamefule and Odemelam, 2008). Iyayi and Losel (1999) recommended the soaking for reducing the level of tannins in legumes and cereal grains. However, Dhurandhar and Chang (1990) were of the opinion that soaking of

navy and red kidney beans for 16 hours had no significant effect on the activities of the trypsin inhibitor. Trugo *et al.* (1990) also reported no effect of soaking on the antinutritional factors in black beans when soaked in water for 16 hours.

2.8.1.3 Toasting/Roasting

Toasting soybean is effective in the reduction of antinutritional factors which causes growth retardation in chickens (Akpodiete *et al.*, 2001). The dietary inclusion of roasted fluted pumpkin pod husk did not affect feed intake and eventually enhanced the performance of broiler chickens fed the diet (Omoikhoje *et al.*, 2009). The challenge associated with toasting is the charring of the seed if not stirred adequately (Abeke and Otu, 2008). Esonu *et al.* (1998) revealed that the sole application of toasting as a processing method may not resnably decrease the antinutritional factors in jackbeans.

2.8.2 Some chemical methods for removing antinutritional factors in feedstuff include:

2.8.2.1 Activated charcoal

The absorptive properties of charcoal cannot be over emphasized. It acts on the gastrointestinal tract by absorbing gases such as hydrogen sulfide, ammonia, binding mycotoxins produced by fungi (Edrington *et al.*, 1997). The mineral content of charcoal form bases with water, lowers the surface tension of digesta, emulsify fat thereby enhancing the function of the liver (Majewska and Siwik, 2006). Activated charcoal has an excellent adsorptive capacity. It is recommended as a good absorbent for many digestive toxicities (MVM, 1994). It absorbs toxins and increases the feed intake of poisonous plants. The growth performances of broiler chickens were

enhanced in the broiler starter phase when wood charcoal was included in their diet (Kutlu *et al.*, 2001). The reports of Odunsi *et al.* (2009) revealed that wood charcoal was effective in the removal of the antinutrients in the neem (*Azadirachta indica*) seed cake for cockerel chickens when pretreated with wood charcoal at 4kg/tone.

2.8.2.2 Bentonite

Bentonites is an absorbent which acts as gut protectants (enterosorbents) when incorporated in animal feed. It binds to aflatoxins in the digestive tract of animals and reduces the absorption of toxins (Grant and Phillips, 1998; Phillip *et al.* 2002). Reports by Schell *et al.* (1993) and Santurio *et al.* (1999) revealed that bentonite ameliorated the effects of toxins on the function of the liver. Dietary supplementation of poultry diet with 5% bentonite enhanced the feed intake and weight gains of chickens that were deficient in essential vitamins, proteins, micro and macronutrients (Southern *et al.*, 1994). The modified forms of natural mortmorillonites (bentonite) have an array of different technological applications.

Investigations on the use of bentonite in animal nutrition are presently receiving attention (Slivka, 2002).

2.8.2.3 Phytase

Many attempts have being made to assess the effect of removing phytate from animal feed. For instance, Newkirk and Classen (2001) reported that the pretreatment of canola meal with phytase enzyme for broilers in order to eliminate phytate improved the nutritional value of the diet. This further enhanced the amino acid digestibility and feed conversion ratio. The authors concluded that changes in the phosphate levels owing to the hydrolysis of phytate makes conclusions regarding the effect of phytate

difficult. Eliminating the effect of phytate in a diet may not enhance the growth performance of the animals except the digestive amino acid and energy concentrations are in optimum levels to promote growth. Therefore to achieve optimum responses, increasing the concentration of different enzymes (phytase) should be exploited (Cowieson *et al.*, 2016).

2.8.2.4 Polyethylene glycol

Different processing methods have being proposed for the detoxification of tannins in grains, seeds, browses plants and agro-industrial by products (Makkar, 2000). Salunkhe *et al.* (1990) reported that polyethylene glycol (PEG) has high affinity for tannins and prevents it from binding to nutrients in the feed. It has been shown that polyethylene glycol having a molecular weight of 4000g has a very high affinity for tannins and is the most effective means of neutralizing tannins in feedstuff (Silanikove *et al.*, 2001). Complexes are formed between PEG and tannins which may reduce the hydrolysis of lipases and subsequently affect the absorption of fatty acid in the small intestine. This could further decrease the circulating triglyceride accompanied by low synthesis of hepatic lipoproteins. This makes the inclusion of PEG limited in improving the growth performance of animals (Imik and Gunlu (2011).

CHAPTER THREE

3.0 Experiment One: Evaluation of the chemical composition and feeding potential of raw African star apple kernel at graded levels in broilers

3.1 Introduction

Some plants used for feeding animals contain antinutritional factors which are biologically-active constituents and referred as “secondary metabolites”. In *Chrysophyllum albidum*, they include saponin, cyanogenic glycoside, oxalate, phytate, tannins. Some of these phytochemicals exhibit adverse effects on the health and atimes confer nutritional advantage to humans and animals if consumed at moderate levels (Kersten *et al.*, 1991; Sugano *et al.*,1993). Antinutritional factors (ANFs) can be defined as substances produced in natural food/feedstuffs by the normal metabolism of species and by different mechanisms like inactivation of some nutrients, diminution of the digestive process or metabolic utilization of feed which exert effects contrary to optimum nutrition (Kumar, 1992). Effects of antinutritional factors are more pronounced in monogastric animals due to their simple stomach unlike in ruminants with four stomach compactment. Antinutritional factors such as saponins, tannins and trypsin inhibitors have side effects on animals which include poor feed conversion ratio, decreased growth rate and intermittent scouring (Yakubu and Wafar, 2014). Thus the utility of the seed kernel of *Chrysophyllum albidum* containing saponin, cyanogenic glycoside, oxalate, phytate, tannin may be limited in poultry by the presence of these ANFs (Kumar, 1992).

3.2 Objective

The objective of this study was to determine the main phytochemicals in *C. albidum* and the optimum level in which the broiler chickens can tolerate the kernel meal when fed raw.

3.3 Materials and Methods

3.3.1 Experimental site

The experiment was carried out in the Poultry Unit of the Teaching and Research Farm, Landmark University, Omu-Aran, Kwara State.

OmuAran has a humid tropical climate with a mean annual rainfall of 1,367mm, occurring between the months of April and November. The dry season lasts from November to early April. The mean minimum and maximum daily temperature is between 25°C and 28°C in the hot season from February to March. The lowest temperature recorded is 20°C during the peak of the harmattan season in January. The relative humidity is 25.53%.

3.3.2 Source of experimental birds

A total of 210 day-old Marshall breed of broiler birds were obtained from Zartech farms at Ibadan, Oyo State, Nigeria.

3.3.3 Collection of star apple seeds

The fruits of *C. albidum* for this study were collected from the various star apple plantations in Osun state, Nigeria. The seeds were obtained from the fruit and

thoroughly washed to remove the foreign materials, immature or broken seeds. They were further dehulled to obtain the kernels.

3.3.4 Experimental diet

Kernels of *C. albidum* were properly dried in the sun to a constant weight and milled for replacing maize in the diets. Seven experimental diets were formulated made of a corn-soy reference diet and six other diets containing raw African star apple kernel (ASAK) meal at graded levels of 0, 5, 10, 15, 20, 25 and 30% corresponding to diets 1, 2, 3, 4, 5, 6 and 7 respectively. The composition of the experimental diets for the broiler starter and finisher phases on as fed basis are presented on Tables 3.1 and 3.2, respectively. The proximate composition of the broiler starter and finisher are presented in Table 3.3 and 3.4 respectively.

3.3.5 Management of experimental birds and data collection

A total of 210, one-week old broiler chicks were used for the trial. The experiment was designed as a complete randomized design. The dietary treatments contained three replicates with 10 chicks per replicate. All the birds were raised under similar management practices (brooding, lighting, feeding and watering) throughout the eight week experimental period for both the starter and finisher phase except for the diets offered that differed. The birds were given feed and water *ad-lib* and weighed weekly. Routine vaccinations and medications were carried out as at when due.

Table 3.1: Composition of the experimental diets for broiler starter (Kg/100Kg)

Diets	T1	T2	T3	T4	T5	T6	T7
Kernel Meal levels %	0	5	10	15	20	25	30
Maize	56.46	53.63	50.81	47.99	45.17	42.34	39.52
Star apple kernel meal	0.00	2.83	5.65	8.47	11.29	14.12	16.94
Soya bean meal	38.04	38.04	38.04	38.04	38.04	38.04	38.04
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Limestone	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin.premix	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100	100	100	100	100	100	100

Calculated analysis of the diets

Feed cost/Kg(₦)	106.00	104.30	102.70	101.10	99.40	97.70	96.10
Crude Protein (%)	22.99	22.63	22.40	22.18	21.95	21.73	21.50
Fat (%)	3.74	3.63	3.52	3.40	3.29	3.18	3.06
Crude fibre (%)	4.02	3.95	3.87	3.79	3.72	3.64	3.57
Ash (%)	1.07	1.04	1.00	0.96	0.93	0.89	0.85
Calcium (%)	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Phosphorus (%)	0.54	0.53	0.52	0.52	0.51	0.50	0.49
Lysine	1.25	1.24	1.23	1.23	1.22	1.21	1.20
Methionine	0.57	0.56	0.55	0.55	0.54	0.54	0.53

Table 3.2: Composition of the experimental diets for broiler finisher (Kg/100Kg)

Diets	T1	T2	T3	T4	T5	T6	T7
Kernel Meal levels %	0	5	10	15	20	25	30
Maize	63.91	60.71	57.52	54.32	51.13	47.93	44.74
Star apple kernel meal	0.00	3.20	6.39	9.59	12.78	15.98	19.17
Soya bean meal	30.19	30.19	30.19	30.19	30.19	30.19	30.19
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bone meal	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Limestone	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin.premix	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100	100	100	100	100	100	100

Calculated analysis of the diets

Feed cost/Kg(₦)	106.00	104.30	102.70	101.10	99.40	97.70	96.10
Metabolizable energy kcal/kg	3153.71	3137.76	3121.86	3105.90	3089.99	3074.04	3058.14
Crude Protein (%)	20.00	19.74	19.49	19.23	18.97	18.71	18.60
Fat (%)	3.77	3.64	3.51	3.38	3.25	3.13	3.00
Crude fibre (%)	3.71	3.63	3.54	3.46	3.37	3.28	3.20
Ash (%)	1.17	1.13	1.09	1.05	1.00	0.96	0.92
Calcium (%)	1.16	1.16	1.16	1.16	1.16	1.16	1.16
Phosphorus (%)	0.65	0.64	0.63	0.62	0.61	0.60	0.59
Lysine	1.08	1.07	1.06	1.05	1.05	1.04	1.03
Methionine	0.54	0.53	0.53	0.52	0.51	0.51	0.50

Table 3.3: Analysed nutrient content of experimental diets for broiler starter

Diets	T1	T2	T3	T4	T5	T6	T7
CKM %	0	5	10	15	20	25	30
Dry matter (%)	90.15	90.37	90.13	90.18	90.67	90.19	90.08
Crude protein (%)	23.20	21.91	22.41	21.98	22.78	23.64	22.99
Ether extract (%)	2.47	2.90	2.70	2.71	2.46	2.36	2.02
Crude fibre (%)	2.64	2.62	2.30	2.77	2.70	3.31	3.06
Ash (%)	8.64	8.11	7.34	9.45	8.59	9.33	7.13
NFE (%)	63.05	64.46	67.53	63.09	63.47	61.36	64.80

Table 3.4: Analysed nutrients content of experimental diets for broiler finisher

Diets	T1	T2	T3	T4	T5	T6	T7
CKM %	0	5	10	15	20	25	30
Dry matter (%)	89.06	89.34	89.30	89.32	89.30	89.15	89.26
Crude protein (%)	19.80	20.51	21.11	21.59	21.57	21.68	21.49
Ether extract (%)	2.21	2.16	2.14	2.09	2.13	2.10	2.04
Crude fibre (%)	2.03	2.50	3.02	3.23	3.47	3.48	3.46
Ash (%)	6.94	7.13	7.52	6.56	6.97	6.46	6.52
NFE (%)	69.02	67.70	66.53	66.53	65.86	66.28	66.49
Gross energy kcal/g	1,026.95	903.68	458.07	443.87	436.03	435.09	348.29

3.3.6 Data collection/response criteria

In the course of the experiment, data were collected on the following performance characteristics: (a) feed consumption, (b) daily weight gain, (c) growth rate, (d) feed conversion ratio, (e) survival rate. At the end of the eight weeks study period, three birds per treatment were randomly selected based on the group average and were weighed, slaughtered and eviscerated for carcass evaluation. The birds were fasted for 12 hours before slaughtering, bled and the slaughter weight taken. The birds were defeathered manually using hot water and eviscerated. The live weight and carcass weight were recorded. The dressing percentage was calculated. Organ weights and the major primal carcass parts were expressed as percentages of the live weight.

3.3.7 Nutrient digestibility trial

The study on apparent nutrient digestibility was carried out at the end of the 8th week of the experimental period. Three birds per treatment were randomly selected and transferred to clean metabolic cages and fed the corresponding treatment diets. The trial lasted for eight days. The first four days were considered as adaptation period and the last four days as experimental period. Records of feed intake and faeces voided were taken during the last four days. The droppings were oven dried, bulked and representative samples were taken for chemical analysis. The samples were analyzed for proximate composition according to the methods of AOAC (1990).

$$\text{Apparent Nutrient Retention} = \frac{\text{Nutrient intake} - \text{Nutrient in faeces}}{\text{Nutrient intake}} \times 100$$

3.3.8 Serum biochemical and haematology analysis

At the end of the experiment, one broiler per replicate in all the treatments was taken at random and blood collected by decapitation. Blood for serum biochemical indices was collected in bottles without EDTA for the analysis of the serum biochemical parameters of (a) blood electrolytes: Ca, Na, K, Cl, and bicarbonate, (b) blood glucose level, (c) total protein, (d) albumin, (e) globulin, (f) albumin/globulin ratio (g) total cholesterol (h) creatinine (i) urea (j) lipid profile (HDL and LDL), (k) transaminase activities- AST, ALT ALP etc. The samples were spurned in the centrifuge at 3,000 rpm and the clearer portion (serum) decanted after centrifugation into another set of plain bottles and were placed in an ice bath and taken to the laboratory.

The blood samples for haematology parameters were pretreated with ethylene diamine tetra-acetate (EDTA), an anti-coagulant and were placed in the refrigerator (4°C) immediately before taken to the laboratory. Haematology indices examined include white blood cell (WBC) and its differential counts (neutrophils, lymphocyte, monocyte, eosinophil and basophils), red blood cell (RBC), packed Cell Volume (PCV), haemoglobin (Hb). The mean cell volume (MCV), mean cell haemoglobin (MCH) and the mean cell haemoglobin concentration (MCHC) were calculated from the values of the RBC, PCV and Hb respectively.

$$MCV = \frac{PCV}{RBC} \times 10$$

$$MCH = \frac{Hb}{RBC} \times 10$$

$$MCHC = \frac{Hb}{PCV} \times 100$$

3.3.9 Histology of the liver

Three birds were selected per treatment at the end of the feeding trial and sacrificed to obtain the liver. Sections were obtained from the anterior lobe of the liver, preserved in 90% saline + 10% formalin solution. The liver tissues from each replicate were processed for histological studies using haematoxylin and eosin stains. Photomicrographs were taken using a digital microscope with a magnification of 400. The analysis was carried out at the histopathological Laboratory of Faculty of Veterinary Medicine, University of Ilorin.

3.4 Statistical analysis

Data collected on the response criteria were subjected to analysis of variance according to the completely randomized design model and differences between treatment means were separated using the Duncan's multiple range test (Steel and Torrie, 1980).

3.5 Chemical analysis of raw *Chrysophyllum albidum* kernel

Proximate composition of the raw ASAK meal was conducted following the procedures of AOAC (2005). The meal was analysed for dry matter, nitrogen free extract, crude protein, ether extract, crude fibre and mineral matter. The soluble carbohydrate was obtained by difference of $100 - \%CP + \%CF + \%Ash + \%EE + \%moisture$. The gross energy was determined by the formula method stated by Carpenter and Clegg (1956).

$$GE \text{ Kcal/g} = CP \times \frac{5.8}{100} + EE \times \frac{9.3}{100} + CF \times \frac{4.2}{100} + NFE \times \frac{4.2}{100}$$

The proximate analysis, phytochemical screening, amino acid profile, water and fat soluble vitamin analysis, macro and micro mineral element analysis of the African star apple kernel meal were carried out in the department of biochemistry laboratory, University of Ilorin. The haematology and serum biochemical analysis of the blood samples together with the histology of the liver of the birds were analyzed in the haematology and histopathology laboratories respectively in the Faculty of Veterinary Medicine, University of Ilorin.

Quantification of the phytochemicals in the raw kernel meal was carried out using the methods described by Sofowora (1993) for the detection of saponins, tannins, phenolics, glycosides and flavonoids etc. Ascorbic acid, fat and water soluble vitamins were determined by the methods of Ayekyaw (1978). The method described by AOAC (2005) was used for mineral analysis. The amino acid profile was determined by the method outlined by Yasuma and Ichikawa (1953). The phytochemical analysis was carried out at the Central Research Laboratory, Tanke, Ilorin.

3.6 Results

3.6.1 Chemical evaluation of the raw African star apple kernel meal

Table 3.5 presents results of proximate composition of the raw ASAK meal. The ASAK meal contained valuable nutrients. The phytochemical content of *C. albidum* is presented on Table 3.6. *C. albidum* contains very high amount of phytate, tannins, flavonoids and total phenolics. It has appreciable amounts of saponins, low amounts of oxalate and terpenoids, respectively.

Table 3.5: Proximate composition of African star apple kernel

Parameters	%
Dry matter	91.38
Crude protein	8.71
Ether extract	3.10
Ash	4.79
Crude fibre	7.42
Soluble carbohydrate	67.36
Gross energy (Kcal/g)	3.93

Table 3.6: Phytochemical analysis of African star apple kernel

Parameters	mg/kg
Saponin	12.15
Phytate	1,308.70
Tannins	1,037.47
Oxalate	0.80
Glycoside	0.78

The macro and micro mineral contents of *C. albidum* is indicated on Table 3.7. The kernel contains reasonable amounts of both the macro and micro minerals. Table 3.8 presents vitamin composition of the raw ASAK meal. The kernel has appreciable amounts of ascorbic acid, water and fat soluble vitamins. The amino acid profile of the raw ASAKM compared with the conventional plant energy source (maize) is presented on Table 3.9.

3.6.2 Growth performance characteristics of broilers fed the raw African star apple kernel meal

Table 3.10 presents data on the growth performance characteristic of broilers fed raw African star apple kernel (ASAK) meal. The final live weights of the birds was significantly ($p < 0.05$) affected as the dietary raw ASAK meal increased. The final weights decreased with a corresponding increase in the dietary inclusion of the raw ASAK meal for the replacement of maize as energy source. The average daily weight gains of the birds was significantly ($p < 0.05$) affected by the dietary inclusion of the raw ASAK meal for replacement of maize. There was a linear decrease in the average daily weight gains as the raw ASAK meal increased in the diet of the birds. The feed conversion ratio (FCR) of the birds was significantly ($p < 0.05$) affected by an increase in the dietary inclusion of the raw ASAK meal in the diet of the birds. There was an increasing poor feed conversion ratio as the raw ASAK meal increased in the diets. There was a decrease in the feed cost N/kg of the birds as the dietary replacement of maize with the raw ASAK meal increased in the diets of the birds. The results of the cost per kg weight gains followed the same trend with the feed conversion ratios. The cost per kg weight gains was significantly ($p < 0.05$) different with an increase in the values as the dietary raw ASAK meal increased. The percent mortality of the birds

Table 3.7: Mineral element composition of African star apple kernel

Parameters	mg/g
Calcium (Ca)	0.08
Phosphorus (P)	0.46
Potassium (K)	0.04
Magnesium (Mg)	0.01
Sodium (Na)	0.82
Manganese (Mn)	0.06
Iron (Fe)	0.82
Aluminium (Al)	0.12
Zinc (Zn)	0.08
Chloride	0.01

Table 3.8: Vitamin composition of African star apple kernel

Parameters	mg/100mg
Water soluble vitamins	
Vitamin B1 (Thiamin)	1.30×10^{-3}
Vitamin B2 (Riboflavin)	2.80×10^{-3}
Vitamin B3 (Niacin)	8.00×10^{-3}
Vitamin B- carotene	0.37
Vitamin C	0.40
Fat soluble vitamins	
Vitamin A (Retinol)	0.69
Vitamin E (Tocopherol)	0.96
Vitamin D	-
Vitamin K	-

Table 3.9: Amino acid profile of raw African star apple kernel compared with plant energy source (maize)

	Raw ASAK	Maize
Parameters	g/100g	g/100
Leucine	7.18	8.82
Lysine	2.86	1.80
Isoleucine	2.62	2.53
Phenylalanine	3.19	3.50
Tryptophan	0.68	-
Valine	2.98	3.00
Methionine	0.64	0.90
Arginine	3.79	3.82
Histidine	1.63	2.00
Threonine	2.30	2.00
Proline	3.05	1.15
Tyrosine	2.92	2.07
Cystine	0.73	0.70
Alanine	3.00	1.70
Glutamic acid	7.27	5.70
Glycine	3.42	2.50
Serine	2.73	1.80
Aspartic acid	6.30	6.21

Source of Amino acid profile of maize; Abiose and Ikujenlola (2014). RCKM=Raw *Chrysophyllum albidum* Kernel Meal

Table 3.10: Growth performance characteristics of broilers fed raw African star apple kernel meal

	T1	T2	T3	T4	T5	T6	T7	SEM	Pvalue
Parameters	(0%)	(5%)	(10%)	(15%)	(20%)	(25%)	(30%)		
Initial live weight (g/bird)	99.04	99.04	99.04	99.52	99.52	100.47	99.04	1.09	0.9985
Final live weights (g/bird)	1910.16 ^a	1255.72 ^b	885.00 ^c	479.24 ^d	474.11 ^d	395.00 ^e	388.83 ^d	4.99	0.0001
Daily weight gains (g/bird/day)	32.34 ^a	20.66 ^b	14.04 ^c	6.78 ^d	6.69 ^d	5.29 ^d	5.15 ^d	0.65	0.0001
Feed intake (g/bird/day)	116.87 ^a	99.37 ^b	91.32 ^b	71.40 ^c	69.90 ^c	68.36 ^c	65.23 ^c	1.45	0.0001
Feed conversion ratio	3.61 ^d	4.84 ^d	6.63 ^c	10.53 ^b	10.32 ^b	12.84 ^a	13.23 ^a	0.54	0.0001
Cost per kg weight gain (₦)	382.32 ^d	505.11 ^d	680.54 ^c	1063.80 ^b	1025.81 ^b	1254.82 ^a	1271.82 ^a	5.42	0.0001
Cost of feed/kg (₦)	106.00	104.30	102.70	101.10	99.40	97.70	96.10		-
% Mortality	0.00	0.00	0.33	0.00	0.33	0.33	0.00	0.35	0.6781

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant (P>0.05)

was not significantly ($p>0.05$) affected by dietary inclusion of the raw ASAK meal in the diet of the birds. The mortalities recorded in treatments 3, 5 and 6 were not attributed to inclusion of the raw ASAK meal in the diets of the birds but were caused due to trampling during the brooding phase of the birds. The feed intake values were significantly ($p<0.05$) affected by the dietary replacement of maize with the raw ASAK meal. There was a linear decrease in the feed intake values per day as the level of the raw ASAK meal increased in the diet.

The dietary intake of the phytochemicals in the broilers fed the raw African star apple kernels is presented on Table 3.11. There was a decrease in the feed intake as the dietary inclusion level of the raw African star apple kernels increased for the replacement of maize as energy source in the diet of the birds.

3.6.3 Carcass characteristics of broilers fed raw African star apple kernel meal

The carcass evaluation of the broilers fed the raw ASAK meal for replacement of maize in their diet is presented on Table 3.12. The differences in the live weights, carcass weights and the dressing percentage were significantly ($p<0.05$) affected across all the treatment groups. There was a sequential decrease in the live weights, carcass weights and dressing percentage of the birds as the raw ASAK meal increased in the diets of the birds. The weights of the carcass components for the head, neck, wings, thigh, drumstick, shank, breast, back were expressed as percentages of the live weights and were lower in all the dietary groups fed the raw ASAK meal compared with the control group. There were inconsistencies in the weights of the internal organs as the raw ASAK meal could not be said to have either or not enhanced the weights of the organs.

Table 3.11: Dietary phytochemical intake of broilers fed raw African star apple kernel meal

	T1	T2	T3	T4	T5	T6	T7	SEM	P value
Parameters	(0%)	(5%)	(10%)	(15%)	(20%)	(25%)	(30%)		
Saponins (mg/bird/day)	0.00 ^g	3.86 ^f	7.09 ^e	8.32 ^d	10.85 ^c	13.27 ^b	15.19 ^a	0.51	0.0001
Phytate (mg/bird/day)	0.00 ^g	416.15 ^f	763.67 ^e	896.10 ^d	1,169.09 ^c	1,429.61 ^b	1,636.48 ^a	4.28	0.0001
Tannins (mg/bird/day)	0.00 ^g	329.90 ^f	605.40 ^e	710.38 ^d	926.79 ^c	926.79 ^b	1,297.31 ^a	3.81	0.0001
Oxalate (mg/bird/day)	0.00 ^g	0.26 ^f	0.47 ^e	0.55 ^d	0.72 ^c	0.72 ^b	1.00 ^a	0.03	0.0001
Glycoside (mg/bird/day)	0.00 ^g	0.25 ^f	0.46 ^e	0.53 ^d	0.70 ^c	0.70 ^b	0.97 ^a	0.03	0.0001

Table 3.12: Carcass characteristics of broilers fed raw African star apple kernel meal

Parameters	T1	T2	T3	T4	T5	T6	T7	SEM	Pvalue
	(0%)	(5%)	(10%)	(15%)	(20%)	(25%)	(30%)		
Live weight (g/bird)	1,910.00 ^a	1,255.00 ^b	985.00 ^c	485.00 ^d	465.00 ^d	465.50 ^d	330.00 ^d	5.91	0.0001
Carcass weights (g/bird)	1,275.00 ^a	760.00 ^b	550.00 ^c	249.00 ^d	245.00 ^d	227.50 ^d	165.00 ^e	3.37	0.0001
Dressing percentage (%)	66.79 ^a	60.91 ^{ab}	55.83 ^{bc}	51.32 ^c	52.66 ^{bc}	48.62 ^c	49.72 ^c	2.53	0.0116
Prime cut and Organ weights	Expressed as % of live weight								
Head	2.97 ^c	3.09 ^c	3.05 ^c	4.29 ^b	4.51 ^b	3.90 ^c	6.29 ^a	0.37	0.0001
Thigh	12.74 ^a	11.42 ^a	9.39 ^b	7.82 ^c	7.68 ^c	7.48 ^c	7.18 ^c	0.53	0.0001
Breast	17.07 ^a	16.60 ^a	14.31 ^{ab}	15.32 ^{ab}	13.11 ^b	8.75 ^c	8.31 ^c	0.77	0.0006
Wings	9.45 ^a	8.84 ^{ab}	7.48 ^d	8.68 ^{abc}	9.42 ^a	8.03 ^{bcd}	7.87 ^{cd}	0.43	0.0065
Shank	5.46 ^a	5.07 ^{ab}	3.96 ^{cd}	4.11 ^{cd}	4.55 ^{bc}	3.82 ^d	3.77 ^d	0.37	0.0023
Neck	6.23 ^{ab}	5.68 ^{abc}	4.67 ^c	5.54 ^{abc}	5.54 ^{abc}	5.61 ^{abc}	6.93 ^a	0.54	0.0809
Drumstick	10.91 ^a	9.22 ^{ab}	7.45 ^{bc}	7.58 ^{bc}	7.71 ^{abc}	5.61 ^c	6.08 ^{bc}	0.81	0.0522
Back	11.64 ^a	11.46 ^a	11.54 ^a	6.99 ^c	9.94 ^{ab}	9.06 ^{bc}	10.06 ^{ab}	0.69	0.0135
Heart	0.49	0.39	0.45	0.50	0.47	0.37	0.61	0.22	0.3588
Lungs	0.53	0.48	0.45	0.57	0.40	0.37	0.58	0.23	0.4048
Liver	2.02	2.20	1.87	1.96	2.22	2.09	2.74	0.48	0.6269
Kidney	0.52	0.44	0.40	0.47	0.29	0.26	0.43	0.23	0.3015
Proventriculus	0.38	0.48	0.42	0.50	0.50	0.52	0.66	0.25	0.5003
Gizzard	2.11 ^c	2.25 ^{bc}	2.95 ^{abc}	3.11 ^{abc}	3.68 ^a	3.26 ^{ab}	4.00 ^a	0.46	0.0220
Small intestine length (cm)	139.32 ^a	126.91 ^b	101.06 ^c	75.94 ^d	52.96 ^e	47.03 ^f	37.90 ^g	0.40	0.0001
Large intestine length (cm)	66.94 ^a	60.30 ^b	52.06 ^c	39.02 ^d	26.10 ^e	25.06 ^f	20.07 ^g	0.39	0.0001

SEM= Standard error of mean;LOS= Level of Significance;*= $P < 0.05$;a,b,c,d,e,f,gMeans with different superscript along the same rows are significantly ($P < 0.05$);NS=NonSignificant

The weights of the heart, lungs, liver, kidney, proventriculus were not significantly ($p>0.05$) affected except the gizzard that was significantly ($p<0.05$) affected. The lengths of the small and large intestines were significantly ($p<0.05$) affected with a decrease in lengths of both intestines as the dietary replacement of corn with the raw ASAK meal increased in the diets of the birds.

3.6.4 Serum biochemical indices of broilers fed raw African star apple kernel meal

Table 3.13 presents the biochemical indices of the broiler chickens given dietary raw ASAK meal. There was a significant ($p<0.05$) increase in the blood calcium levels as the raw ASAK meal increased in the diet of the birds. There was a significant ($p<0.05$) difference in the serum sodium values as the replacement of maize by the raw ASAK meal increased in the diet of the birds, however the trend in the result were irregular. There was a steady increase from T1 to T3 followed by a decrease between T4 and T5 and subsequently an increase in T6 and T7 respectively. The serum potassium and chloride levels also followed the same trend with that of the sodium values of the birds. The bicarbonate values of the birds were not significantly ($p>0.05$) affected by the inclusion of the raw ASAK meal meal in the diet of the birds. There were significant ($p<0.05$) increases in the blood glucose and the serum urea levels as the raw ASAK meal increased in the diet of the birds. There was a significant ($p<0.05$) decrease in the creatinine levels of the birds as the inclusion of the raw ASAK meal increased in the diet of the birds.

Table 3.13: Serum biochemical indices of broilers fed raw African star apple kernel meal

Parameters	T1 0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Glucose (mg/dl)	127.93 ^d	135.14 ^c	142.34 ^b	145.95 ^b	158.56 ^a	156.76 ^a	160.36 ^a	0.29	0.0001
Calcium (mg/dl)	2.10 ^c	2.10 ^c	2.20 ^{bc}	2.40 ^{bc}	2.30 ^{bc}	2.50 ^b	2.90 ^a	0.27	0.0084
Sodium (mEq/l)	138.00 ^c	140.00 ^{bc}	145.00 ^a	140.00 ^{bc}	138.00 ^c	143.00 ^b	142.00 ^b	0.88	0.0189
Potassium (mEq/l)	4.30 ^{cd}	4.40 ^{bcd}	4.50 ^{bc}	4.30 ^{cd}	4.10 ^d	4.70 ^{ab}	4.90 ^a	0.26	0.0103
Urea (mg/dl)	7.21 ^d	7.81 ^{cd}	8.41 ^{bcd}	8.41 ^{bcd}	9.61 ^{abc}	10.21 ^{ab}	10.81 ^a	0.08	0.0122
Creatinine (mg/ml)	0.08 ^a	0.05 ^b	0.04 ^{bc}	0.04 ^{bc}	0.03 ^c	0.03 ^c	0.01 ^d	0.03	0.0001
Total cholesterol (mg/dl)	72.81 ^a	35.58 ^b	15.47 ^c	15.60 ^{cd}	17.73 ^d	15.47 ^c	11.60 ^{cd}	0.05	0.0001
HDL Cholesterol (mg/dl)	15.47 ^a	11.60 ^b	7.73 ^c	3.87 ^d	3.87 ^d	3.87 ^d	3.87 ^d	0.02	0.0001
LDL Cholesterol (mg/dl)	59.21 ^a	30.94 ^b	7.73 ^c	7.73 ^c	3.87 ^c	3.87 ^c	3.87 ^c	0.04	0.0001
Triglyceride (mg/dl)	11.51 ^a	5.31 ^b	4.43 ^{bc}	4.43 ^{bc}	3.54 ^c	2.66 ^d	2.65 ^d	0.04	0.0001
Total protein (g/l)	31.00 ^c	36.00 ^{bc}	39.00 ^{ab}	40.00 ^{ab}	42.00 ^{ab}	44.00 ^a	45.00 ^a	1.17	0.0156
Albumin (g/l)	27.00	28.00	26.00	27.00	24.00	23.00	18.00	1.96	0.0831
Globulin (g/l)	4.00 ^d	8.00 ^d	13.00 ^c	13.00 ^c	18.00 ^b	21.00 ^b	27.00 ^a	1.31	0.0001
Albumin-Globulin ratio	8	3	2	2	1	1	0	-	-
Aspartate Aminotransaminase (u/l)	7.00 ^f	16.00 ^e	50.20 ^d	57.60 ^c	60.91 ^{bc}	64.31 ^{ab}	69.00 ^a	1.84	0.0001
Alanine Aminotransaminase (u/l)	14.00 ^g	29.00 ^f	38.20 ^e	59.30 ^d	72.15 ^c	82.00 ^b	94.00 ^a	1.24	0.0001
Alkaline phosphate (u/l)	10.46 ^f	12.47 ^e	15.65 ^d	16.08 ^d	19.76 ^a	18.37 ^c	18.92 ^b	0.95	0.0001

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant (P>0.05); HDL=High Density Lipid;LDL=Lipid Density Lipid.

There were significant ($p < 0.05$) differences for the total cholesterol, high density lipid (HDL) cholesterol, low density lipid (LDL) cholesterol and triglyceride respectively with a linear decrease in their values as the dietary inclusion level of the test ingredient increased in the diet of the birds. There was a significant ($p < 0.05$) increase in the total protein and globulin levels as the raw ASAK meal increased in the diet of the birds. The albumin levels revealed a decrease in the trend as the raw ASAK meal increased in the diet of the birds however the values obtained were not statistically ($p > 0.05$) different from each other. The serum aspartate transaminase (AST), alanine transaminase (ALT) and alkaline phosphate (ALP) levels of the birds significantly ($p < 0.05$) increased linearly as the dietary inclusion level of the raw ASAK meal increased in the diet of the birds.

3.6.5 Haematology indices of broilers fed raw African star apple kernel meal

The haematology indices of the birds fed the raw ASAK meal is presented on Table 3.14. The red blood cells, haemoglobin, packed cell volume and the mean cell volume were significantly ($p < 0.05$) affected with a linear increase in the values as the raw ASAK meal increased in the diet of the birds. The mean cell haemoglobin of the birds was not statistically ($p \geq 0.05$) different by the inclusion of the raw ASAK meal in the diet of the birds. There was an irregular pattern in the MCH with an increase from T1 to T2 followed by a decrease in T3 to T4 and an increase between T5 and T7. There was a significant ($p < 0.05$) decrease in the mean cell haemoglobin concentration of the birds as the raw ASAK meal increased in the diet of the birds.

The white blood cell was significantly ($p < 0.05$) affected with a linear decrease as the raw ASAK meal increased in the diet of the birds. The white blood differentials were

Table 3.14: Haematology indices of broilers fed raw African star apple kernel meal

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Red Blood Cell (x 10 ¹² /l)	3.12 ^d	3.08 ^d	6.33 ^{ab}	6.52 ^a	5.83 ^c	5.95 ^c	6.09 ^{bc}	0.10	0.0001
Haemoglobin (g/dl)	6.80 ^d	6.60 ^d	11.80 ^c	12.30 ^b	12.90 ^{ab}	13.20 ^a	13.40 ^a	0.25	0.0001
Packed Cell Volume (%)	29.00 ^b	29.00 ^b	35.00 ^a	37.00 ^a	35.00 ^a	36.00 ^a	37.00 ^a	1.25	0.0001
Mean Cell Volume (fl)	51.28 ^c	51.94 ^c	55.29 ^b	56.74 ^b	60.03 ^a	60.50 ^a	60.75 ^a	0.95	0.0001
Mean Cell Haemoglobin (pg)	21.79	21.42	18.6	18.86	22.15	22.35	22.00	0.83	0.0553
Mean Cell Hae. Conc (g/dl)	42.50 ^a	41.25 ^a	33.71 ^{bc}	33.24 ^c	36.85 ^b	36.66 ^b	36.22 ^{bc}	0.90	0.0011
White Blood Cell (x 10 ⁹ /l)	16.1 ^a	15.5 ^a	10.55 ^b	9.52 ^{bc}	8.19 ^c	6.13 ^d	5.89 ^d	0.58	0.0001
White Blood Cell Differential Counts									
Neutrophils (%)	64.00 ^b	70.00 ^a	71.00 ^a	68.00 ^a	68.00 ^a	64.00 ^b	70.00 ^a	1.02	0.0080
Lymphocyte (%)	35.00 ^b	30.00 ^c	26.00 ^d	29.00 ^{cd}	40.00 ^a	36.00 ^b	38 ^{ab}	0.97	0.0001
Monocyte (%)	1.00 ^c	0.00 ^d	2.00 ^b	3.00 ^a	1.00 ^c	0.00 ^d	1.00 ^c	0.27	0.0001
Eosinophils (%)	0.00 ^b	0.00 ^b	1.00 ^a	0.00 ^b	1.00 ^a	0.00 ^b	1.00 ^a	0.15	0.0001
Basophils (%)	-	-	-	-	-	-	-	-	

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;a,b,c,dMeans with different superscript along the same rows are significantly (P<0.05);NS=Non Significant (P>0.05);Mean Cell Hae. Conc= Mean Cell Haemoglobin Concentration.

also significantly ($p < 0.05$) affected except the basophils that had no value all through. The neutrophil values of the birds was significantly ($p < 0.05$) affected by an increase in the replacement of maize by the raw ASAK meal. The neutrophil was irregular in pattern as there was an increase from T1 to T3 followed by decrease in T4 and T5, T6 slightly lower than the former and a sudden increase in T7. The lymphocyte, monocyte and eosinophils differentials were significantly ($p < 0.05$) different across the treatment groups and also followed the same trend with the neutrophil differential.

3.6.6 Nutrient retention of broilers fed raw African star apple kernel meal

Table 3.15 presents the nutrient retention of broilers fed the raw ASAK meal. The nutrient retention of the dry matter, fat and soluble carbohydrate were significantly ($p < 0.05$) affected as the raw ASAK meal increased in the diet of the birds. The crude protein retention was not statistically ($p > 0.05$) different among the treatment groups. There was a linear decrease in the dry matter retention as the raw ASAK meal increased in the diet of the birds. The trend in the crude protein retention revealed that the birds on the control diet had better crude protein digestibility compared with its counterparts in other treatment groups. There was a linear decrease in the fat and soluble carbohydrate retention as the raw ASAK meal increased in the diet of the birds.

3.6.7 Histology of the liver of broilers fed raw African star apple kernel meal

The photomicrographs showing the liver of the birds fed the raw ASAK meal are shown on plates 1-7. The sections of the liver revealed that, as the raw ASAK meal increased in the diet of the birds, the architecture of the liver in the birds were severely affected with severe hepatocyte perturbation and inflammation of the bile duct.

Table 3.15: Nutrient retention of broilers fed raw African star apple kernel meal

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Dry matter	80.39 ^a	42.66 ^b	40.28 ^b	34.87 ^{bc}	31.31 ^c	30.05 ^c	31.58 ^c	1.32	0.0001
Crude protein	86.96	78.96	77.56	77.63	73.52	72.61	72.99	4.35	0.3630
Ether extract	78.89 ^a	72.79 ^b	70.76 ^b	54.99 ^c	52.95 ^c	49.87 ^d	49.15 ^d	0.91	0.0001
Soluble carbohydrate	60.68 ^a	62.90 ^a	50.25 ^b	45.41 ^b	40.91 ^{bc}	41.94 ^{bc}	33.88 ^c	1.41	0.0011
Crude fibre	91.81 ^{bc}	89.71 ^c	94.21 ^b	97.57 ^a	97.43 ^a	97.58 ^a	98.15 ^a	0.76	0.0007

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c} Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant (P>0.05)

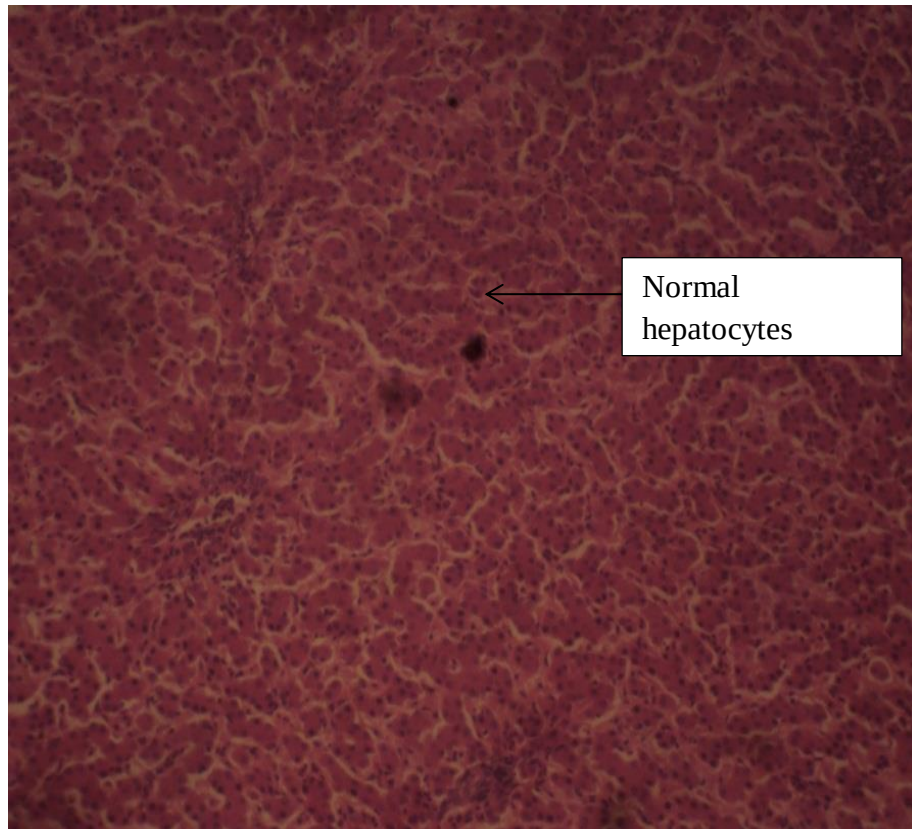


Plate i - Photomicrograph showing the liver of broilers fed the control diet

H/E Stain Mag. X400

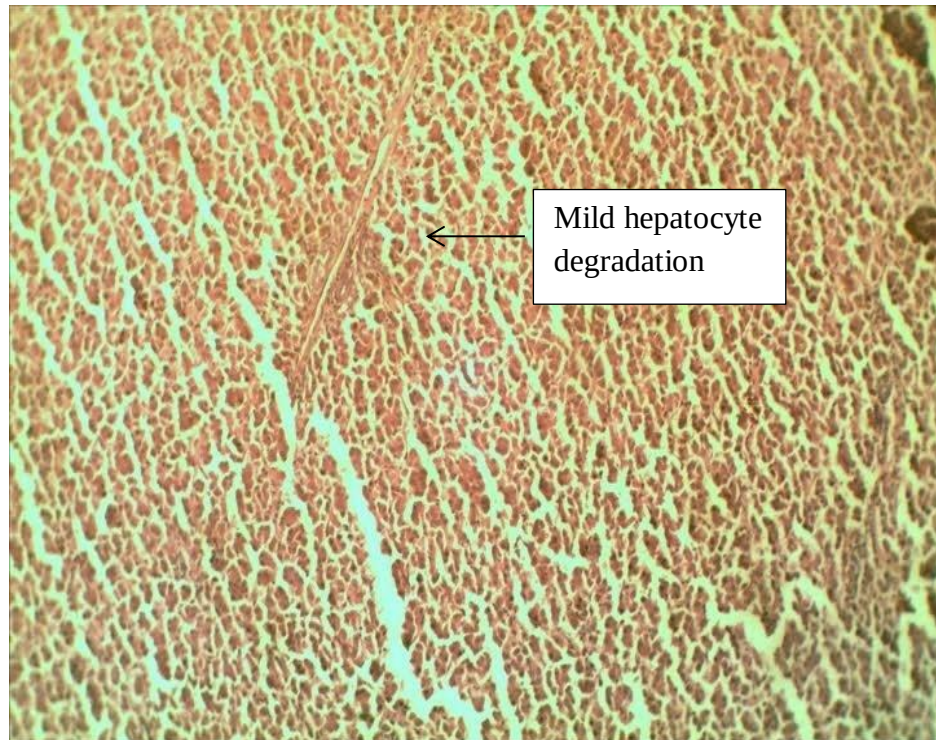


Plate ii: Photomicrograph showing the liver of broilers fed 5% raw African star apple kernel meal

H/E Stain Mag. X400

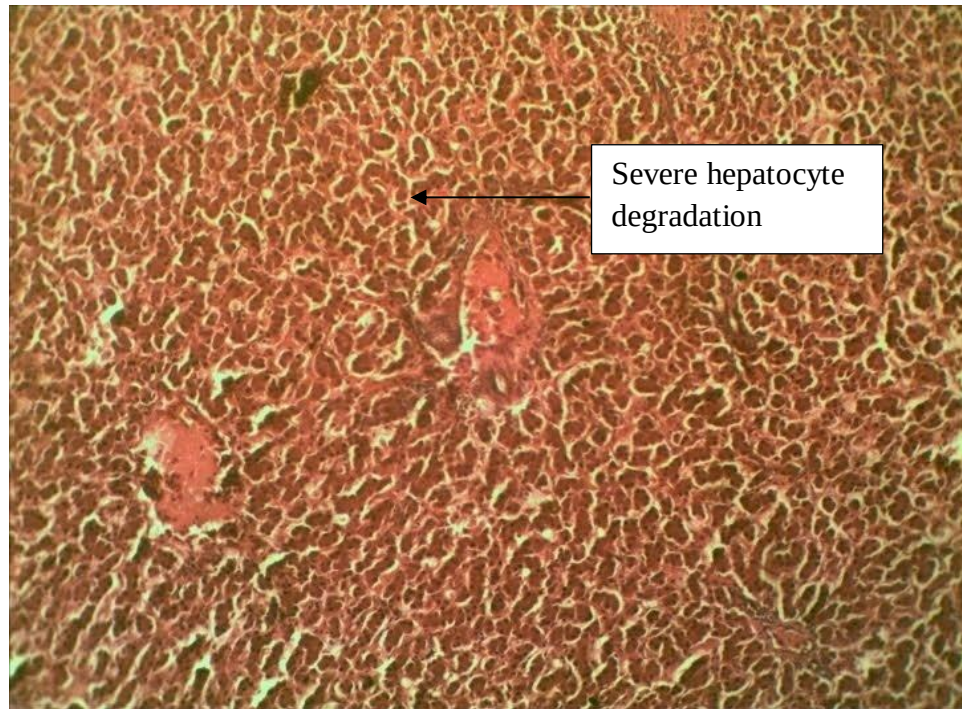


Plate iii: Photomicrograph showing the liver of broilers fed 10% raw African star apple kernel meal

H/E Stain Mag. X400

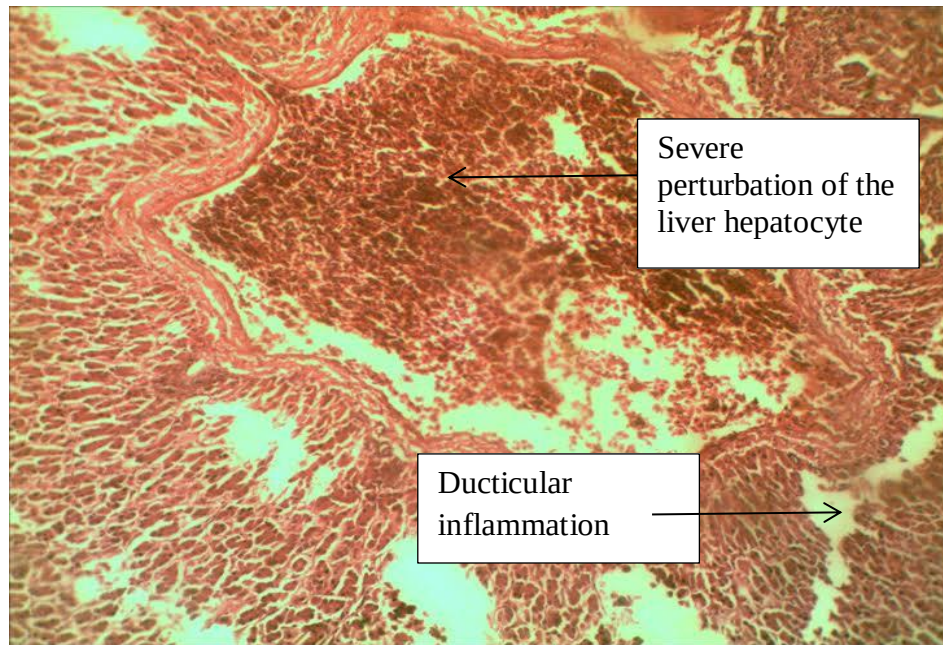


Plate iv: Photomicrograph showing the liver of broilers fed 15% raw African star apple kernel meal

H/E Stain Mag. X400

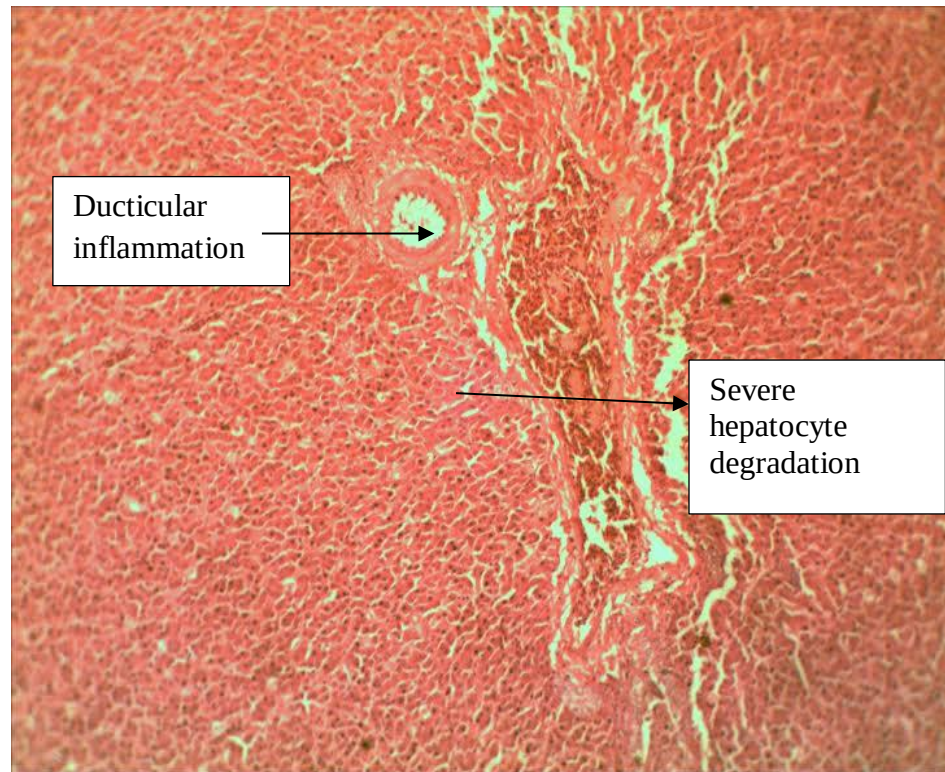


Plate v: Photomicrograph showing the liver of broilers fed 20% raw African star apple kernel meal

H/E Stain Mag. X400

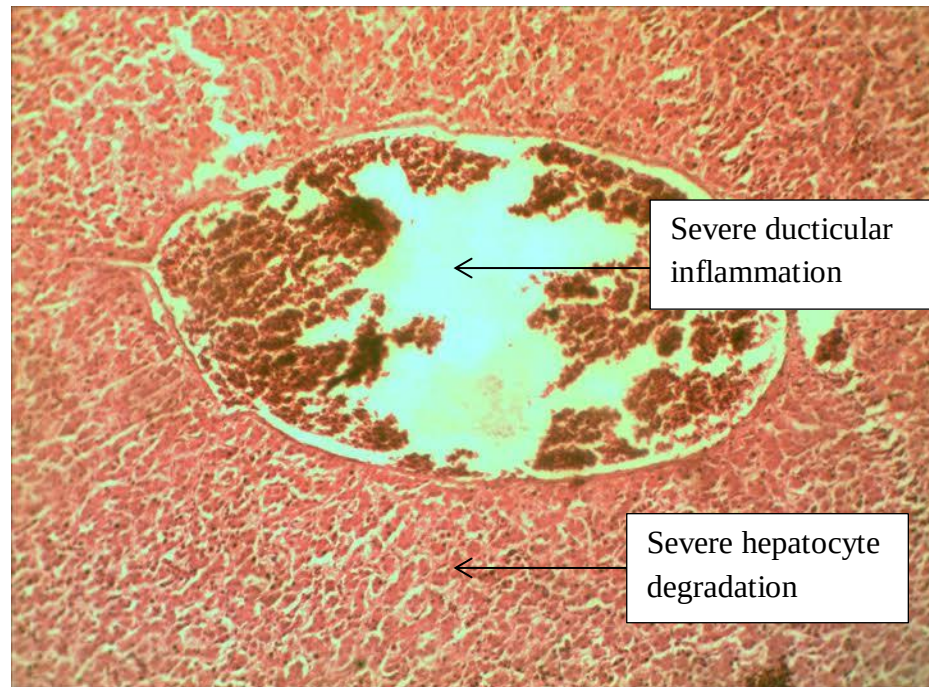


Plate vi: Photomicrograph showing the liver of broilers fed 25% raw African star apple kernel meal

H/E Stain Mag. X400

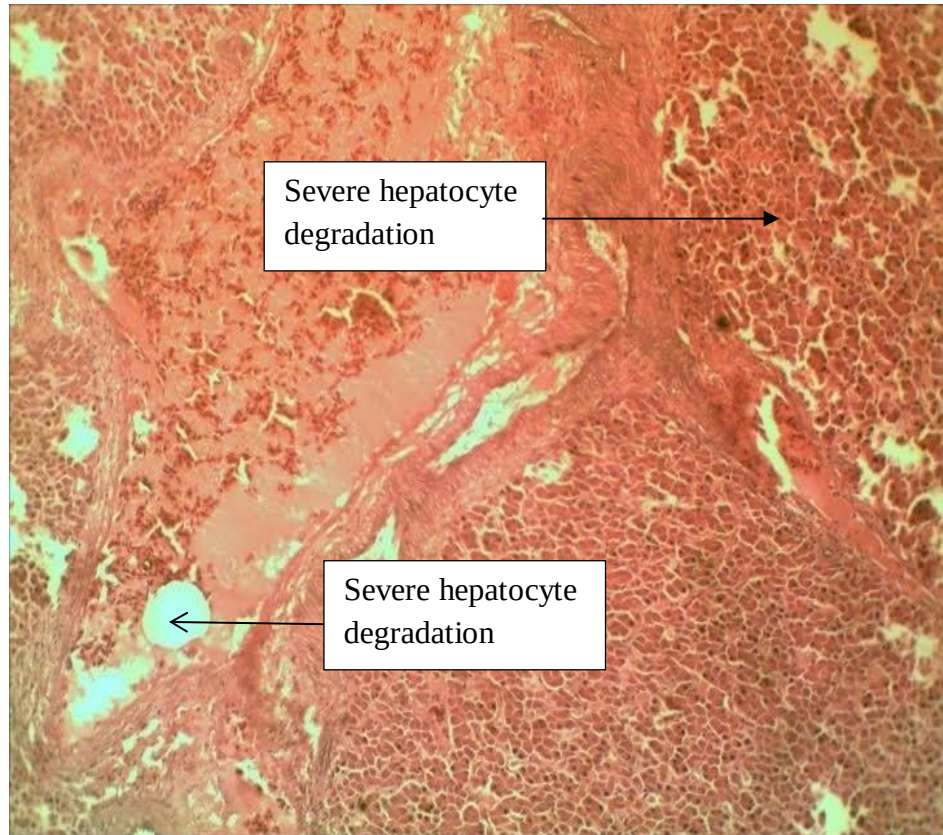


Plate vii: Photomicrograph showing the liver of broilers fed 30% raw African star apple kernel meal

H/E Stain Mag. X400

3.6.8 Profitability of broilers fed raw African star apple kernel meal for dietary replacement of maize

Table 3.16 shows the profitability of replacing maize with raw African star apple kernel meal in broilers diet. The total feed intake, total weight gain and total cost of production per bird were higher in the animals fed the control diet, although there was a decrease in the feed cost per kg as the replacement of maize with the raw ASAK meal increased in the diet. The reduction in the prices could not inturn enhance the profit on investment. The highest profit was obtained from the birds fed the control diet, followed by those fed 5 and 10% raw ASAK meal respectively. Losses in investment were recorded in birds fed from 15-30% inclusion levels of the raw ASAK meal.

Table 3.16 Profitability of broilers fed raw African star apple kernel meal for dietary replacement of maize

	T1	T2	T3	T4	T5	T6	T7	SEM	Pvalue
	(0%)	(5%)	(10%)	(15%)	(20%)	(25%)	(30%)		
Parameters									
Total feed intake (g/bird)	5,492.89 ^a	4,607.39 ^b	4,292.04 ^c	3,355.80 ^d	3,285.30 ^e	3,212.92 ^f	3,065.85 ^g	4.35	0.0001
Total weight gain (g/bird)	1811.12 ^a	1156.68 ^b	785.96 ^c	379.72 ^d	374.59 ^d	294.53 ^e	289.79 ^f	1.65	0.0001
Final live weight (g/bird)	1910.16 ^a	1255.72 ^b	885.00 ^c	479.24 ^d	474.11 ^d	395.00 ^e	388.83 ^d	4.99	0.0001
Cost of feed/kg (₦)	106.00	104.30	102.70	101.10	99.40	97.70	96.10	-	-
(a) Cost of DOC/Medication	160.00	160.00	160.00	160.00	160.00	160.00	160.00	-	-
(b)Cost of feeding /bird = FC x TFI (₦)	582.25	487.12	440.12	339.27	326.56	313.90	294.62	-	-
Total cost of production/bird = (a+b) (₦)	742.25	647.12	600.79	499.27	486.56	473.90	454.62	-	-
Revenue = Fnwt x sales/kg	1,623.64	1,067.36	752.25	407.35	402.99	335.75	330.51	-	-
Profit (₦) = Revenue – TC	881.39	420.24	151.46	-91.92	-83.57	-138.15	-124.00	-	-
Sale's price/kg (₦)	850	850	850	850	850	850	850	-	-

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant. DOC= Day Old Chicks; FC= Feed Cost; TFI= Total Feed Intake; Fnwt=Final live weight; TC=Total cost of production; Naira=₦

3.7 Discussion

Chemical composition: The kernel was found to be very high in energy and low in crude protein making it a suitable novel feed for replacing maize as an energy source in animal feeding. The soluble carbohydrate of 67.36% observed in this study is within the range of 44.8- 69.6% reported by Sule *et al.* (2014) for maize. The meal also has appreciable levels of minerals, fat and crude fibre which were similar with the values of 1.10 -2.95%, 2.17-4.43, and 2.10-26.77 reported by Sule *et al.* (2014) for the mineral, fat and crude fibre compositions of maize, respectively. The raw ASAK meal was very high in phytate, tannins and saponins necessitating the need for proper processing methods for its suitability in animal feeding. The observed higher levels of some essential amino acids (threonine, lysine, isoleucine, arginine, glycine and proline) in the raw ASAK meal and the similar values obtained for histidine, valine compared with the values reported by Abiose and Ikujenlola (2014) for maize suggest that the ASAK meal if well processed could be a very good alternative novel energy feed for corn in poultry diet. The kernel was found to be lower in methionine in relation to maize and also having sub optimal levels of both water and fat soluble vitamins requiring the need for supplementation.

Growth performance characteristics: The decrease in the final live weights of the birds as the dietary inclusion of the raw ASAK meal for replacement of maize increased in the diets of the birds could be supported by the findings of Ojako and Igwe (2008) that antinutritional factors like saponins, cyanogenic glycoside, oxalate, phytate and tannins diminish nutrients bioavailability if present at high concentrations. Similarly Igile (1996) reported that these phytochemicals elicit toxic biological responses with possible physiological implications. The increasing replacement of maize by the raw ASAK meal

in the diets of the birds may have elicited toxic biological responses in the birds with possible physiological implications such as the reduced final live weights recorded in dietary treatments 2, 3, 4, 5, 6 and 7 compared with their counterpart in the control diet. The reports of Roeder (1995) also supports the findings of this study that these phytochemicals cause reduced growth rate.

The average daily weight gains of the birds was a reflection of their daily feed intake as the birds on the control diet had the highest average daily weight gains due to the highest feed intake and there was a corresponding decrease in the average daily weight gains in treatment 2-7 attributed to decreased dietary feed intake. The reduced weight gains observed in treatments 2-7 is also in line with the findings of Su and Guo (1986) and Pant *et al.* (1989) that saponins reduce uptake of nutrients (carbohydrates, proteins) and hence reduce growth rate and feed efficiency in monogastric animals. The decrease in the feed intake for birds fed 15%, 20%, 25% and 30% raw ASAK meal is in line with the findings of Aletor (1993) that tannins cause decrease in feed consumption in animals especially monogastrics. The decreased feed intake observed corroborates the findings of Tapiers *et al.* (2002) who reported that tannins have astringent properties that affect palatability, reduce feed intake and consequently body growth.

The effect of the raw ASAK meal on the feed conversion ratios among the treatment groups is note worthy. The best FCR observed in birds fed the control diet was due to the absence of antinutritional factors (ANFs) in the diets of the birds followed by the birds fed 5% raw ASAK meal because the ANFs present in their feed was below the levels which severe deleterious effects would have manifested in the birds. Dietary replacement of maize by the raw ASAK meal above 5% inclusion led to poor feed conversion ratios as

observed in treatments 3, 4, 5, 6 and 7 respectively. This assertion is in line with the reports of Elkin *et al.* (1990) that tannins adversely affect feed intake and feed efficiency in broiler chickens. Similarly, Annongu, (2012) reported that dietary saponins are poorly absorbed leading to losses of nutrients including energy and protein thereby causing depressed growth in poultry. The reports of Yakubu and Wafar (2014) affirmed that antinutritional factors affect animals negatively. The ANFs present in the raw ASAK meal limited the utilization of the nutrients present in the diets for the animals use. This view corroborates the findings of Kumar (1992) that the utility of the seed kernel of *Chrysophyllum albidum* containing saponins, cyanogenic glycosides, oxalates, phytates and tannins may be limited in poultry by their presence.

The feed cost ₦/kg was not statistically analyzed but it was observed that there was a reduction in the feed cost ₦/kg as the level of the raw ASAK meal increased in the diet. This observation agreed with the report of Apata and Ojo (2000) that the high cost of feed was largely due to the exorbitant price of conventional feed ingredients. The increase in the cost per kg weight gains as the level of the raw ASAK meal increased in the diet of the birds was as a result of the poor feed conversion ratios of the birds in treatments 3, 4, 5, 6 and 7 though there was a reduction in the feed cost/kg as the raw ASAK meal inclusion levels increased, it implies that the birds in treatments 3, 4, 5, 6 and 7 will consume more feed to attain an increase in kg/weight gain despite the depressed intake of the birds owing to the presence of tannins limiting the palatability of the feed and also the limiting effects of the ANFs on the bioavailability of the nutrients in the animal's body. The reports of Aletor (1993) who opined that phytates inhibit protein digestion by

forming complexes with them and tannins decreasing feed intake in monogastric animals, supports the findings of this study.

The percent mortality gives an indication that the birds could tolerate inclusion of the test ingredient in their diet for replacement of maize. This suggests that with proper processing methods of the ASAK meal, it could be a good novel feedstuff for animal feeding. The mortalities recorded in treatments 3, 5 and 6 were caused via trampling during the brooding phase of the birds and not attributed to the effect of the test ingredient. The increasing dietary intake of the phytochemicals in the diets of the broilers further attest to the poor growth performance characteristics recorded.

Carcass characteristics: The decrease in the live weights, dressing percentage, carcass weights and its components as the raw ASAK meal inclusion levels increased in the diets of the birds were as a result of the reduced final live weights and poor feed conversion ratio of the birds in treatments 3, 4, 5, 6 and 7 which were responsible for the poor carcass characteristics in these treatment groups. The insignificant effect of the raw ASAK meal on the internal organs for the heart, lungs, liver, kidney and proventriculus could be as result of the relative weights of the birds when these organs were expressed as percentages of the live weights of the birds. The increase in the size of the gizzard as the inclusion level of the raw ASAK meal increased in the diet could be as a result of the birds inability to effectively utilize the test ingredient. The decrease in the length of the small and large intestines could be attributed to the relative live weights of the birds due to the effect of the phytochemicals.

Serum biochemistry is a generalized medium of assessing the health status of animals. Blood parameters are potent indices of the physiological, pathological and nutritional status of an organism (Babatunde and Olusanya (1992). Changes in blood constituent are indirect indices to assess the metabolic state of an animal as well as the quality of the feed. The increase in the blood glucose as the level of the raw ASAK meal increased in the diet in relation to the birds on the control diet together with those fed lower levels of 5% and 10% raw ASAK meal is suggestive of a hyperglycemic effect and this may increase the metabolic burden placed on the liver. The irregular pattern of 138.00 to 145.00 mmol/l obtained for sodium and 4.1 to 7.1mmol/l obtained for potassium as the raw ASAK meal increased in the diet of the birds were probably as a result of the differences in each animal's ability to regulate osmotic pressure, maintain membrane potentials, acid- base balance and transmit nerve impulses. The similar values of sodium observed for the birds on the control diet and those fed 20% raw African star apple kernel meal attests that the raw ASAK meal will not in any way cause kidney damage.

Urea is known to be a function of protein quality as high level is an indication of low protein quality (Oke *et al.*, 2016). The increase in the serum urea as the raw ASAK meal increased in the diet is an indication that the amino acids in the raw ASAK meal are imbalanced since high urea levels are associated with poor quality protein or excess tissue catabolism, therefore the higher the inclusion rate of the raw African star apple kernel meal, the more the birds survived at the expense of their body reserve.

The significant decrease in the serum creatinine of the birds as the level of raw African star apple kernel meal increased in the diet gives evidence to the fact that the birds were surviving at the expense of their body reserves thus suggesting the reduced

weight in the birds as the level of raw ASAK meal increased in the diet. This is in line with the findings of Ogbuewu *et al.* (2010) that the level of serum creatinine signals the extent of muscle wastage.

The decrease in the total cholesterol levels were partly due to the reduced dry matter intake of the birds as the raw ASAK meal increased in the diet of the birds. Dietary inclusion of the raw ASAK meal in the diet of broilers do not pose a challenge as regards cholesterol deposition in the birds as animals on the control diet had more cholesterol serum levels than those on dietary inclusion level of 5, 10, 15, 20, 25 and 30% respectively. The presence and increasing contents of ANFs as the level of the raw ASAK meal increased in the diet of the birds may have lowered the level of serum cholesterol concentration. This agrees with the findings of Nkwocha (2014) that anti-nutritional factors assert physiological effect on lowering the level of plasma cholesterol concentration in albino rats.

The high density lipid (HDL) cholesterol for animals on the control diet and those fed lower inclusion levels of 5% and 10% raw ASAK meal may have impacted positively on the function of the liver due to the higher values recorded in treatments 1, 2 and 3 compared with their counterparts in treatments 4, 5, 6 and 7 with low HDL cholesterol levels. HDL serve as acceptors of cholesterol from various tissues. They promote the removal of cholesterol from cells and its secretion into the bile by the liver (Vander *et al.* 1998). HDL transports excess or un used cholesterol from the tissue back to the liver where it is broken down to bile acids and then excreted, this makes HDL beneficial to health. The low density lipid (LDL) cholesterol observed as the level of raw ASAK meal increased in the diet implies that the inclusion of raw ASAK meal at higher levels in the

diet of the birds may not likely predispose the birds to atherosclerosis resulting from LDL cholesterol (Vander *et al.*, 1998). LDL cholesterol is often designated “bad” cholesterol since high levels of it in the plasma is linked with increased deposition of cholesterol in the arterial walls (Vander *et al.*, 1998).

The increase in the total protein and globulin indicated nutritional inadequacy probably due to the non-availability of the nutrients to the animals as a result of the anti-nutrients present in the raw ASAK meal. Onifade and Tewe (1993) had earlier reported that serum protein, albumins and globulins are generally influenced by total protein intake. The higher total protein, albumin and globulin values recorded in this study as the dietary inclusion level of the raw ASAK meal increased in treatments 2, 3, 4, 5, 6 and 7 compared with their counterpart in treatment 1 attest to the nutritional potentials of the raw ASAK meal in terms of complementing the protein needs of the birds when corn is replaced with it.

The increase in the ALP, AST and ALT as the level of raw ASAK meal increased in the diets suggest that the raw kernels may have impacted negatively on the liver function. The increase in the ALP and AST values obtained in this study as the level of raw ASAK meal increased in the diet is not of much clinical significance. This is in line with the findings of Odutola (1992) that the elevation of the ALP and AST could not still have confirmed liver damage because ALP and AST originate from different tissues such as the liver, bones, intestine and placenta while the ALT has its highest concentration in the liver (Atangwho *et al.*, 2007; Sodipo *et al.*, 2009). Therefore, a measure of ALT in the serum is of greater diagnostic specificity in confirming or excluding liver damage. The increase in the ALT values for the birds in treatments 2, 3, 4, 5, 6 and 7 compared with

those in treatment 1 suggest that there may be a likelihood of liver damage by raw ASAK meal.

Haematolgy indices: The range of $3.08-6.52 \times 10^{12}/\text{dl}$ for the red blood cells (RBC) was within the normal range of $3-6 \times 10^6/\text{dl}$ for chicken reported by Madubuike and Ekenyem (2006). It was observed that as the level of the raw ASAK meal increased in the diet, the red blood cells (RBC) increased. The iron present in the kernels may have influenced erythropoiesis which in turn favoured the production of RBC. The increase in the haemoglobin concentration (Hb) as the level of the raw ASAK meal increased in the diet of the birds could be attributed to the appreciable level of iron in the raw *Chrysophyllum albidum* kernels. The range in the Hb values of 6-13% reported by Aiello and Mays (1998) and Iheukwumere *et al.* (2008) gives credence to the findings of this study. Zuckerman (2011) had earlier reported that haemoglobin deficiencies, low PCV values and MCV indicate anaemic conditions. In this present study, the higher inclusion level of the raw ASAK meal in the diet of the birds increased the haemoglobin concentration suggesting that ASAK meal as a novel feed has good potentials for replacing maize in the diet of the birds without predisposing the birds to anaemic conditions. The range of 6.8-13.4g/dl haemoglobin concentration of the birds reported in this study is within the range of 7-18.6g/dl for healthy birds reported by Aiello and Mays (1998). This implies that the inclusion of the ASAK meal in the diet of the birds do not affect the health status of the birds. The result of this finding also suggests that the blood of the birds had an appreciable oxygen carrying capacity which shows that nutrient transport by the blood was not impaired by feeding *Chrysophyllum albidum* kernel meal. The range of PCV

(29-37%) across the dietary treatments is within the normal range reported by Ogbuewu *et al.*(2010). This indicated that the birds were neither dehydrated nor anaemic.

The mean cell volume (MCV) of 51.28-60.75fl obtained in this study is contrary to the range of 115-127fl reported by Swenson (1993). Increased MCV readings may indicate macrolytic anaemia, B₆ or folic acid deficiency. Decreased MCV readings may indicate microlytic anaemia possibly caused by iron deficiency. In this present study, the lower MCV recorded compared with the values reported by Swenson (1993) cannot be attributed to microlytic anaemia due to the high concentration of haemoglobin recorded in this study. The variation may be due to the type of feed ingredients used in formulating the diet, sex of the bird, breed and differences in the environments in which the experiments were conducted. The MCV reflects the size of RBC by expressing the volume occupied by a single RBC. The increase in the MCV as the raw ASAK meal increased in the diet of the birds suggests that the size of the red blood cells were enhanced by the volume occupied by each red blood cell.

The mean cell haemoglobin (MCH) gives the average weight of haemoglobin in the red blood cells. The similarity in the MCH for the dietary treatments implies that the inclusion of ASAK in the diet of the birds may not influence the average weight of the haemoglobin in the blood. The MCH is not as accurate as MCHC in the diagnosis of severe anaemia as a result of the use of RBC in its calculation. Decreased MCH is associated with microlytic anaemia and increased MCH is associated with macrolytic anaemia. The low range of 18.6-22.0pg mean cell haemoglobin reported in this study compared with 25-27pg reported by Swenson (1993) may not give a clue if the birds were anaemic in relation to the high MCHC recorded in this study.

The mean cell haemoglobin concentration (MCHC) value of 33.71-42.50g/dl reported in this study is contrary and higher than the value of 21-23g/dl reported by Swenson (1993). MCHC measures the average concentration of haemoglobin in red blood cells. It is the most valuable in evaluating the therapy for anaemia because haemoglobin and haematocrit are used not RBC its calculation. Low MCHC means that a unit of packed RBC contains less haemoglobin than normal and a high MCHC means that there is more haemoglobin in a unit of RBC. Decreased MCHC levels may indicate iron deficiency, blood loss and B₆ deficiency. In this present study the higher MCHC compared with the values reported by Swenson (1993) implies that the birds did not exhibit any anaemic symptom.

The increase in the white blood cells (WBC) of the birds fed 0% and 5% raw *Chrysophyllum albidum* kernels compared with their counterparts fed higher levels of 10, 15, 20, 25, and 30% raw *Chrysophyllum albidum* kernels could be as a result of the limited exposure of the birds to the antinutrients in the raw *Chrysophyllum albidum* kernels thus increasing their white blood cells while their counterparts on higher levels of the raw *Chrysophyllum albidum* kernels had lower white blood cells because the bird's immune system may have responded to the toxicity of the antinutrients in the raw ASAK meal thus reducing the leucocytes count. This assertion could be supported by the findings of Chineke *et al.* (2006) who reported that apart from genotype, age and sex, the differences in haematology indices may be caused by nutritional, environmental and hormonal factors. Soetan *et al.* (2013) had earlier reported that animals with low white blood cell values are exposed to high risks of disease infection while those with high counts are capable of generating antibodies in the process of phagocytosis and have a

high degree of resistance to diseases. This implies that in the case of disease infection, the birds fed the control diet and 5% raw ASAK meal will be more resistant to disease infection by generating antibodies through the process of phagocytosis compared to the birds fed higher inclusion levels of 10, 15, 20, 25 and 30 raw ASAK meal. The values obtained for lymphocytes, neutrophils and monocytes suggest the resistance of the birds in disease conditions. High lymphocyte values would be recorded in viral and bacterial infections such as coccidiosis. High neutrophil values would be recorded in parasitic infection e.g. lice while high monocyte values would be recorded in instances of injuries to body tissues. Increased neutrophil count generally indicates stress or infection also suggesting that the raw ASAK meal may not predispose the birds to stress or disease infections since the neutrophil count of the birds fed 0% and 25% raw ASAK meal were at par. This implies that the inclusion of ASAK in the diets of the birds may not be responsible for either high or low neutrophil counts. Therefore, the replacement of maize with ASAK meal did not adversely affect the physiological status of the birds. High values of eosinophils may be associated with worm infections or exposure to substances that cause allergic reactions (Aro and Oju, 2013). The low values obtained for eosinophils revealed that the birds were not challenged by worms or exposed to any allergic substance that would have caused reactions or deleterious effects.

Nutrient retention: The report of Aletor (1993) that tannins reduce feed intake in monogastrics conforms to the findings of this study. The increasing levels of tannins in the diet of the birds as the graded levels of the raw ASAK meal increased in the diet of the birds may have formed complexes with the digestive enzymes in the birds fed 5, 10, 15, 20, 25 and 30% compared with their counterparts in the control diet not fed the test

ingredient thus limiting the digestibility of dry matter and the undigested feed voided out without the nutrients utilized and retained by the animals.

The decrease in the crude protein retention, though not statistically significant as dietary inclusion of the raw ASAK meal increased in the diet of the birds could be supported by earlier reports that phytic acid has a negative effect on amino acid digestibility thereby posing problems to non ruminant animals due to insufficient amount of intrinsic phytase necessary to hydrolyse the phytic complex (Turner, 2006).

The decrease in the ether extract retention as the raw ASAK meal inclusion levels increased in the diet of the birds is in line with the findings of Su and Guo (1986); Pant *et al.* (1989) that saponins interferes with the absorption of lipids, vitamin A, vitamin E and causes hypocholesteromia by binding cholesterol, making it unavailable for absorption. The increasing presence of the antinutrients in dietary treatments 4, 5, 6 and 7 compared with their counterparts in treatments 1, 2 and 3 fed the control and lower inclusion levels of the raw ASAK meal limited the fat and soluble carbohydrate retentions in these treatment groups. The increase in the crude fibre retention as the dietary inclusion level of the raw ASAK meal increased in relation to their counterpart fed the control and 5% raw ASAK meal may be attributed to the higher level of crude fibre in the raw ASAK meal compared with corn.

Histology of the liver sections of the birds as the raw *Chrysophyllum albidum* kernel meal increased in the diet of the birds showed abnormal liver architecture due to the presence of anti-nutritional factors in the feed. The severe hepatocyte degradation and inflammation of the bile ducts observed in the liver of the birds fed increasing raw C.

albidum kernel meal is in line with the findings of Ortiz *et al.* (1994), who reported that, chicks fed tannin containing diets showed hydropic degeneration of hepatocytes of the liver. Saponins have also been reported to alter cell wall permeability and therefore produce some toxic effects when ingested (Belmar *et al.*, 1999). The combined effects of tannins, saponins and other antinutritional factors in the raw *Chrysophyllum albidum* fed to the broiler chickens impacted negatively on the histology of the liver.

The profitability of replacing maize with raw ASAK meal: The replacement of maize with the raw ASAK meal do not justify its use, as there was higher revenue and profit from the birds fed the control diet despite the reduction in feed cost per kilogram of the diets formulated with increasing inclusion level of the raw ASAK meal. This is attributed to the poor palatability of the feed and its utilization by the birds. This implies that, the investor or farmer will have higher returns on capital investment from the use of maize compared to supplementation with raw African star apple kernels in the diet of the broilers.

It is concluded that the kernel was found to be very high in energy and low in crude protein making it a suitable novel feed as energy source. The phytochemical analysis of the raw kernels contained very high amount of phytate, tannins saponins and low amounts of oxalate and glycosides respectively. The broilers could not utilize the raw ASAK meal in their diet with respect to the growth performance indices. The best inclusion level of the raw kernels was 5% with a final live weight of 1.23kg compared to 1.91kg obtained for those on the control diet. The feed conversion ratio was between 4.83 and 13.23. There was severe hepatocyte degradation of the liver beyond 10% dietary inclusion level of the raw kernels. The African star apple kernel meal may have

positively influenced erythropoiesis, therefore, the need to adequately process the kernels for optimum utilization by the birds.

CHAPTER FOUR

4.0 Experiment Two: The effect of replacing maize with processed *Chrysophyllum albidum* kernel meal with activated charcoal in broilers

4.1 Introduction

The presence of antinutritional in feedstuff/food revealed that it has deleterious effects when consumed in certain amounts. It has been proven by numerous authors in many *in vivo* assay and different feeding trials for animals. Anti-nutrients/toxins present in plant food or feedstuffs constitute a serious impediment to the use of alternative feedstuff for animal production. The increasing threat to proper nutrition and health of humans and animals has earned the attention of researchers proffering solutions to the toxicities it causes. Some of the approaches include the addition of physical binders or sequestering agents to feed in an attempt to reduce toxicity and reactivity of the bound toxins to prevent intestinal absorption. Some physical adsorbents used include silicates, organic polymers of esterified glucan, inorganic polymers such as cholestyramine, polyvinylpyrrolidone, activated charcoal, coal, carbon, others (Soetan and Oyewole, 2009; Edem, *et al.*, 2011; Ukana *et al.*, 2012).

Activated charcoal is used in beef and dairy cattle production to prevent waste, treat bloat, remove mycotoxins, control internal parasites and to increase milk production and immunity. In horses, it is applied to treat laminitis and aid digestion. In monogastric swine, activated charcoal reduces mortality, odour from excretions and increase resistance to disease and performance (Homestead Organics, 2004). Reports revealed that activated charcoal adsorbs toxins and enhances the intake of poisonous plants (George *et al.*, 2000). Kutlu *et al.* (2001) reported that the inclusion of wood charcoal

improved the performance of broiler chickens during the broiler starter phase. There is no information on the use of activated charcoal for the treatment of *C.albidum* kernels for feeding broilers.

4.2 Objective

The objective of this experiment was to evaluate the potential of activated charcoal in binding the phytochemicals in the star apple kernels by enhancing its suitability in broiler's nutrition.

4.3 Materials and Methods

4.3.1 Experimental site

The experiment was carried out in the Poultry Unit of the Teaching and Research Farm, Landmark University, Omu-Aran, Kwara State.

4.3.2 Source of experimental birds

A total of 210, day-old Cobb breed of broiler birds were obtained from Zartech farms at Ibadan, Oyo State, Nigeria.

4.3.3 Collection of African star apple seeds

The fruits of *C. albidum* for this study were collected from the various star apple plantations in Osun state, Nigeria. The seeds were obtained from the fruit, thoroughly washed to remove the foreign materials, properly sun dried to a constant weight and were further dehulled to obtain the kernels.

4.3.4 Experimental diet

The kernels obtained from the seed were soaked for 12 hours, boiled for 30 minutes and sun dried. The sun dried kernels were milled, pretreated with activated charcoal at 5g/kg and placed in tightly sealed containers for seven days before inclusion in the diet. Seven experimental diets were formulated made of a corn-soy reference diet and six other diets containing processed African star apple kernel using activated charcoal (ASAK^{AC}) meal for replacing maize in the diet of the birds at graded levels of 0, 5, 10, 15, 20, 25 and 30% corresponding to diets 1, 2, 3, 4, 5, 6 and 7 respectively. The composition of the experimental diets for the broiler starter and finisher phases on as fed basis are presented on Tables 4.1 and 4.2, respectively. The proximate composition of the broiler starter phase and finisher are presented on Table 4.3 and 4.4 respectively. The proximate composition of the processed ASAK^{AC} meal is presented on Table 4.5.

4.3.5 Management of experimental birds and data collection

A total of 210, day-old broiler chicks were used for the trial. The chicks were fed for one week on a standard broiler starter diet before the commencement of the experiment for both the starter and finisher phases. The experiment was designed as a complete randomized design. The dietary treatments contained three replicates with 10 chicks per replicate. All the birds were raised under similar management practices (brooding, lighting, feeding and watering) throughout the eight week experimental period for both the starter and finisher phase except for the diets offered that differed. The birds were given feed and water *ad-lib* and weighed weekly. Routine vaccinations and medications were carried out as at when due.

Table 4.1: Composition of the experimental diets for broiler starter processed with activated charcoal (Kg/100Kg)

Diets	T1	T2	T3	T4	T5	T6	T7
CKM levels %	0	5	10	15	20	25	30
Maize	56.46	53.63	50.81	47.99	45.17	42.34	39.52
CKM	0.00	2.83	5.65	8.47	11.29	14.12	16.94
SBM	38.04	38.04	38.04	38.04	38.04	38.04	38.04
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Limestone	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
V. premix	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100	100	100	100	100	100	100

Calculated analysis of the diets

Feed cost/Kg (₦)	105.98	104.75	103.17	101.52	99.88	98.23	97.26
ME kcal/kg	3132.74	3118.63	3104.57	3090.52	3076.46	3062.35	3077.62
CP (%)	22.99	22.63	22.40	22.18	21.95	21.73	21.50
Fat (%)	3.74	3.63	3.52	3.40	3.29	3.18	3.06
C. fibre (%)	4.02	3.95	3.87	3.79	3.72	3.64	3.57
Ash (%)	1.07	1.04	1.00	0.96	0.93	0.89	0.85
Calcium (%)	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Phosphorus	0.54	0.53	0.52	0.52	0.51	0.50	0.49
Lysine	1.25	1.24	1.23	1.23	1.22	1.21	1.20
Methionine	0.57	0.56	0.55	0.55	0.54	0.54	0.53
A.Charcoal/g(₦)	-	0.13	0.13	0.13	0.13	0.13	0.13

CKM= Chrysophyllum kernel meal; ME=Metabolizable energy; CP=Crude protein; C.fibre= Crude fibre; V.premix; Vitamin premix; A.charcoal= Activated charcoal.

Table 4.2: Composition of the experimental diets for broiler finisher processed with activated charcoal (Kg/100Kg)

Diets	T1	T2	T3	T4	T5	T6	T7
CKM levels %	0	5	10	15	20	25	30
Maize	63.91	60.71	57.52	54.32	51.13	47.93	44.74
CKM	0.00	3.20	6.39	9.59	12.78	15.98	19.17
SBM	30.19	30.19	30.19	30.19	30.19	30.19	30.19
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bone meal	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Limestone	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
V. premix	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100	100	100	100	100	100	100

Calculated analysis of the diet

Feed cost/Kg (₦)	105.98	104.75	103.17	101.52	99.88	98.23	97.26
ME kcal/kg	3153.71	3137.76	3121.86	3105.90	3089.99	3074.04	3058.14
CP (%)	20.00	19.74	19.49	19.23	18.97	18.71	18.60
Fat (%)	3.77	3.64	3.51	3.38	3.25	3.13	3.00
C. fibre (%)	3.71	3.63	3.54	3.46	3.37	3.28	3.20
Ash (%)	1.17	1.13	1.09	1.05	1.00	0.96	0.92
Calcium (%)	1.16	1.16	1.16	1.16	1.16	1.16	1.16
Phosphorus	0.65	0.64	0.63	0.62	0.61	0.60	0.59
Lysine	1.08	1.07	1.06	1.05	1.05	1.04	1.03
Methionine	0.54	0.53	0.53	0.52	0.51	0.51	0.50
A.charcoal/g (₦)	0.13	0.13	0.13	0.13	0.13	0.13	0.13

CKM= Chrysophyllum kernel meal; ME=Metabolizable energy; CP=Crude protein; C.fibre= Crude fibre; A.charcoal=Activated charcoal.

Table 4.3: Analysed nutrient content of experimental diets for broiler starter

	D		I	E	T	S	
Parameters	T1	T2	T3	T4	T5	T6	T7
Dry matter (%)	87.45	87.66	87.43	87.47	87.95	87.48	87.38
Crude protein (%)	22.50	21.25	21.74	21.32	22.10	22.93	22.30
Ether extract (%)	2.40	2.81	2.62	2.63	2.39	2.29	1.96
Crude fibre (%)	2.56	2.54	2.23	2.69	2.69	3.21	2.97
Ash (%)	8.38	7.87	7.12	7.17	8.33	9.05	6.92
NFE (%)	48.61	50.19	52.93	48.67	49.52	47.00	50.24

Table 4.4: Analysed nutrient content of experimental diets for broiler finisher

	D		I	E	T	S	
Parameters	T1	T2	T3	T4	T5	T6	T7
Dry matter (%)	86.39	86.66	86.62	86.64	86.62	86.48	86.58
Crude protein (%)	20.21	19.89	20.48	20.94	20.92	21.03	20.85
Ether extract (%)	2.14	2.10	2.08	2.03	2.07	2.04	1.98
Crude fibre (%)	2.97	2.43	2.93	3.13	3.37	3.38	3.36
Ash (%)	6.73	6.92	6.29	6.36	6.76	6.27	6.32
NFE (%)	54.34	55.32	54.21	54.18	53.50	53.76	54.03
Gross energy kcal/g	1050.36	809.70	568.23	446.25	423.31	402.28	413.66

Table 4.5: Proximate composition of processed African star apple kernel meal using activated charcoal

Parameters	%
Dry matter	89.20
Crude protein	16.51
Ether extract	1.92
Ash	4.43
Crude fibre	5.91
Soluble carbohydrate	60.43
Gross energy (kcal/g)	3.94

4.3.6 Data collection/response criteria

In the course of the experiment, data were collected on the performance characteristics: (a) feed consumption, (b) daily weight gain, (c) growth rate, (d) feed conversion ratio, (e) survival rate, (f) Carcass evaluation: at the end of the eight weeks study period, three birds per treatment were randomly selected based on the group average and were weighed, slaughtered and eviscerated for carcass evaluation. The birds were fasted for 12 hours before slaughtering, bled and the slaughter weight taken. The birds were defeathered manually using hot water and eviscerated. The live weight and carcass weight were recorded. The dressing percentage was calculated. Organ weights and the major primal carcass parts were expressed as percentages of the live weight.

4.3.7 Nutrient digestibility trial

The study on apparent nutrient digestibility was carried out at the end of the 8th week of the experimental period. Three birds per treatment were randomly selected and transferred to clean metabolic cages and fed the corresponding treatment diets. The trial lasted for eight days. The first four days were considered as adaptation period and the last four days as experimental period. Records of feed intake and faeces voided were taken during the last four days. The droppings were oven dried, bulked and representative samples were taken for chemical analysis. The samples were analyzed for proximate composition according to the methods of AOAC (1990).

$$\text{Apparent Nutrient Retention} = \frac{\text{Nutrient intake} - \text{Nutrient in faeces}}{\text{Nutrient intake}} \times 100$$

4.3.8 Serum biochemical and haematology analysis

At the end of the experiment, one broiler per replicate in all the treatments was taken at random and blood collected by decapitation. Blood for serum biochemical indices was collected in bottles without EDTA for the analysis of the serum biochemical parameters of (a) blood electrolytes: Ca, Na, K, Cl, and bicarbonate, (b) blood glucose level, (c) total protein, (d) albumin, (e) globulin, (f) albumin/globulin ratio (g) total cholesterol (h) creatinine (i) urea (j) lipid profile (HDL and LDL), (k) transaminase activities- AST, ALT ALP etc. The samples were spurned in the centrifuge at 3,000 rpm and the clearer portion (serum) decanted after centrifugation into another set of plain bottles and were placed in an ice bath and taken to the laboratory.

The blood samples for haematology parameters were pretreated with ethylene diamine tetra-acetate (EDTA), an anti-coagulant and were placed in the refrigerator (4°C) immediately before taken to the laboratory. Haematology indices examined include white blood cell (WBC) and its differential counts (neutrophils, lymphocyte, monocyte, eosinophil and basophils), red blood cell (RBC), packed Cell Volume (PCV), haemoglobin (Hb). The mean cell volume (MCV), mean cell haemoglobin (MCH) and the mean cell haemoglobin concentration (MCHC) were calculated from the values of the RBC, PCV and Hb respectively.

$$\text{MCV} = \frac{\text{PCV}}{\text{RBC}} \times 10$$

$$\text{MCH} = \frac{\text{Hb}}{\text{RBC}} \times 10$$

$$\text{MCHC} = \frac{\text{Hb}}{\text{PCV}} \times 100$$

4.3.9 Histology of the liver

Three birds were selected per treatment at the end of the feeding trial and sacrificed to obtain the liver. Sections were obtained from the anterior lobe of the liver, preserved in 90% saline + 10% formalin solution. The liver tissues from each replicate were processed for histological studies using haematoxylin and eosin stains. Photomicrographs were taken using a digital microscope with a magnification of 400. The analysis was carried out at the histopathological laboratory of Central Research Laboratory, Tanke, Ilorin.

4.4 Statistical analysis

Data collected on the response criteria were subjected to analysis of variance according to the completely randomized design model and differences between treatment means were separated using the Duncan's multiple range test (Steel and Torrie, 1980).

4.5 Results

4.5.1 Physical treatment and chemical analysis of African star apple kernel meal

The treatment of the raw kernels with activated charcoal was preceded by physical treatment of soaking and boiling to determine the treatment group that will mostly reduce the antinutritional factors in the kernels before the pretreatment of the milled kernels with activated charcoal for onward inclusion in the diet.

The kernels were partitioned into three groups which involved:

1. Soaking the kernels for 12 hours and boiling for 30 minutes.
2. Soaking the kernels for 24 hours and boiling for 1 hour.
3. Soaking the kernels for 48 hours and boiling for 2 hours.

Table 4.6 presents the phytochemicals in the various soaking and boiling time for the *C. albidum* kernels. It was observed that the group in which the kernels was soaked for 12 hours and boiled for 30 minutes was mostly suitable for further chemical treatment owing to the reduction in the level of saponins, phytate, oxalate and glycoside in relation to group 2 and 3 respectively. However the level of tannins increased in all the groups in relation to the tannin content in the raw kernels. The saponin, phytate, oxalate and glycoside content in the raw *Chrysophyllum. albidum* kernel meal decreased by 74.16%, 88.06%, 97.50% and 99.99% after soaking and boiling for 12 hours and 30 minutes respectively, for the tannin content, there was an increase of 18.69%.

The phytochemical analysis of the processed African star apple kernel using activated charcoal (ASAK^{AC}) meal is presented on Table 4.7. It was observed that, there was a further decrease in the saponins, phytate, and tannins content in relation to the soaked and boiled raw kernels for 12 hours and 30minutes respectively and a slight increase in the oxalate and glycoside content after treatment with activated charcoal, however the values obtained were lower than the raw kernels.

Table 4.6: Phytochemical analysis of the raw versus the soaking/boiling intervals of the African star apple kernels

Parameters	Raw kernels (mg/kg)	Soaked 12hours Boiled 30 mins (mg/kg)	Soaked 24hours Boiled 1 hour (mg/kg)	Soaked 48hours Boiled 2 hours (mg/kg)
Saponins	12.15	3.14	3.12	3.14
Phytate	1,308.70	156.25	155.23	154.77
Tannins	1,037.47	1,276.04	1375.00	1,312.50
Oxalate	0.80	0.02	2.83	7.13
Glycoside	0.78	0.000071	0.000048	0.000053

Table 4.7: Phytochemical analysis of processed African star apple kernel meal using activated charcoal

Parameters	mg/kg
Saponin	1.38
Phytate	0.31
Tannins	8.30
Oxalate	0.29
Glycoside	0.02

4.5.2 Growth performance characteristics of broilers fed processed African star apple kernel meal using activated charcoal

Table 4.8 presents the growth performance characteristics of broilers fed processed ASAK^{AC} meal. The growth performance characteristics of the birds fed the processed ASAK^{AC} meal showed mild improvement compared to the birds fed the raw ASAK meal. The growth performance characteristics of the birds on the processed ASAK^{AC} meal were very poor in relation to the birds fed the control diet. The final live weights, average daily weight gains and the feed intake values of the birds significantly ($p < 0.05$) decreased as the processed ASAK^{AC} meal increased in the diet of the birds for the replacement of maize as energy source. The feed conversion ratio favoured the birds fed the control diet compared to those fed the processed ASAK^{AC} meal. There was an increased poor feed conversion ratio as the processed ASAK^{AC} meal increased in the diets. The results of the cost per kg weight gains also followed the same trend with the feed conversion ratios. There was a decrease in the feed cost N/kg of the birds as the dietary replacement of maize with the processed ASAK^{AC} meal increased in the diets of the birds. The percent mortality of the birds was not significantly ($p > 0.05$) affected by the dietary inclusion of the processed ASAK^{AC} meal in the diet of the birds.

The phytochemical dietary intake of broilers fed the processed African star apple kernel using activated charcoal meal is presented on Table 4.9. The residual phytochemicals in the diets was shown to be responsible for the poor growth performance indices observed in the birds.

Table 4.8: Growth performance characteristics of broilers fed processed African star apple kernel meal using activated charcoal

Parameters	T1	T2	T3	T4	T5	T6	T7	SEM	Pvalue
	(0%)	(5%)	(10%)	(15%)	(20%)	(25%)	(30%)		
Initial live weight (g/bird)	131.25	131.25	131.25	131.25	131.25	131.25	131.25	-	-
Final live weights (g/bird)	2020.00 ^a	1170.00 ^b	900.00 ^c	759.97 ^d	684.93 ^e	639.98 ^f	604.98 ^g	3.68	0.0001
Daily weight gains (g/bird/day)	40.18 ^a	22.10 ^b	16.35 ^c	13.37 ^d	11.78 ^e	10.82 ^f	10.07 ^g	0.08	0.0001
Feed intake (g/bird/day)	116.77 ^a	97.55 ^b	92.44 ^c	78.38 ^d	76.05 ^e	73.60 ^f	68.62 ^g	0.41	0.0001
Feed conversion ratio	2.91 ^f	4.41 ^e	5.65 ^d	5.86 ^c	6.45 ^b	6.80 ^a	6.81 ^a	0.03	0.0001
Cost per kg weight gain (₦)	308.40 ^f	462.29 ^e	583.25 ^d	594.90 ^c	644.89 ^b	667.96 ^a	662.34 ^a	4.30	0.0001
Cost of feed/kg (₦)	105.98	104.75	103.17	101.52	99.88	98.23	97.26		-
% Mortality	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d,e,f,g}Means with different superscript along the same rows are significant (P<0.05);NS=Non Significant (P>0.05)

Table 4.9: Dietary phytochemical intake of broilers fed processed African star apple kernel meal using activated charcoal

Parameters	T1	T2	T3	T4	T5	T6	T7	SEM	P value
	(0%)	(5%)	(10%)	(15%)	(20%)	(25%)	(30%)		
Saponins (mg/bird/day)	0.00 ^g	0.43 ^f	0.82 ^e	1.04 ^d	1.34 ^c	1.62 ^b	1.82 ^a	0.51	0.0001
Phytate (mg/bird/day)	0.00 ^g	0.10 ^f	0.18 ^e	0.23 ^d	0.30 ^c	0.36 ^b	0.40 ^a	4.28	0.0001
Tannins (mg/bird/day)	0.00 ^g	2.59 ^f	4.90 ^e	6.24 ^d	8.07 ^c	9.76 ^b	10.92 ^a	3.81	0.0001
Oxalate (mg/bird/day)	0.00 ^g	0.09 ^f	0.17 ^e	0.22 ^d	0.28 ^c	0.34 ^b	0.38 ^a	0.03	0.0001
Glycoside (mg/bird/day)	0.00 ^g	4.7x10 ^{-3f}	8.9x10 ^{-3e}	1.13x10 ^{-2d}	1.46x10 ^{-2c}	1.76x10 ^{-2b}	1.97x10 ^{-2a}	0.03	0.0001

4.5.3 Carcass characteristics of broilers fed processed African star apple kernel meal using activated charcoal

The carcass characteristics of the broilers fed processed African star apple kernel using activated charcoal meal is presented on Table 4.10. The carcass characteristics of the broilers fed the processed ASAK^{AC} meal were fairer than when fed raw to the birds, though far below the optimum for the birds on the control diet. The differences in the live weights, carcass weights and the dressing percentage were significantly ($p < 0.05$) affected across the treatment groups on the test feedstuff. There was a corresponding decrease in the live weights, carcass weights and dressing percentage of the birds as the processed ASAK^{AC} meal increased in the diets of the birds. The weights of the carcass components for the head, neck, wings, thigh, drumstick, shank, breast, back expressed as percentages of the live weights were lower in all the dietary groups fed the processed ASAK^{AC} meal compared with the control group. The weights of the heart, liver, kidney, proventriculus and the gizzard were significantly ($p < 0.05$) affected except the lungs that was not significantly ($p > 0.05$) affected. There was a significant ($p < 0.05$) decrease in the lengths of the small and large intestines as the dietary replacement of corn with the processed ASAK^{AC} meal increased in the diets of the birds compared with birds fed the control diet.

4.5.4 Serum biochemical indices of broilers fed processed African star apple kernel meal using activated charcoal

Table 4.11 presents the serum biochemical indices of broilers fed processed African star apple kernel using activated charcoal meal. The pattern in the values of the biochemical indices of the birds fed the processed ASAK^{AC} meal were fairer in relation to the birds fed the increasing inclusion level of the raw African star kernel meal for replacing maize

Table 4.10: Carcass characteristics of broilers fed processed African star apple kernel meal using activated charcoal

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Live weight (g/bird)	2020.00 ^a	1170.00 ^b	900.00 ^c	759.97 ^d	684.93 ^e	639.98 ^f	604.98 ^g	3.68	0.0001
Carcass weights (g/bird)	1318.20 ^a	754.54 ^b	579.68 ^c	400.95 ^d	360.50 ^e	313.69 ^f	286.40 ^g	5.87	0.0001
Dressing percentage (%)	65.28 ^a	64.49 ^b	64.41 ^b	52.76 ^c	52.63 ^c	49.02 ^d	47.34 ^e	0.37	0.0001
Prime cut and Organ weights	expressed as % of live weight								
Head	2.45 ^g	3.30 ^e	3.34 ^d	3.39 ^c	3.04 ^f	3.54 ^a	3.47 ^b	0.01	0.0001
Thigh	10.92 ^a	10.19 ^b	8.38 ^c	7.84 ^d	7.27 ^e	6.84 ^f	6.66 ^g	0.04	0.0001
Breast	21.05 ^a	18.00 ^c	18.71 ^b	11.28 ^g	12.90 ^d	11.86 ^e	11.59 ^f	0.07	0.0001
Wings	8.23 ^b	7.89 ^c	8.48 ^a	6.63 ^f	6.98 ^d	6.91 ^e	6.88 ^e	0.03	0.0001
Shank	4.27 ^b	4.92 ^a	4.17 ^c	3.80 ^f	3.72 ^g	3.92 ^e	3.98 ^d	0.02	0.0001
Neck	5.47 ^c	6.02 ^a	5.62 ^b	4.75 ^e	4.91 ^d	4.12 ^g	4.29 ^f	0.02	0.0001
Drumstick	8.64 ^a	8.49 ^b	8.43 ^b	7.63 ^c	7.43 ^d	6.99 ^e	7.64 ^c	0.06	0.0001
Back	11.24 ^c	12.33 ^b	12.57 ^a	10.59 ^d	10.28 ^f	10.42 ^e	10.15 ^g	0.05	0.0001
Heart	0.36 ^e	0.44 ^a	0.40 ^c	0.39 ^d	0.32 ^f	0.42 ^b	0.36 ^e	0.01	0.0001
Lungs	0.54	0.52	0.55	0.56	0.53	0.52	0.56	0.03	0.3251
Liver	3.09 ^c	2.34 ^f	2.93 ^d	3.27 ^a	3.19 ^b	2.71 ^e	2.13 ^g	0.01	0.0001
Kidney	0.53 ^a	0.47 ^b	0.44 ^{bc}	0.42 ^c	0.39 ^d	0.35 ^e	0.34 ^e	0.02	0.0001
Proventriculus	0.41 ^e	0.56 ^b	0.53 ^c	0.52 ^d	0.52 ^d	0.56 ^b	0.62 ^a	0.02	0.0001
Gizzard	1.78 ^g	2.28 ^f	2.37 ^d	2.40 ^e	2.55 ^b	2.34 ^e	2.61 ^a	0.01	0.0001
Small intestine length (cm)	140.71 ^a	128.18 ^b	102.07 ^c	76.70 ^d	53.49 ^e	47.50 ^f	38.27 ^g	4.18	0.0001
Large intestine length (cm)	67.61 ^a	60.90 ^b	52.58 ^c	39.41 ^d	26.36 ^e	25.31 ^f	20.40 ^g	2.08	0.0001

SEM= Standard error of mean;LOS= Level of Significance,*=P<0.05;^{a,b,c,d,e,f,g}Means with different superscript along the same rows are significant (P<0.05);NS=Non Significant (P>0.05)

Table 4.11: Serum biochemical indices of broilers fed processed African star apple kernel meal using activated charcoal

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Glucose (mg/dl)	94.84 ^d	101.37 ^d	105.47 ^c	109.38 ^{bc}	112.72 ^b	118.75 ^{ab}	126.28 ^a	2.51	0.0005
Calcium (ppm)	11.04 ^{ab}	11.23 ^a	11.02 ^{ab}	11.18 ^a	10.99 ^b	9.91 ^{bc}	9.42 ^c	0.61	0.0137
Sodium (mEq/l)	109.74 ^{ab}	117.53 ^a	115.94 ^{ab}	110.05 ^{ab}	106.17 ^{ab}	113.09 ^{ab}	104.22 ^b	2.50	0.1685
Potassium (mg/dl)	17.70 ^d	19.93 ^c	21.88 ^{bc}	20.81 ^c	23.73 ^b	24.65 ^a	24.91 ^a	1.12	0.0001
Urea (mg/dl)	26.92 ^e	35.41 ^d	39.54 ^c	41.27 ^{bc}	42.95 ^b	44.56 ^{ab}	46.50 ^a	2.29	0.0001
Creatinine (mg/ml)	0.71 ^a	0.52 ^b	0.46 ^c	0.39 ^d	0.34 ^e	0.26 ^f	0.21 ^g	0.02	0.0001
Total cholesterol (mg/dl)	69.45 ^a	64.93 ^{ab}	61.71 ^b	54.56 ^c	48.75 ^d	43.78 ^{de}	39.51 ^e	1.78	0.0001
HDL Cholesterol (mg/dl)	11.54 ^a	10.77 ^{ab}	10.23 ^b	9.01 ^c	8.03 ^d	7.18 ^{de}	6.45 ^e	0.53	0.0001
LDL Cholesterol (mg/dl)	56.38 ^a	52.62 ^{ab}	49.94 ^b	44.02 ^c	39.19 ^d	35.06 ^e	31.53 ^e	2.63	0.0001
Triglyceride (mg/dl)	12.78 ^a	10.15 ^b	9.39 ^{bc}	9.02 ^c	8.64 ^c	7.14 ^d	5.86 ^e	0.52	0.0001
Total protein (mg/dl)	14.76 ^c	12.97 ^d	13.60 ^{cd}	15.08 ^c	15.22 ^c	20.82 ^b	23.82 ^a	0.97	0.0001
Albumin (g/l)	0.31 ^b	0.23 ^c	0.30 ^b	0.29 ^b	0.30 ^b	0.33 ^{ab}	0.34 ^a	0.02	0.0002
Globulin (g/l)	14.45 ^{cd}	12.73 ^d	13.30 ^{cd}	14.79 ^c	14.92 ^c	20.49 ^b	23.48 ^a	0.95	0.0001
Albumin-Globulin ratio	0.02	0.01	0.02	0.01	0.02	0.01	0.01	-	
Aspartate Aminotransaminase (u/l)	10.68 ^e	23.00 ^c	19.49 ^d	21.50 ^{cd}	25.50 ^b	27.00 ^{ab}	28.50 ^a	1.30	0.0001
Alanine Aminotransaminase (u/l)	12.80 ^c	8.60 ^e	8.80 ^e	10.20 ^{de}	10.80 ^d	19.40 ^b	25.80 ^a	0.88	0.0001
Alkaline phosphate (u/l)	0.92 ^d	1.84 ^c	2.30 ^b	2.76 ^a	2.76 ^a	2.69 ^a	2.76 ^a	0.14	0.0001

SEM= Standard error of mean;LOS= Level of Significance;*= $P<0.05$;^{a,b,c,d,e,f}Means with different superscript along the same rows are significantly ($P<0.05$);NS=Non Significant ($P>0.05$); HDL=High Density Lipid;LDL=Lipid Density Lipid.

in the diet of the birds. There was a significant ($p<0.05$) linear increase in the blood calcium and potassium levels as the processed ASAK^{AC} meal increased in the diet of the birds. The serum sodium values were significantly ($p<0.05$) affected, however, the trend in the result were irregular. The highest serum sodium value was observed in T2, whereas T1, T3, T4, T5 and T6 were statistically similar and the lowest observed in T7. The blood glucose and serum urea levels significantly ($p<0.05$) increased with an increasing inclusion level of the processed ASAK^{AC} meal in the diet of the birds. There was a significant ($p<0.05$) decrease in the creatinine levels of the birds as the inclusion level of the processed ASAK^{AC} meal increased in the diet of the birds.

There were significant ($p<0.05$) differences for the total cholesterol, high density lipid (HDL) cholesterol, low density lipid (LDL) cholesterol and triglyceride respectively with a linear decrease in their values as the dietary inclusion level of the processed ASAK^{AC} meal increased in the diet of the birds. The serum total protein, albumin and globulin were significantly ($p<0.05$) affected as the dietary inclusion level of the processed ASAK^{AC} meal increased. The trend in the values were irregular, there was decrease from T1 to T2 followed by an increase from T3 to T7 for the total protein. The result obtained for the serum albumin for the birds fed the raw ASAK meal was not significant whereas significant for the birds fed the processed ASAK^{AC} meal. The albumin values obtained for T1, T3, T4, T5, T6, respectively were statistically similar, the lowest and highest recorded in T2 and T7, respectively for the birds fed the processed ASAK^{AC} meal. The values obtained for the serum globulin also followed a similar trend with the serum albumin. The serum aspartate transaminase (AST), alanine transaminase (ALT) and alkaline phosphate (ALP) levels of the birds fed the processed ASAK^{AC} meal were

significantly ($p<0.05$) affected and the values obtained revealed an increase in the trend similar to the significant ($p<0.05$) linear increase observed in the birds fed the raw ASAK meal. The values obtained for the AST, ALT and ALP were higher than the value recorded for those on the control diet.

4.5.5 Haematology indices of broilers fed processed African star apple kernel meal using activated charcoal

The haematology indices of broilers fed processed African star apple kernel using activated charcoal meal is presented on Table 4.12. The red blood cell of the birds fed the processed ASAK^{AC} meal was significantly ($p<0.05$) affected, there was an increase in the red blood cells as the processed ASAK^{AC} meal increased in the diet of the birds compared with the birds on the control diet. The haemoglobin and the packed cell volume were not significantly ($p>0.05$) affected by the processed ASAK^{AC} meal unlike in the birds that were fed the raw ASAK meal, although there was a linear increase in the values but not statistically significant. The mean cell volume of the birds was significantly ($p<0.05$) affected, however accompanied by an irregular trend. The MCV values of the birds on the control diet were statistically similar those on treatment 2 and 4 and higher than their counterpart on treatments 3, 5, 6 and 7 respectively. The mean cell haemoglobin and mean cell haemoglobin concentration were significantly ($p<0.05$) affected by dietary inclusion of the processed ASAK^{AC} meal in the diet of the birds and also followed a similar trend with the mean cell volume. The white blood cell of the broilers on the processed ASAK^{AC} meal were not significantly ($p>0.05$) affected, although there was a linear increase in the white blood cells as the processed ASAK^{AC} meal increased in the diet of the birds unlike in the birds fed the raw ASAK meal that were significantly ($p<0.05$) affected.

Table 4.12: Haematology indices of broilers fed processed African star apple kernel meal using activated charcoal

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Red Blood Cell (x 10 ¹² /l)	2.32 ^c	2.33 ^c	2.40 ^{bc}	2.45 ^{bc}	2.53 ^b	2.60 ^{ab}	2.65 ^a	0.04	0.0641
Haemoglobin (g/dl)	8.54	8.54	8.73	8.87	9.02	9.12	9.30	0.16	0.4704
Packed Cell Volume (%)	30.14	30.33	31.00	31.77	32.24	32.79	33.21	0.77	0.3141
Mean Cell Volume (fl)	129.73 ^a	129.99 ^a	128.66 ^b	129.51 ^a	127.30 ^c	125.96 ^d	124.87 ^e	0.10	0.0001
Mean Cell Haemoglobin (pg)	36.78 ^a	36.62 ^a	36.24 ^b	36.15 ^b	35.61 ^c	35.03 ^d	35.00 ^d	0.02	0.0001
Mean Cell Hae. Conc (g/dl)	28.35 ^a	28.17 ^b	28.17 ^b	27.91 ^e	27.97 ^d	27.81 ^f	28.02 ^c	0.01	0.0001
White Blood Cell (x 10 ⁹ /l)	234.34	235.78	239.53	241.44	242.59	244.41	246.05	2.12	0.9230

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d,e,f}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant (P>0.05);Mean Cell Hae. Conc= Mean Cell Haemoglobin Concentration.

4.5.6 Nutrient retention of broilers fed processed African star apple kernel meal using activated charcoal

Table 4.13 presents the nutrient retention of broilers fed processed African star apple kernel using activated charcoal meal. The nutrient retention of the dry matter, crude protein, ether extract and soluble carbohydrate were significantly ($p < 0.05$) affected with a linear decrease as the processed ASAK^{AC} meal increased in the diet of the birds in relation to the birds on the control diet. The trend in the nutrient retention of the birds fed the processed ASAK^{AC} meal was fairer compared to their counterpart fed the raw ASAK meal.

4.5.7 Histology of the liver of broilers fed processed African star apple kernel meal using activated charcoal

The photomicrographs showing the liver of the birds fed the processed African star apple kernel meal are shown on plates 1-7. The sections of the liver revealed a distortion in the architecture of the liver as the processed ASAK^{AC} meal increased in the diet of the birds accompanied with a severe deposition of tars in the central vein of the liver.

4.5.8 Profitability of broilers fed processed African star apple kernel meal using activated charcoal for dietary replacement of maize

Table 4.14 shows the profitability of replacing maize with processed African star apple kernel using activated charcoal meal in broilers diet. The total feed intake, total weight gain and total cost of production per bird were higher in the birds fed the control diet, although there was a decrease in the feed cost per kg as the replacement of maize with the processed ASAK^{AC} meal increased in the diet. The reduction in the prices could not inturn enhance the profit on investment. The highest profit was obtained from the birds fed the control diet and the lowest obtained in the group fed 30% inclusion level of the

Table 4.13: Nutrient retention of broilers fed processed African star apple kernel meal using activated charcoal

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Dry matter	87.01 ^a	72.76 ^b	66.99 ^c	56.73 ^d	58.41 ^d	56.88 ^d	49.25 ^e	1.63	0.0001
Crude protein	86.80 ^a	77.03 ^b	77.05 ^b	74.46 ^{bc}	70.60 ^{bc}	67.82 ^c	62.72 ^d	2.91	0.0014
Ether extract	80.17 ^a	73.28 ^b	61.30 ^{bc}	61.19 ^{bc}	60.76 ^{bc}	56.05 ^c	47.85 ^d	5.05	0.0053
Soluble carbohydrate	62.79 ^a	61.05 ^a	56.27 ^b	54.99 ^b	53.27 ^{bc}	53.05 ^{bc}	49.99 ^c	1.53	0.0007

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d} Means with different superscript along the same rows are significantly (P<0.05)

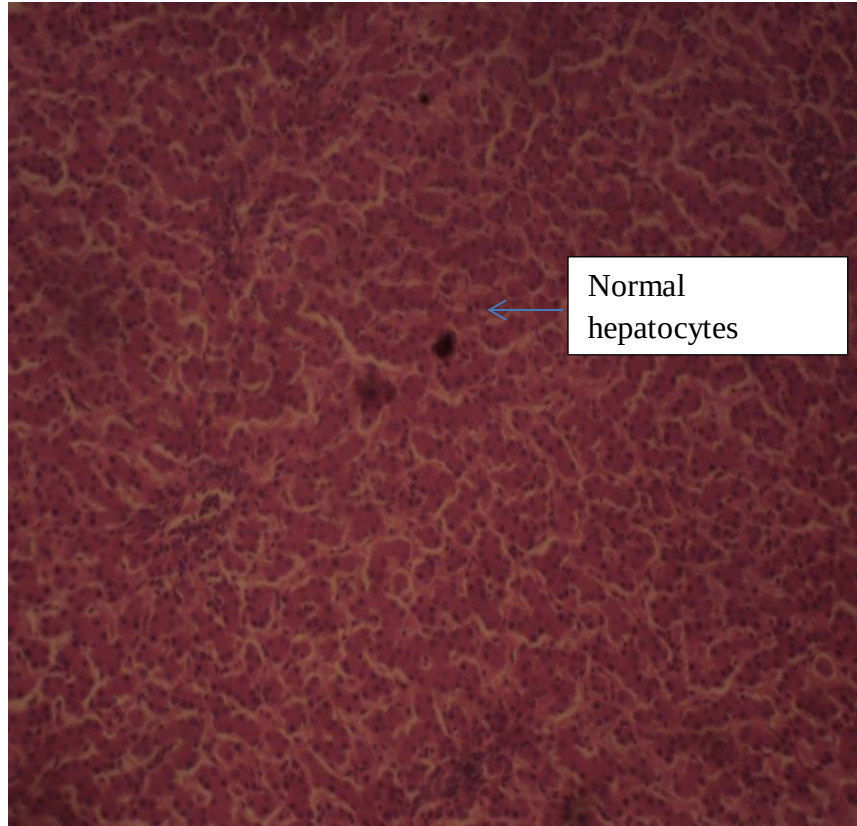


Plate i - Photomicrograph showing the liver of broilers fed the control diet
H/E Stain Mag. X400

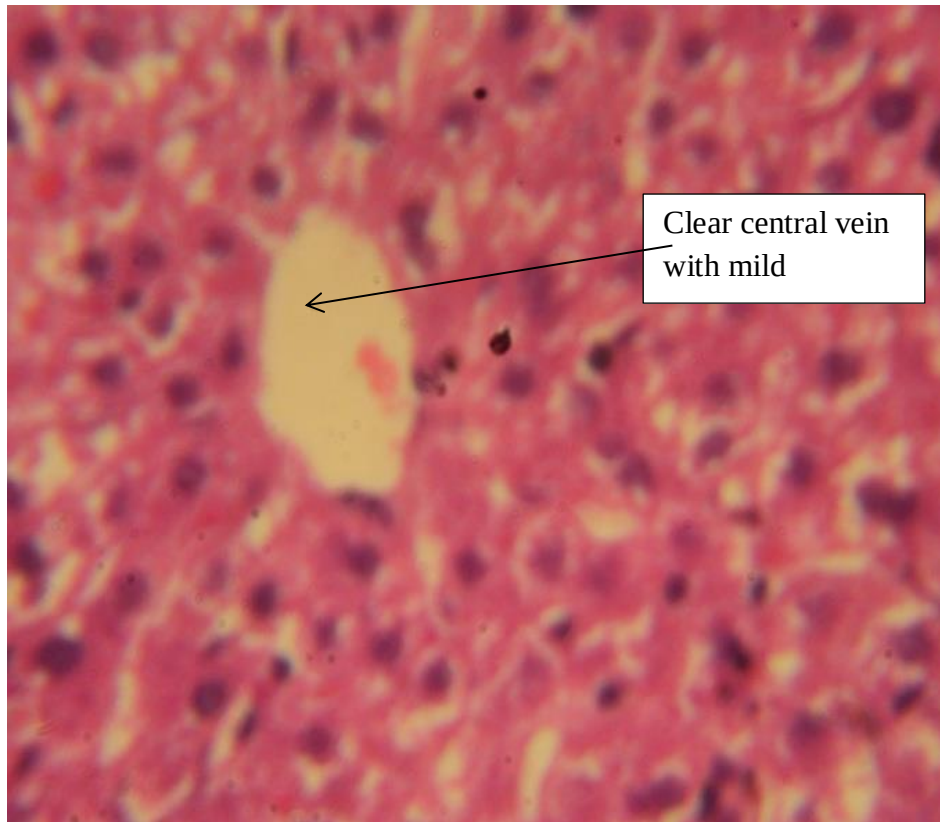


Plate ii - Photomicrograph showing the liver of broilers fed 5% processed African star apple kernel meal using activated charcoal

H/E Stain. Mag. X400

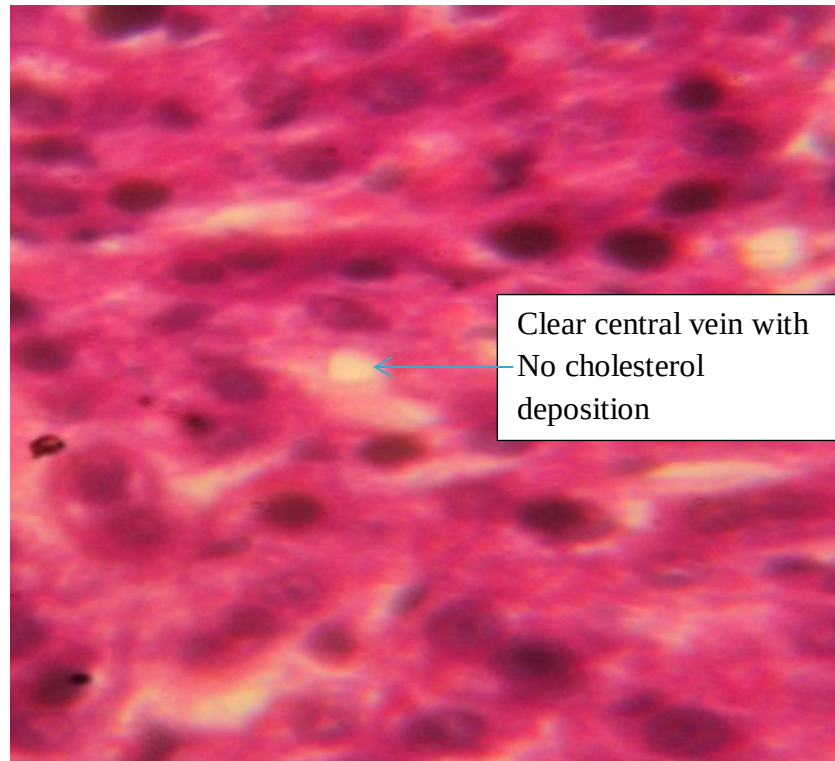


Plate iii - Photomicrograph showing the liver of broilers fed 10% processed African star apple kernel meal using activated charcoal

H/E Stain. Mag. X400

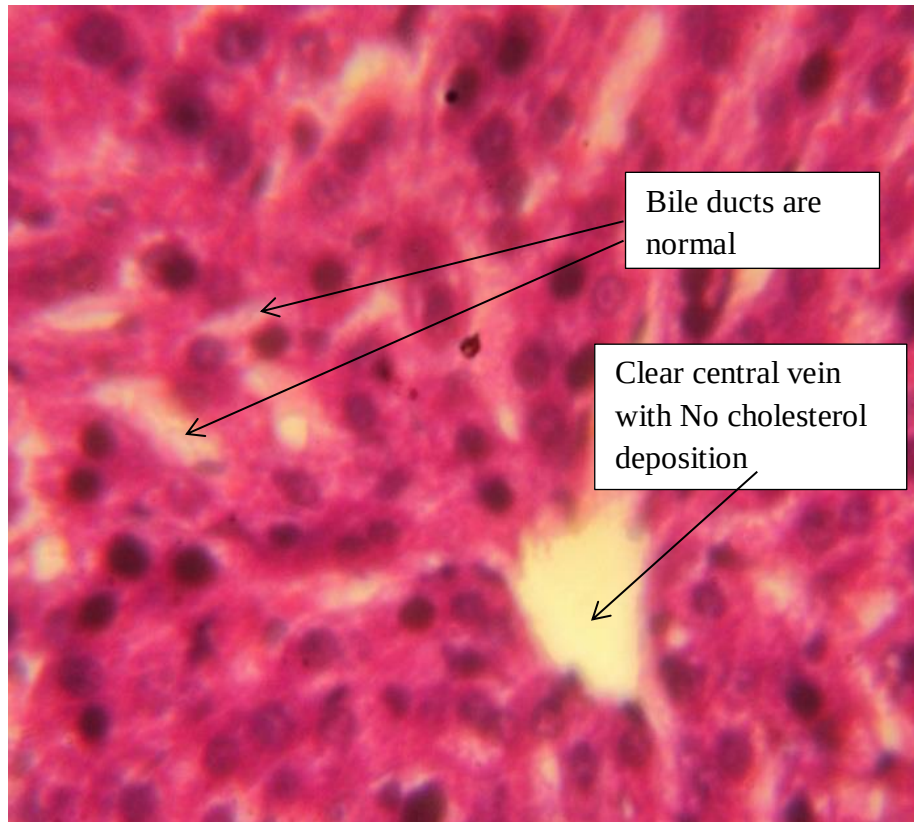


Plate iv - Photomicrograph showing the liver of broilers fed 15% processed African star apple kernel meal using activated charcoal

H/E Stain. Mag. X400

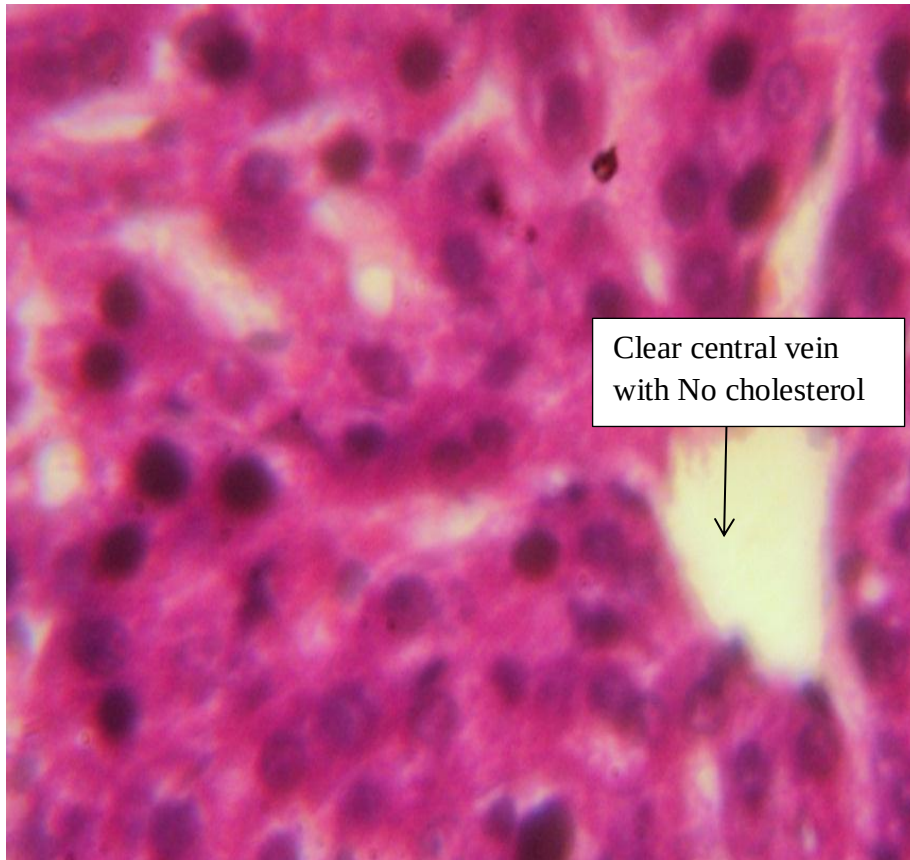


Plate v - Photomicrograph showing the liver of the birds fed 20% processed African star apple kernel meal using activated charcoal

H/E Stain. Mag. X400

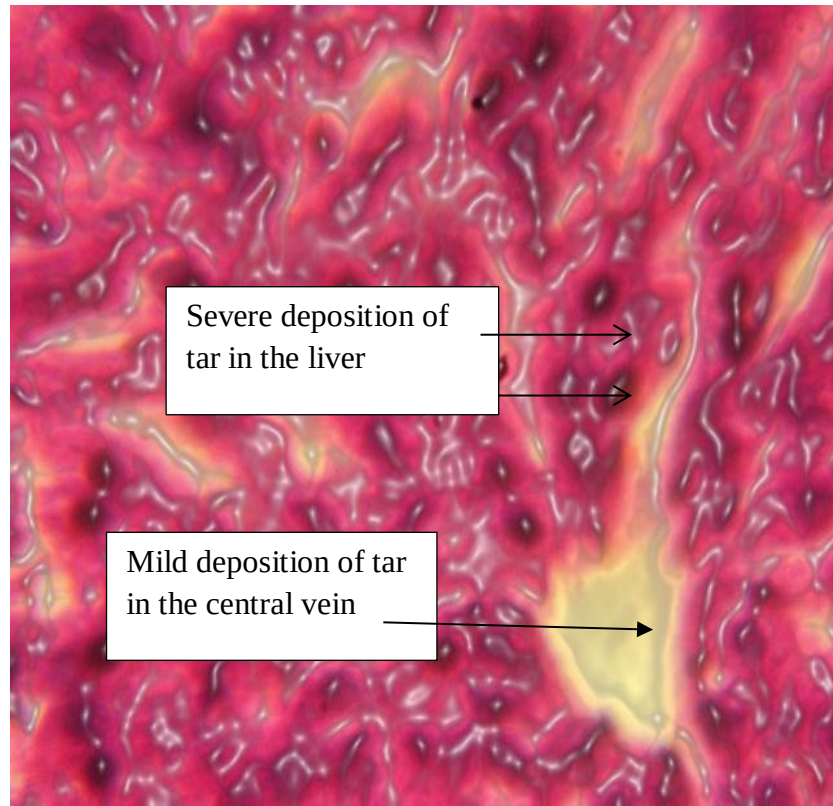


Plate vi - Photomicrograph showing the liver of broilers fed 25% processed African star apple kernel meal using activated charcoal

H/E Stain. Mag. X400

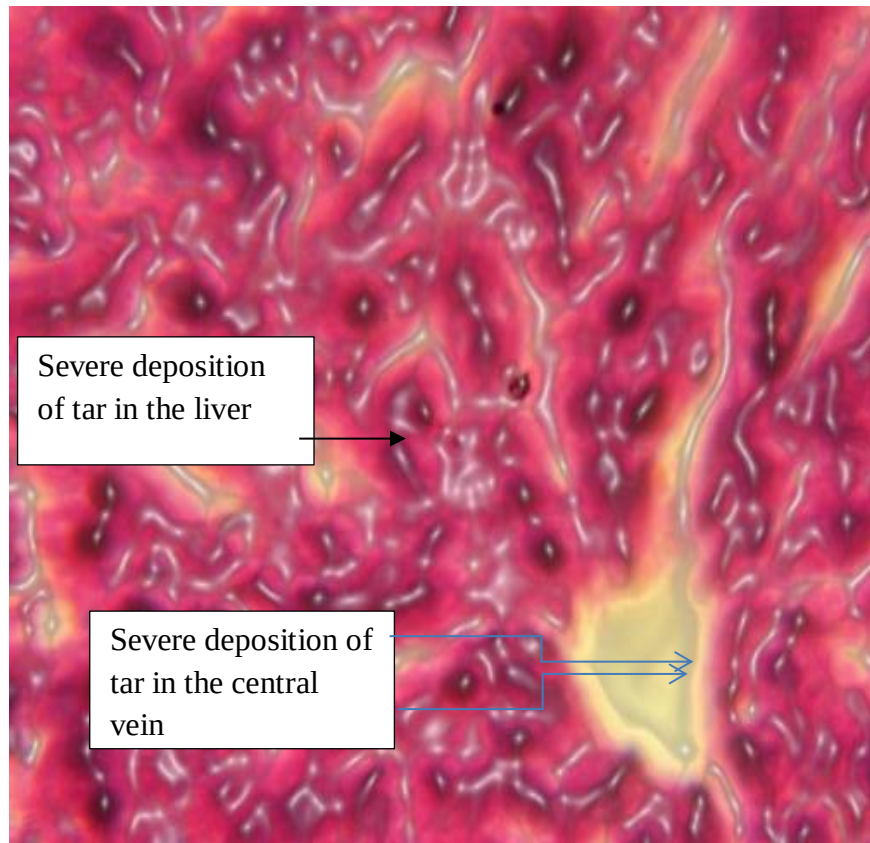


Plate vii - Photomicrograph showing the liver of broilers fed 30% processed African star apple kernel meal using activated charcoal

H/E Stain. Mag. X400

Table 4.14: Profitability of broilers fed processed African star apple kernel meal using activated charcoal for dietary replacement of maize

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Total feed intake (g/bird)	5,488.19 ^a	4,584.85 ^b	4,344.68 ^c	3,683.86 ^d	3,574.35 ^e	3,459.20 ^f	3,225.14 ^g	4.35	0.0001
Total weight gain (g/bird)	1,888.75 ^a	1,038.75 ^b	768.75 ^c	628.72 ^d	553.73 ^d	508.73 ^e	473.73 ^f	1.65	0.0001
Final live weight (g/bird)	1,888.75 ^a	1,170.00 ^b	900.00 ^c	759.97 ^d	684.93 ^d	639.98 ^e	604.98 ^d	4.99	0.0001
Cost of feed/kg (₦)	105.98	104.75	103.17	101.52	99.88	98.23	97.26	-	-
(a) Cost of DOC/Medication	160.00	160.00	160.00	160.00	160.00	160.00	160.00	-	-
(b)Cost of feeding /bird = FC x TFI (₦)	581.64	480.26	448.24	373.99	357.01	339.80	313.68	-	-
Total cost of production/bird = (a+b) (₦)	741.64	640.26	608.24	533.99	517.01	499.80	473.68	-	-
Revenue = Fnwt x sales/kg	1,717.00	994.50	765.00	645.97	582.19	543.98	514.23	-	-
Profit (₦) = Revenue – TC	975.36	354.24	156.76	111.99	65.18	44.19	40.56	-	-
Sale's price/kg (₦)	850	850	850	850	850	850	850	-	-

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant. DOC= Day Old Chicks; FC= Feed Cost; TFI= Total Feed Intake; Fnwt=Final live weight; TC=Total cost of production; Naira=₦

processed ASAK^{AC} meal. There was a mild improvement in the birds fed the processed CKM with activated charcoal over the group fed the raw *C. albidum* kernels. The returns on investment for the dietary treatment of 10-30% processed ASAK^{AC} meal may not justify the total cost of production.

4.6 Discussion

Soaking and Boiling of the African star apple kernels: The increase in the tannin content of the soaked and boiled kernels compared to the raw kernels were as a result of the changes in the dry matter. This assertion could be supported by the findings of Vidal-Valverde *et al.* (1992), who reported that some metabolic reactions could occur during soaking which inturn affects some constituent compounds. The findings in this study is contrary to the reports of Ahamefule and Odomelam (2008), that soaking for 24 hours would produce better result with regard to the removal of tannin in feed ingredients. In this study, an increase in the soaking period from 12 to 24 and 48 hours increased the tannin content in *Chrysophyllum albidum* kernels. The effect of cooking on the *C. albidum* kernels may have being masked by the metabolic changes that occurred during soaking. However, cooking of the *C. albidum* kernels may not have had much effect on the tannin content as there was an increase in the tannin content for all the groups which involved soaking for 12, 24 and 48 hours and a corresponding boiling interval of 30, 60 and 120 minutes respectively. The reports of Mbajuwa (1995), that cooking inactivates the activities of tannins and Balogun *et al.* (2001), who opined that antinutritional factors in legume seeds were destroyed after 30 minutes of cooking do not corroborate with the findings of this study with respect to decrease in the tannin content in the *C. albidum* kernels.

Growth performance characteristics: The most probable explanation for the depressed final live weight, weight gain and average daily weight gains in the birds fed beyond 5% inclusion level of the processed ASAK^{AC} meal is mainly attributed to the presence of the phytochemicals still present in the ASAK even after processing. These antinutritional factors may have constituted a hindrance to the bio-availability of nutrients to the birds. The non availability of the nutrients to the animal's body might have impacted negatively on the feed conversion ratio. The increasing cost per kg weight gains as the processed ASAK^{AC} meal increased in the diet despite the reduction in the feed cost were as a result of the poor feed conversion ratio, as the birds will have to consume more to attain a kilogram in body weight. Tannins for example form complex linkage with protein hence poor digestibility leading to loss of protein and consequently poor growth. The low feed intake recorded as the processed ASAK^{AC} meal increased in the diets could be supported by the findings of Douglas *et al.* (1993), who reported that tannins reduces dry matter intake due to reduced palatability.

Activated charcoal has been recommended as a general toxin absorbing agent and routinely used for various digestive toxicities (MVM, 1994), although there were mild improvements on the use of the processed ASAK^{AC} meal on the growth performance characteristics of the birds over their counterpart fed the raw ASAK meal, its effect on the ANFs in the ASAK was less effective for the enhanced performance characteristics of the birds. The effectiveness of activated charcoal for the removal of ANFs in the ASAK is contrary to the findings of Odunsi *et al.* (2009) who reported the effectiveness of wood charcoal as an absorbing agent of anti-nutritive factors in feed when used to pretreat neem (*Azadirachta indica*) seed cake in the diet of cockerel chickens. The findings on the

use of activated charcoal for the detoxification of feedstuff do not agree with the reports of Kutlu *et al.* (2001), that inclusion of wood charcoal improved the performance of broiler chickens during the first four weeks of age.

Carcass characteristics: The decrease in the live weights, dressing percentage, carcass weights and its components as the inclusion level of the processed ASAK^{AC} meal increased in the diets of the birds was as a result of the reduced final live weights and poor feed conversion ratio of the birds fed between 10 and 30% inclusion level of the processed ASAK^{AC} meal. The effect of the processed ASAK^{AC} meal on the internal organs of the heart, liver, kidney and proventriculus except for the lungs could be as a result of the relative weights of the birds when these organs were expressed as percentages of the live weights of the birds due to the effect of the phytochemicals on the performance characteristics which were not reasonably alleviated by the absorbent (activated charcoal) in the animal's body.

Serum biochemical indices: The increase in the serum calcium and potassium levels as the processed ASAK^{AC} meal increased in the diet of the birds were ascribed to the appreciable levels of these minerals in the seed. This assertion could be supported by the findings of Ukana *et al.* (2012), that calcium and magnesium were higher in the seeds of African star apple. The sodium levels do not follow a specific pattern, however the similarities between the values obtained in the birds fed the control diet and those fed 10, 15, 20, 25 and 30% processed ASAK^{AC} meal attest to the nutritional adequacy of the ASAK for normal metabolic activities. The elevation in the blood glucose of the birds fed the processed ASAK^{AC} meal over those on the control diet might perhaps be ascribed to the influence of the ASAK in the diet which probably increased the energy content and

enhanced the glucose level in the birds. A similar effect in the serum blood glucose was also observed in the broilers fed the raw ASAK meal suggesting that, the blood glucose of broilers would be elevated when fed ASAK meal irrespective of processing method applied or not. Ogbuewu *et al.* (2011) had earlier reported that, concentration of serum glucose is directly associated with energy utilization and metabolism in the animal's body.

The increase in the serum urea as the dietary inclusion level of the processed ASAK^{AC} meal increased in the diet over their counterpart on the control diet might perhaps be associated with the breakdown of the body tissues, since the nitrogen and energy supplied in the diet was not accessible resulting to damaged tissues, thereby increasing the serum urea levels of the birds on the test diets. This is in conformity with the report of Omoikhoje *et al.* (2003), that urea is an indirect measure of protein utilization in the animals. The decrease in the creatinine levels in relation to those on the control diet suggests the level of muscle damage. The creatinine values in this study did not exceed the normal range of 0.6 to 2.5mg/dl reported by Taiwo and Ogunsanmi (2003), however the creatinine values (0.21 to 0.52mg/dl) of the birds fed 5-30% processed ASAK^{AC} meal fell below the normal range, this suggest the tendency of muscle wastage, hence the reduced weights of the birds on the test diet. This is in line with the findings of Ogbuewu *et al.* (2010), that the level of serum creatinine signals the extent of muscle damage.

The decline in the total cholesterol, high density lipid, low density lipid and triglyceride as the dietary inclusion level of the processed ASAK^{AC} meal increased in the diet compared with their counterpart on the control diet do not impact negatively on the birds as the range in the values (39.51-69.45mg/dl) obtained for the total cholesterol were

within the normal values (30.15-85.05mg/dl) reported by Waziri *et al.* (2010). The irregular trend in the total protein, albumin and globulin values observed as the dietary inclusion level of the processed ASAK^{AC} meal increased could be attributed to interference in protein synthesis from the phytochemicals in the ASAK. Although irregular trends were observed in the albumin and globulin values of the birds, the similarity in the values obtained for those fed the control diet and 5 to 20% processed ASAK^{AC} meal suggest the safety of the test ingredient and nutritional adequacy of the diet which agrees with the report of Odunsi *et al.* (2009), that albumin synthesis in animals is related to the available protein present in the diets.

The linear increase in the AST, ALT and ALP as the dietary inclusion level of the processed ASAK^{AC} meal increased in the diet of the birds indicated that the broiler chickens have a challenge in handling the digestion of the African star apple kernels irrespective of whether fed raw or processed. Sodipo *et al.* (2009) had earlier reported that saponins inhibit enzyme activities and nutrient absorption. The presence of saponins and other phytochemicals not completely detoxified by the activated charcoal may have increased the enzyme activities of AST, ALT and ALP in the liver of the birds fed the test diet compared to those fed the control diets.

Haematology indices: The red blood cell, packed cell volume and haemoglobin of the broilers fed the raw ASAK meal were affected whereas only the red blood cell of the broilers fed the processed ASAK^{AC} meal was significantly affected, this implies that, the activated charcoal may have altered the PCV and Hb values of the broilers fed the processed ASAK^{AC} meal. The PCV values of 30.14-33.21% obtained for the birds fed processed ASAK^{AC} meal were still within the normal range of 23-55% for healthy birds

reported by Maxwell *et al.* (1990) which showed that the birds were not anaemic. PCV is an index of toxicity, any reduction in its concentration in the blood usually suggests the presence of toxic factors which has adverse effect on blood formation (Oyawoye and Ogunkunle, 1998). The haemoglobin values (8.54-9.30g/dl) obtained for the birds fed the processed ASAK^{AC} meal were within the recommended haemoglobin concentration of 7-18.6g/dl for healthy birds reported by Aiello and Mays (1998). This implies the safety of activated charcoal for the processing of ASAK and its inclusion in the diet of the birds. The values obtained for the red blood cells of the experimental birds may suggest nutritional adequacy of the test diets.

The values obtained for the mean cell volume (124.87-129.73) of the birds on the processed ASAK^{AC} meal were within the normal range of 115-127fl reported by Swenson (1993). The MCV of the broilers fed the processed ASAK^{AC} meal were enhanced compared to the broilers fed raw ASAK meal with lower MCV of 51.28-60.75fl affirming the suitability of activated charcoal for the processing of ASAK with regard to the blood indices. The higher values of 35.00-36.78pg obtained for the MCH and 27.81-28.35 for the MCHC compared with the values of 25-27pg and 21-23g/dl reported by Swenson (1993) for the MCH and MCHC respectively for healthy birds suggest that, the birds were not anaemic. The values obtained for the mean cell volume, mean cell haemoglobin and mean cell haemoglobin concentration were within the normal range reported for avian species suggesting that, the processed African star apple kernel meal improved the blood parameters and attests to the nutritional adequacy of the diets and safety of the test ingredient for broilers. The non significant effect of the white blood cells observed in the birds fed the processed ASAK^{AC} meal suggest that the absorbent

(activated charcoal) may have impacted positively on the immune system of the birds thus ruling out the possibility of any infection attributed from feeding the test ingredient to the birds. The birds fed the raw ASAK meal were significantly affected and accompanied by an increase in the white blood cells which may be attributed to the high concentration of the phytochemicals in the raw ASAK meal.

Nutrient retention; The decrease observed in the dry matter, crude protein, ether extract and soluble carbohydrate retention of the birds fed the increasing inclusion levels of the processed ASAK^{AC} meal were as a result of the incomplete detoxification of the ANFs particularly tannins, saponins and phytate still present in the processed ASAK^{AC} meal. Saponins have been shown to bind to the cells of the small intestine thereby affecting the absorption of nutrients across the intestinal wall (Annongu, 2012). The effect of saponins exerted on the intestinal walls limited the absorption of the available nutrients from the digested crude protein, ether extract and soluble carbohydrate coupled with the low dry matter intake attributed to the astringent taste of the feed from tannins was responsible for the poor dry matter, crude protein, ether extract and soluble carbohydrate retention. This assertion is in line with findings of Hassan *et al.* (2003) and Ravindran *et al.* (2006), that tannins in poultry diets reduce dry matter intake, body weight gain, feed efficiency and nutrient digestibility. Although the nutrient retention of the birds fed the processed ASAK^{AC} meal was fairer than those fed the raw ASAK meal. In this study, the poor nutrient retention of the birds implies that activated charcoal was less effective in the processing of the raw ASAK meal for broilers.

Histology of the liver: The increasing deposition of tars in the liver of the birds as the inclusion level of the processed ASAK^{AC} meal increased in the diet is a reflection of poor

feed intake and poor absorption of the nutrients due to the presence of saponins in the diet. The effect of saponins in chicks have been reported to reduce growth, feed efficiency and interfere with the absorption of dietary lipids, cholesterol, bile acids and vitamin A and E (Jenkins and Atwal, 1994). The presence of tars in the vein suggests that activated charcoal may have also contributed to the absence of cholesterol in the central veins. This implies that, processing of feedstuff with activated charcoal limits cholesterol deposition in the liver. The processing of ASAK meal or novel feedstuff with activated charcoal, preferably at lower doses in poultry may not affect the histology of the liver, however the use of activated charcoal for the removal of phytochemicals in the African star apple kernels do not mitigate against the adverse effect in the animal's body.

The profitability of replacing maize with processed ASAK^{AC} meal: The replacement of maize with the processed ASAK^{AC} meal do not justify its use for all the inclusion levels, as there was a higher revenue and profit from the birds fed the control diet despite the reduction in feed cost per kilogram of the diets formulated with increasing inclusion level of the processed ASAK^{AC} meal. This is attributed to the poor palatability of the feed and its utilization by the birds. This implies that, the investor or farmer will have higher returns on capital investment from the use of maize compared to dietary replacement of maize with African star apple kernels in the diet of the broilers.

It is concluded that using activated charcoal for the processing of African star apple kernel meal revealed mild improvement based on the growth performance indices over the birds fed the raw ASAK meal, however the birds on the test ingredient performed poorly in relation to the birds on the control diet. The mineral content of the dietary African star apple kernel meal may have positively influenced erythropoiesis, therefore

ASAK could be used to fortify feedstuff that do not enhance erythropoiesis to further improve the blood indices. The observed deposition of tars in the liver suggests that, the activated charcoal may have also limited feed consumption probably due to the bitter taste thus limiting the effective utilization by the birds. The use of activated charcoal for the treatment of African star apple kernel meal do not adequately detoxify the phytochemicals in the kernels for optimum utilization by the birds, hence the need to explore other processing methods.

CHAPTER FIVE

5.0 Experiment Three: The effect of replacing maize with processed African star kernel meal using bentonite in broilers

5.1 Introduction

Bentonite is one of the clay minerals in the smectite group, it has an array of applications in the industries for environmental protection with a good capability of binding water and preventing mineral nutrients from been washed up in the soil by enhancing soil fertility and preventing erosion (Stejskal, 1996). It acts as an excellent adsorptive material for heavy metals and germs (Hassen *et al.*, 2003; Katsumata *et al.*, 2003). It also serves as a good anti-nutritive agent (Abdel-Wahhab *et al.*, 1999; Phillips *et al.*, 2002).

Bentonite acts as gut protectants (enterosorbents) and binds toxins from the digestive tract thus reducing their absorption in the animal (Grant and Phillips, 1998; Phillips *et al.*, 2002). Its mode of action, involves preventing the adverse effects of toxins on the efficiency and function of the liver without affecting the mineral metabolism of the animals (Schell *et al.* 1993a, b; Santurio *et al.*; 1999). In a trial involving the potentials of different adsorbents in binding toxins, bentonites was better followed by kaolin-pectin (Ditter *et al.*, 1983). There seems to be no information on the use of bentonite for the treatment of African star apple kernels for feeding broilers.

5.2 Objective

This objective of this experiment was to determine the detoxification capability of supplemental bentonite for the pretreatment of African star apple kernel meal based diets for broilers.

5.3 Materials and Methods

5.3.1 Experimental site

The experiment was carried out in the Poultry Unit of the Teaching and Research Farm, Landmark University, Omu-Aran, Kwara State.

5.3.2 Source of experimental birds

A total of 210, day-old Cobb breed of broiler birds were obtained from Zartech farms at Ibadan, Oyo State, Nigeria.

5.3.3 Collection of African star apple seeds

The fruits of *C. albidum* for this study were collected from the various star apple plantations in Osun state, Nigeria. The seeds were obtained from the fruit, thoroughly washed to remove the foreign materials, properly sun dried to a constant weight and were further dehulled to obtain the kernels.

5.3.4 Experimental diet

The kernels obtained from the seed were soaked for 12 hours, boiled for 30 minutes and sun dried. The sun dried kernels were milled, pretreated with bentonite at 20g/kg and placed in tightly sealed containers for seven days before inclusion in the diet. Seven experimental diets were formulated made of a corn-soy reference diet and six other diets containing processed African star apple kernel meal using bentonite (ASAK^{BN}) meal for replacing maize in the diet of the birds at graded levels of 0, 5, 10, 15, 20, 25 and 30% corresponding to diets 1, 2, 3, 4, 5, 6 and 7 respectively. The composition of the experimental diets for the broiler starter and finisher phases on as fed basis are presented on Tables 5.1 and 5.2, respectively.

Table 5.1: Composition of the experimental diets for broiler starter processed with bentonite (Kg/100Kg)

Diets	T1	T2	T3	T4	T5	T6	T7
CKM levels %	0	5	10	15	20	25	30
Maize	56.46	53.63	50.81	47.99	45.17	42.34	39.52
CKM	0.00	2.83	5.65	8.47	11.29	14.12	16.94
SBM	38.04	38.04	38.04	38.04	38.04	38.04	38.04
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Limestone	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
V. premix	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100	100	100	100	100	100	100

Calculated analysis of the diets

Feed cost/Kg (₦)	105.98	104.35	102.72	101.09	99.46	97.83	96.20
ME kcal/kg	3132.74	3118.63	3104.57	3090.52	3076.46	3062.35	3077.62
CP (%)	22.99	22.63	22.40	22.18	21.95	21.73	21.50
Fat (%)	3.74	3.63	3.52	3.40	3.29	3.18	3.06
C. fibre (%)	4.02	3.95	3.87	3.79	3.72	3.64	3.57
Ash (%)	1.07	1.04	1.00	0.96	0.93	0.89	0.85
Calcium (%)	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Phosphorus	0.54	0.53	0.52	0.52	0.51	0.50	0.49
Lysine	1.25	1.24	1.23	1.23	1.22	1.21	1.20
Methionine	0.57	0.56	0.55	0.55	0.54	0.54	0.53
Bentonite/g (₦)	-	0.005	0.005	0.005	0.005	0.005	0.005

CKM= Chrysophyllum kernel meal; ME=Metabolizable energy; CP=Crude protein; C.fibre= Crude fibre

Table 5.2: Composition of the experimental diets for broiler finisher processed with bentonite(Kg/100Kg)

Diets	T1	T2	T3	T4	T5	T6	T7
CKM levels %	0	5	10	15	20	25	30
Maize	63.91	60.71	57.52	54.32	51.13	47.93	44.74
CKM	0.00	3.20	6.39	9.59	12.78	15.98	19.17
SBM	30.19	30.19	30.19	30.19	30.19	30.19	30.19
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bone meal	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Limestone	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
V. premix	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100	100	100	100	100	100	100

Calculated analysis of the diets

Feed cost/Kg (N)	105.98	104.35	102.72	101.09	99.46	97.83	96.20
ME kcal/kg	3153.71	3137.76	3121.86	3105.90	3089.99	3074.04	3058.14
CP (%)	20.00	19.74	19.49	19.23	18.97	18.71	18.60
Fat (%)	3.77	3.64	3.51	3.38	3.25	3.13	3.00
C. fibre (%)	3.71	3.63	3.54	3.46	3.37	3.28	3.20
Ash (%)	1.17	1.13	1.09	1.05	1.00	0.96	0.92
Calcium (%)	1.16	1.16	1.16	1.16	1.16	1.16	1.16
Phosphorus	0.65	0.64	0.63	0.62	0.61	0.60	0.59
Lysine	1.08	1.07	1.06	1.05	1.05	1.04	1.03
Methionine	0.54	0.53	0.53	0.52	0.51	0.51	0.50
Bentonite/g (N)	-	0.005	0.005	0.005	0.005	0.005	0.005

CKM= Chrysophyllum kernel meal; ME=Metabolizable energy; CP=Crude protein; C.fibre= Crude fibre.

The proximate composition of the broiler starter phase and finisher are presented on Table 5.3 and 5.4 respectively. The proximate composition and the phytochemical analysis of the treated CKM with bentonite are presented on Table 5.5 and 5.6 respectively.

5.3.5 Management of experimental birds and data collection

A total of 210, day-old broiler chicks were used for the trial. The chicks were fed for one week on a standard broiler starter diet before the commencement of the experiment for both the starter and finisher phases. The experiment was designed as a complete randomized design. The dietary treatments contained three replicates with 10 chicks per replicate. All the birds were raised under similar management practices (brooding, lighting, feeding and watering) throughout the eight week experimental period for both the starter and finisher phase except for the diets offered that differed. The birds were given feed and water *ad-lib* and weighed weekly. Routine vaccinations and medications were carried out as at when due.

5.3.6 Data collection/response criteria

In the course of the experiment, data were collected on the performance characteristics: (a) feed consumption, (b) daily weight gain, (c) growth rate, (d) feed conversion ratio, (e) survival rate, (f) Carcass evaluation: at the end of the eight weeks study period, three birds per treatment were randomly selected based on the group average and were weighed, slaughtered and eviscerated for carcass evaluation. The birds were fasted for 12 hours before slaughtering, bled and the slaughter weight taken. The birds were defeathered manually using hot water and eviscerated. The live weight and carcass

Table 5.3: Analysed nutrient content of experimental diets for broiler starter

	D		I	E	T	S	
Parameters	T1	T2	T3	T4	T5	T6	T7
Dry matter (%)	90.06	90.28	90.04	90.09	90.58	90.10	89.99
Crude protein (%)	23.28	22.89	22.67	22.69	22.78	23.14	22.92
Ether extract (%)	3.18	2.39	2.41	2.40	2.42	2.34	2.33
Crude fibre (%)	2.64	2.62	2.80	2.97	3.15	3.35	3.06
Ash (%)	7.63	9.10	9.33	9.45	9.41	9.49	9.52
NFE (%)	53.33	53.28	52.83	52.58	52.82	51.78	52.16

Table 5.4: Analysed nutrient content of experimental diets for broiler finisher

	D		I	E	T	S	
Parameters	T1	T2	T3	T4	T5	T6	T7
Dry matter (%)	88.97	89.25	89.21	89.23	89.21	89.06	89.17
Crude protein (%)	19.78	20.49	21.08	20.59	20.67	20.89	20.09
Ether extract (%)	2.23	2.18	2.25	2.19	2.23	2.31	2.41
Crude fibre (%)	2.05	2.51	3.00	3.23	3.37	3.51	3.54
Ash (%)	6.98	7.13	7.51	7.56	7.47	7.56	7.59
NFE (%)	57.93	56.94	55.37	55.66	55.47	54.79	55.54
Gross Energy (kcal/g)	1,096.00	1,025.26	964.93	835.92	823.51	790.44	504.26

Table 5.5: Proximate composition of processed African star apple kernel meal using bentonite

Parameters	%
Dry matter	92.54
Crude protein	11.33
Ether extract	1.83
Ash	3.77
Crude fibre	5.87
Soluble carbohydrate	69.73
Gross energy (kcal/g)	4.00

Table 5.6: Phytochemical analysis of processed African star apple kernel meal using bentonite

Parameters	mg/kg
Saponin	1.27
Phytate	0.26
Tannins	8.69
Oxalate	0.31
Glycoside	4.80×10^{-3}

weight were recorded. The dressing percentage was calculated. Organ weights and the major primal carcass parts were expressed as percentages of the live weight.

5.3.7 Nutrient digestibility trial

The study on apparent nutrient digestibility was carried out at the end of the 8th week of the experimental period. Three birds per treatment were randomly selected and transferred to clean metabolic cages and fed the corresponding treatment diets. The trial lasted for eight days. The first four days were considered as adaptation period and the last four days as experimental period. Records of feed intake and faeces voided were taken during the last four days. The droppings were oven dried, bulked and representative samples were taken for chemical analysis. The samples were analyzed for proximate composition according to the methods of AOAC (1990).

$$\text{Apparent Nutrient Retention} = \frac{\text{Nutrient intake} - \text{Nutrient in faeces}}{\text{Nutrient intake}} \times 100$$

5.3.8 Serum biochemical and haematology analysis

At the end of the experiment, one broiler per replicate in all the treatments was taken at random and blood collected by decapitation. Blood for serum biochemical indices was collected in bottles without EDTA for the analysis of the biochemical parameters of (a) blood electrolytes: Ca, Na, K, Cl, and bicarbonate, (b) blood glucose level, (c) total protein, (d) albumin, (e) globulin, (f) albumin/globulin ratio (g) total cholesterol (h) creatinine (i) urea (j) lipid profile (HDL and LDL), (k) transaminase activities- AST, ALT ALP etc. The samples were spurned in the centrifuge at 3,000 rpm and the clearer

portion (serum) decanted after centrifugation into another set of plain bottles and were placed in an ice bath and taken to the laboratory.

The blood samples for haematology parameters were pretreated with ethylene diamine tetra-acetate (EDTA), an anti-coagulant and were placed in the refrigerator (4°C) immediately before taken to the laboratory. Haematological indices examined include white blood cell (WBC) and its differential counts (neutrophils, lymphocyte, monocyte, eosinophil and basophils), red blood cell (RBC), packed Cell Volume (PCV), haemoglobin (Hb). The mean cell volume (MCV), mean cell haemoglobin (MCH) and the mean cell haemoglobin concentration (MCHC) were calculated from the values of the RBC, PCV and Hb respectively.

$$MCV = \frac{PCV}{RBC} \times 10$$

$$MCH = \frac{Hb}{RBC} \times 10$$

$$MCHC = \frac{Hb}{PCV} \times 100$$

5.3.9 Histology of the liver

Three birds were selected per treatment at the end of the feeding trial and sacrificed to obtain the liver. Sections were obtained from the anterior lobe of the liver, preserved in 90% saline + 10% formalin solution. The liver tissues from each replicate were processed for histological studies using haematoxylin and eosin stains. Photomicrographs were taken using a digital microscope with a magnification of 400. The analysis was carried out at the histopathological laboratory of Central Research Laboratory, Tanke, Ilorin.

5.4 Statistical analysis

Data collected on the response criteria were subjected to analysis of variance according to the completely randomized design model and differences between treatment means were separated using the Duncan's multiple range test (Steel and Torrie, 1980).

5.5 Results

5.5.1 Growth performance characteristics of broilers fed processed African star apple kernel meal using bentonite

Table 5.7 presents the growth performance characteristics of broilers fed processed African star apple kernel using bentonite (ASAK^{BN}) meal. The growth performance characteristics of the broilers fed the processed ASAK^{BN} meal were enhanced compared with the birds fed the raw ASAK meal, however there was a corresponding decrease in the performance characteristics of the birds as the dietary level of the processed ASAK^{BN} meal increased in the diet in relation to those on the control diet. The final live weights, average daily weight gains and the feed intake values of the birds significantly ($p < 0.05$) decreased as the processed ASAK^{BN} meal increased in the diet of the birds for replacement of maize as energy source. The feed conversion ratio favoured the birds on the control diet compared to those fed the processed ASAK^{BN} meal. There was an increased poor feed conversion ratio as the processed ASAK^{BN} meal increased in the diets. The results of the cost per kg weight gains also followed the same trend with the feed conversion ratios. There was a decrease in the feed cost N/kg of the birds as the dietary replacement of maize with the processed ASAK^{BN} meal increased in the diets of the birds. The percent mortality of the birds was not significantly ($p > 0.05$) affected by the dietary inclusion of the processed ASAK^{BN} in the diet of the birds.

Table 5.7: Growth performance characteristics of broilers fed processed African star apple kernel meal using bentonite

Parameters	T1	T2	T3	T4	T5	T6	T7	SEM	Pvalue
	(0%)	(5%)	(10%)	(15%)	(20%)	(25%)	(30%)		
Initial live weight (g/bird)	122.75	122.75	122.75	122.75	122.75	122.75	122.75	-	-
Final live weights (g/bird)	2028.50 ^a	1438.46 ^b	1078.46 ^c	858.47 ^d	818.47 ^e	806.97 ^f	788.47 ^g	3.47	0.0001
Daily weight gains (g/bird/day)	40.54 ^a	27.99 ^b	20.33 ^c	15.65 ^d	14.80 ^e	14.55 ^f	14.16 ^g	0.07	0.0001
Feed intake (g/bird/day)	118.11 ^a	97.65 ^b	90.02 ^c	76.39 ^d	74.00 ^e	72.71 ^f	70.93 ^g	0.38	0.0001
Feed conversion ratio	2.91 ^e	3.48 ^d	4.42 ^c	4.88 ^b	5.00 ^b	4.99 ^a	5.00 ^a	0.06	0.0001
Cost per kg weight gain (₦)	308.40 ^e	363.14 ^d	454.02 ^c	493.32 ^{ab}	497.30 ^a	488.17 ^{ab}	481.00 ^b	2.12	0.0001
Cost of feed/kg (₦)	105.98	104.35	102.72	101.09	99.46	97.83	96.20		
% Mortality	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d,e,f,g}Means with different superscript along the same rows are significant (P<0.05);NS=Non Significant (P>0.05)

The phytochemical dietary intake of broilers fed the processed ASAK^{BN} meal is presented on Table 5.8. The incomplete detoxification of the phytochemicals in the diets further attest to the poor growth performance characteristics observed in the birds fed from 15-30% inclusion level of the processed ASAK^{BN} meal.

5.5.2 Carcass characteristics of broilers fed processed African star apple kernel meal using bentonite

The carcass characteristics of broilers fed processed ASAK^{BN} meal is presented on Table 5.9. The result of the carcass characteristics of the birds fed the processed ASAK^{BN} meal were fairer than when fed raw to the birds, though far below the optimum for the birds on the control diet. The differences in the live weights, carcass weights and the dressing percentage were significantly ($p < 0.05$) affected across the treatment groups fed the processed ASAK^{BN} meal. There was a corresponding decrease in the live weights, carcass weights and dressing percentage of the birds as the processed ASAK^{BN} meal increased in the diets of the birds. The weights of the carcass components for the neck, wings, thigh, drumstick, shank, breast, back expressed as percentages of the live weights were lower in all the dietary groups fed the processed ASAK^{BN} meal compared with the control group except the head that was lower in the control group. The weights of the heart, liver, kidney, proventriculus and the gizzard were significantly ($p < 0.05$) affected except the lungs that was not significantly ($p > 0.05$) affected. There was a significant ($p < 0.05$) decrease in the lengths of the small and large intestines as the dietary replacement of maize with the processed ASAK^{BN} meal increased in the diets of the birds compared with birds on the control diet.

Table 5.8: Dietary phytochemical intake of broilers fed processed African star apple kernel meal using bentonite

Parameters	T1	T2	T3	T4	T5	T6	T7	SEM	P value
	(0%)	(5%)	(10%)	(15%)	(20%)	(25%)	(30%)		
Saponins (mg/bird/day)	0.00 ^g	0.40 ^f	0.73 ^e	0.93 ^d	1.20 ^c	1.48 ^b	1.73 ^a	0.51	0.0001
Phytate (mg/bird/day)	0.00 ^g	0.08 ^f	0.15 ^e	0.19 ^d	0.25 ^c	0.31 ^b	0.36 ^a	4.28	0.0001
Tannins (mg/bird/day)	0.00 ^g	2.72 ^f	5.00 ^e	6.37 ^d	8.22 ^c	10.10 ^b	11.82 ^a	3.81	0.0001
Oxalate (mg/bird/day)	0.00 ^g	0.10 ^f	0.18 ^e	0.23 ^d	0.30 ^c	0.36 ^b	0.43 ^a	0.03	0.0001
Glycoside (mg/bird/day)	0.00 ^g	1.5x10 ^{-3f}	2.8x10 ^{-3e}	3.5x10 ^{-3d}	4.5x10 ^{-3c}	5.6x10 ^{-3b}	6.5x10 ^{-3a}	0.03	0.0001

Table 5.9: Carcass characteristics of broilers fed processed African star apple kernel meal using bentonite

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Live weight (g/bird)	2028.50 ^a	1438.46 ^b	1078.46 ^c	858.47 ^d	818.50 ^e	806.97 ^f	788.47 ^g	3.47	0.0001
Carcass weights (g/bird)	1325.20 ^a	930.77 ^b	647.50 ^c	517.80 ^d	414.75 ^e	410.04 ^e	397.50 ^f	6.12	0.0001
Dressing percentage (%)	65.32 ^a	64.70 ^a	60.03 ^b	60.31 ^b	50.67 ^c	50.81 ^c	50.41 ^c	0.33	0.0001
Prime cut and Organ weights	Expressed as % of live weight								0.0001
Head	2.43 ^g	2.57 ^f	3.01 ^e	3.64 ^a	3.12 ^d	3.19 ^c	3.37 ^b	0.01	0.0001
Thigh	10.87 ^a	10.31 ^b	9.20 ^d	9.69 ^c	7.74 ^e	7.34 ^f	7.27 ^g	0.03	0.0001
Breast	20.91 ^a	19.81 ^b	16.53 ^c	15.93 ^d	14.62 ^e	12.63 ^f	12.40 ^g	0.05	0.0001
Wings	8.19 ^a	7.70 ^c	7.10 ^e	7.89 ^b	7.64 ^d	7.86 ^b	6.88 ^f	0.02	0.0001
Shank	4.25 ^a	4.17 ^c	4.10 ^d	4.26 ^a	4.20 ^b	3.97 ^f	4.01 ^e	0.01	0.0001
Neck	5.44 ^c	5.81 ^b	5.24 ^d	5.90 ^a	4.38 ^f	4.65 ^e	4.13 ^g	0.02	0.0001
Drumstick	8.60 ^a	8.62 ^a	8.28 ^b	7.84 ^d	8.10 ^c	7.42 ^e	6.89 ^f	0.07	0.0001
Back	11.29 ^a	12.16 ^a	12.57 ^a	11.59 ^d	11.28 ^f	11.42 ^e	10.15 ^g	0.05	0.0001
Heart	0.35 ^e	0.38 ^c	0.39 ^b	0.40 ^a	0.40 ^a	0.37 ^d	0.37 ^d	0.01	0.0001
Lungs	0.55	0.53	0.56	0.57	0.54	0.53	0.54	0.03	0.4744
Liver	3.08 ^c	2.63 ^e	2.85 ^d	3.09 ^c	3.23 ^a	3.19 ^b	3.18 ^b	0.01	0.0001
Kidney	0.54 ^a	0.49 ^b	0.46 ^{bc}	0.44 ^{cd}	0.41 ^d	0.36 ^e	0.35 ^e	0.02	0.0001
Proventriculus	0.40 ^e	0.45 ^c	0.43 ^d	0.48 ^b	0.47 ^b	0.47 ^b	0.48 ^a	0.01	0.0001
Gizzard	1.77 ^f	2.42 ^d	2.46 ^c	2.50 ^b	2.61 ^a	2.42 ^d	2.35 ^e	0.01	0.0001
Small intestine length (cm)	144.88 ^a	131.99 ^b	105.10 ^c	78.98 ^d	55.08 ^e	48.91 ^e	39.42 ^f	1.20	0.0001
Large intestine length (cm)	69.62 ^a	62.71 ^b	54.14 ^c	40.48 ^d	27.14 ^e	26.06 ^e	21.91 ^f	2.14	0.0001

SEM= Standard error of mean;LOS= Level of Significance,*=P<0.05;^{a,b,c,d,e,f,g}Means with different superscript along the same rows are significant (P<0.05);NS=Non Significant (P>0.05)

5.5.3 Serum biochemical indices of broilers fed processed African star apple kernel meal using bentonite

Table 5.10 presents the serum biochemical indices of broilers fed processed ASAK^{BN} meal. The pattern in the values of the biochemical indices of the birds fed the processed ASAK^{BN} meal were fairer in relation to the birds fed the increasing inclusion level of the raw ASAK meal for replacing maize in the diet of the birds. There was a significant ($p<0.05$) linear increase in the serum sodium, calcium and potassium levels as the processed ASAK^{BN} meal increased in the diet of the birds. The blood glucose and serum urea levels significantly ($p<0.05$) increased with an increasing inclusion level of the processed ASAK^{BN} meal in the diet of the birds. There was a significant ($p<0.05$) decrease in the creatinine levels of the birds as the inclusion level of the processed ASAK^{BN} meal increased in the diet of the birds.

There were significant ($p<0.05$) differences for the total cholesterol, high density lipid (HDL) cholesterol, low density lipid (LDL) cholesterol and triglyceride respectively with a linear decrease in their values as the dietary inclusion level of the processed ASAK^{BN} meal increased in the diet of the birds. The serum total protein, albumin and globulin were significantly ($p<0.05$) affected and accompanied by a corresponding increase as the dietary inclusion level of the processed ASAK^{BN} meal increased except for treatment 2 that was lower than other treatments. The serum AST, ALT and ALP levels of the birds fed the processed ASAK^{BN} meal were significantly ($p<0.05$) affected. The AST, ALT and ALP activities increased as dietary inclusion level of the processed ASAK^{BN} meal increased in the diet. The values obtained for AST and ALP in the birds fed the processed ASAK^{BN} meal were higher than the values obtained for those on the control

Table 5.10: Serum biochemical indices of broilers fed processed African star apple kernel meal using bentonite

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Glucose (mg/dl)	91.99 ^d	98.32 ^{cd}	102.30 ^{cd}	106.09 ^{bc}	109.34 ^{bc}	115.19 ^{ab}	122.49 ^a	2.03	0.0005
Calcium (ppm)	10.70 ^{ab}	9.13 ^c	9.61 ^{bc}	10.69 ^{ab}	10.66 ^{ab}	10.85 ^a	10.89 ^a	0.19	0.0137
Sodium (mEq/l)	106.44 ^{ab}	101.09 ^b	102.98 ^{ab}	109.69 ^{ab}	106.75 ^{ab}	114.00 ^a	112.46 ^{ab}	2.03	0.1685
Potassium (mg/dl)	17.16 ^d	19.33 ^c	21.22 ^{bc}	20.19 ^c	23.02 ^{ab}	23.91 ^a	24.16 ^a	0.41	0.0001
Urea (mg/dl)	26.11 ^g	34.34 ^f	38.35 ^e	40.03 ^d	41.66 ^c	43.22 ^b	45.10 ^a	0.74	0.0001
Creatinine (mg/ml)	0.69 ^a	0.50 ^b	0.45 ^c	0.37 ^d	0.32 ^e	0.25 ^f	0.20 ^g	0.02	0.0001
Total cholesterol (mg/dl)	63.37 ^a	62.98 ^{ab}	59.85 ^b	52.93 ^c	47.28 ^d	42.46 ^{de}	38.33 ^e	1.03	0.0001
HDL Cholesterol (mg/dl)	11.19 ^a	10.45 ^{ab}	9.92 ^b	8.74 ^c	7.78 ^d	6.96 ^{de}	6.26 ^e	0.17	0.0001
LDL Cholesterol (mg/dl)	54.69 ^a	51.04 ^{ab}	48.44 ^b	42.69 ^c	38.01 ^d	34.01 ^{de}	30.58 ^e	0.85	0.0001
Triglyceride (mg/dl)	12.39 ^a	9.84 ^b	9.10 ^{bc}	8.75 ^c	8.38 ^c	6.92 ^d	5.86 ^e	0.51	0.0001
Total protein (mg/dl)	14.32 ^c	12.58 ^d	13.19 ^{cd}	14.63 ^c	14.76 ^c	20.20 ^b	23.11 ^a	0.94	0.0001
Albumin (g/l)	0.29 ^b	0.22 ^c	0.29 ^b	0.28 ^b	0.29 ^b	0.32 ^{ab}	0.33 ^a	0.01	0.0002
Globulin (g/l)	14.02 ^{cd}	12.35 ^d	12.90 ^{cd}	14.34 ^c	14.47 ^c	19.88 ^b	22.78 ^a	0.92	0.0001
Albumin-Globulin ratio	0.02	0.02	0.02	0.02	0.02	0.02	0.01	-	0.0001
Aspartate Aminotransaminase (u/l)	10.68 ^e	22.31 ^c	18.91 ^d	20.85 ^{cd}	24.73 ^b	26.19 ^{ab}	27.64 ^a	1.26	0.0001
Alanine Aminotransaminase (u/l)	15.32 ^c	8.34 ^e	8.53 ^e	9.89 ^{de}	10.47 ^d	18.81 ^b	25.02 ^a	0.85	0.0001
Alkaline phosphate (u/l)	0.89 ^d	1.78 ^c	2.23 ^b	2.67 ^a	2.67 ^a	2.60 ^a	2.67 ^a	0.13	0.0001

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05,^{a,b,c,d,e,f}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant (P>0.05); HDL=High Density Lipid;LDL=Lipid Density Lipid.

diet, however the ALT activity was higher in the birds fed the control diet compared with its counterpart fed 5, 10, 15 and 20% processed ASAK^{BN} meal.

5.5.4 Haematology indices of broilers fed processed African star apple kernel meal using bentonite

The haematology indices of broilers fed processed African star apple kernel using bentonite meal is presented on Table 5.11. The red blood cell of the birds fed the processed ASAK^{BN} meal was significantly ($p < 0.05$) affected, there was an increase in the red blood cells as the processed ASAK^{BN} meal increased in the diet of the birds compared with the birds on the control diet. The haemoglobin and the packed cell volume were not significantly ($p > 0.05$) affected by the processed ASAK^{BN} meal unlike in the birds that were fed the raw ASAK meal, although there was a linear increase in the values but not statistically significant. There were significant ($p < 0.05$) differences in the mean cell volume, mean cell haemoglobin and mean cell haemoglobin concentration with a corresponding decrease as the processed ASAK^{BN} meal increased in the diet. The white blood cells of the birds was not significantly ($p > 0.05$) affected by the processed ASAK^{BN} meal unlike the broilers fed the raw ASAK meal but the trend revealed an increase which was statistically insignificant.

5.5.5 Nutrient retention of broilers fed processed African star apple kernel meal using bentonite

Table 5.12 presents the nutrient retention of broilers fed processed African star apple kernel using bentonite meal. The nutrient retention of the dry matter, crude protein, ether extract and soluble carbohydrate were significantly ($p < 0.05$) affected with a linear decrease as the processed ASAK^{BN} meal increased in the diet of the birds in relation to

Table 5.11: Haematology indices of broilers fed processed African star apple kernel meal using bentonite

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Red Blood Cell (x 10 ¹² /l)	2.42 ^c	2.43 ^{bc}	2.51 ^{abc}	2.55 ^{abc}	2.64 ^{abc}	2.71 ^{ab}	2.77 ^a	0.04	0.0069
Haemoglobin (g/dl)	8.90	8.90	9.10	9.24	9.40	9.50	9.69	0.17	0.4685
Packed Cell Volume (%)	31.39	31.59	32.30	33.09	33.59	34.16	34.60	0.62	0.3146
Mean Cell Volume (fl)	129.74 ^{ab}	130.02 ^a	128.68 ^c	129.43 ^b	127.23 ^d	126.04 ^e	124.91 ^f	0.10	0.0001
Mean Cell Haemoglobin (pg)	36.77 ^a	36.62 ^b	36.25 ^c	35.60 ^d	35.60 ^d	35.05 ^e	35.01 ^e	0.03	0.0001
Mean Cell Hae. Conc (g/dl)	28.34 ^a	28.16 ^b	28.17 ^b	27.91 ^e	27.98 ^d	27.81 ^f	28.02 ^c	0.002	0.0001
White Blood Cell (x 10 ⁹ /l)	234.34	235.78	239.53	241.44	242.59	244.41	246.05	4.33	0.9320

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d,e,f}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant (P>0.05);Mean Cell Hae. Conc= Mean Cell Haemoglobin Concentration.

Table 5.12: Nutrient retention of broilers fed processed African star apple kernel meal using bentonite

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Dry matter	88.83 ^a	75.43 ^b	71.37 ^c	60.33 ^d	59.34 ^d	56.21 ^d	55.61 ^d	2.06	0.0001
Crude protein	86.74 ^a	79.39 ^{ab}	78.69 ^{ab}	79.11 ^{ab}	77.78 ^{ab}	74.80 ^b	71.81 ^b	4.04	0.1186
Ether extract	81.79 ^a	75.14 ^{ab}	67.41 ^b	64.18 ^{bc}	58.16 ^{bc}	55.93 ^{bc}	50.24 ^c	3.90	0.0450
Soluble carbohydrate	63.85 ^a	60.32 ^b	54.88 ^c	53.88 ^{cd}	52.94 ^d	51.05 ^{de}	50.05 ^e	0.64	0.0001

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d} Means with different superscript along the same rows are significantly (P<0.05).

the birds on the control diet. The trends in the nutrient retention of the birds fed the processed ASAK^{BN} meal were fairer compared to their counterpart fed the raw ASAK meal.

5.5.6 Histology of the liver of broilers fed processed African star apple kernel meal using bentonite

The photomicrographs showing the liver of the birds fed the processed African star apple kernel using bentonite meal are presented on plates 1-7. The sections of the liver revealed a distortion in the architecture of the liver as the processed ASAK^{BN} meal increased in the diet of the birds. The birds on the control diet had normal hepatocyte while those fed 5% inclusion level had mild inflammation of the bile duct and also mild cholesterol deposition in the central vein. An increase in the inclusion level at 10% was accompanied by mild hepatocyte degradation while higher dietary intake levels between 15 and 30% inclusion levels resulted in severe hepatocyte degradation.

5.5.7 Profitability of broilers fed processed African star apple kernel meal using bentonite for dietary replacement of maize

Table 5.13 shows the profitability of broilers fed processed African star apple kernel using bentonite. The total feed intake, total weight gain and total cost of production per bird were higher in the birds fed the control diet, although there was a decrease in the feed cost per kg as the replacement of maize with the processed *C. albidum* kernel meal with bentonite increased in the diet. The reduction in the prices could not inturn enhance the profit on investment. The highest profit was obtained from the birds fed the control diet and the lowest obtained in the group fed 30% inclusion level of the processed

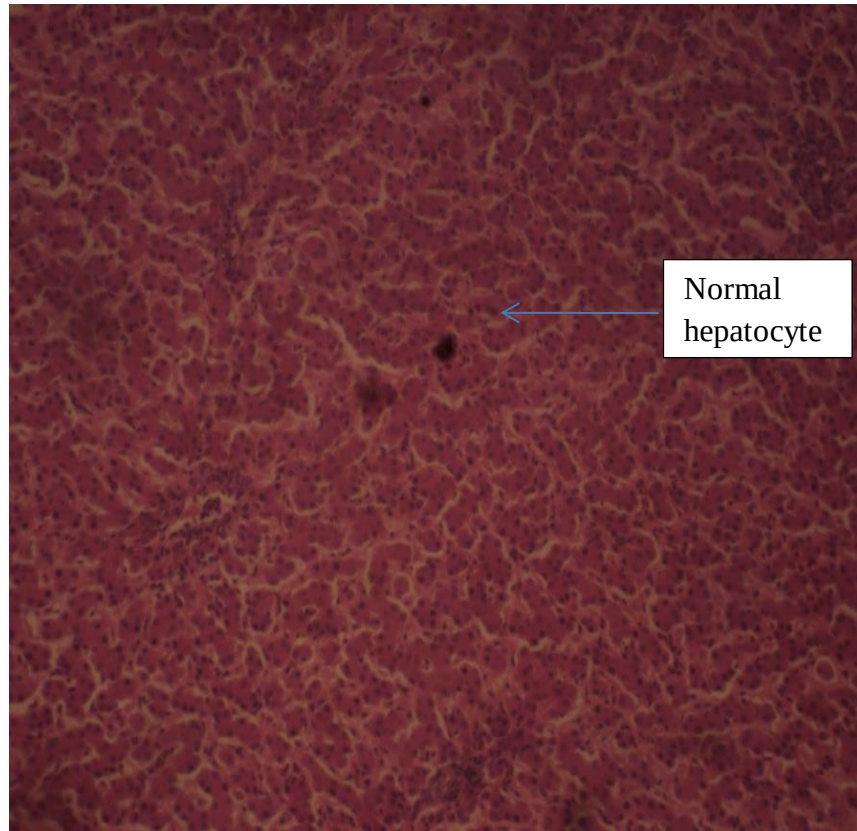


Plate i - Photomicrograph showing the liver of broilers fed the control diet

H/E Stain Mag. X400

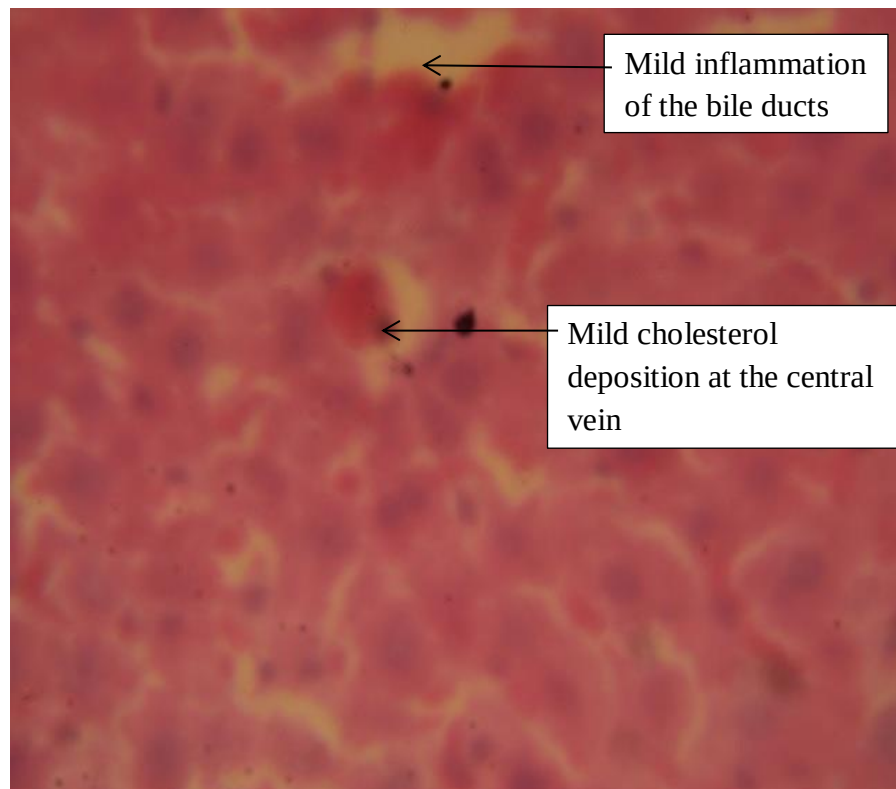


Plate ii - Photomicrograph showing the liver of broilers fed 5% processed African star apple kernel meal using bentonite

H/E Stain. Mag. X400

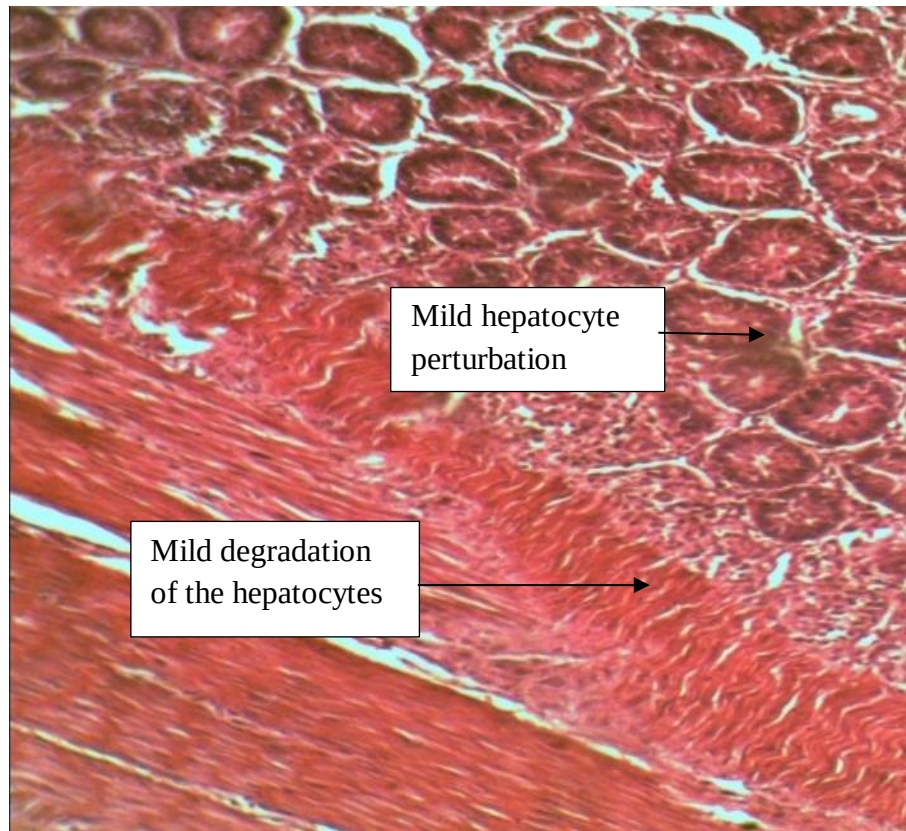


Plate iii - Photomicrograph showing the liver of broilers fed 10% processed African star apple kernel meal using bentonite

H/E Stain. Mag. X400

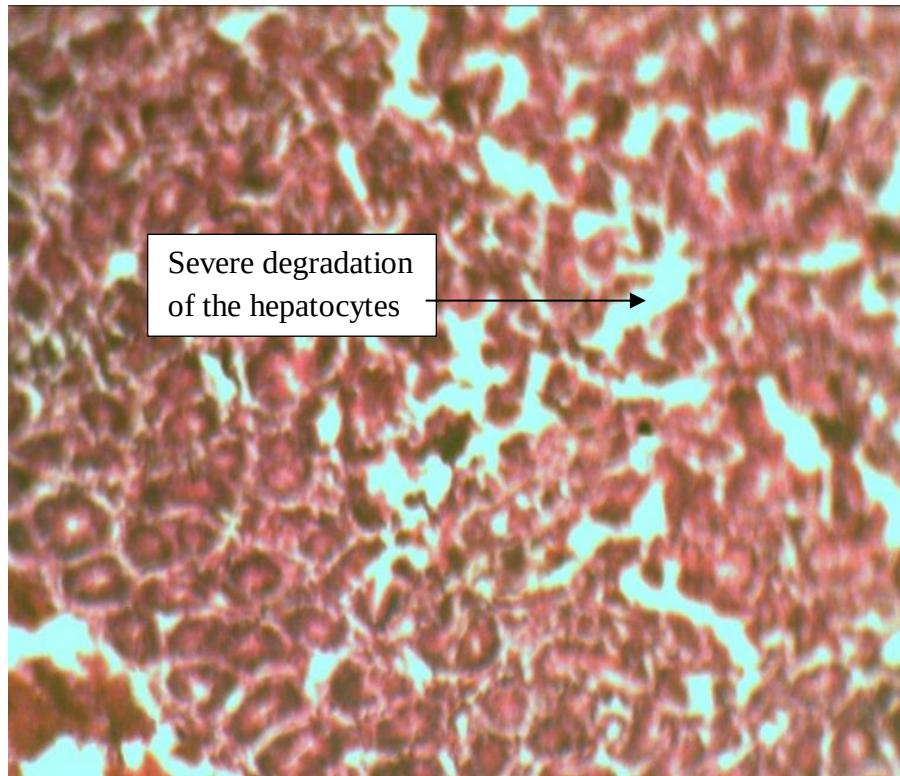


Plate iv - Photomicrograph showing the liver of broilers fed 15% processed African star apple kernel meal using bentonite

H/E Stain Mag. X400

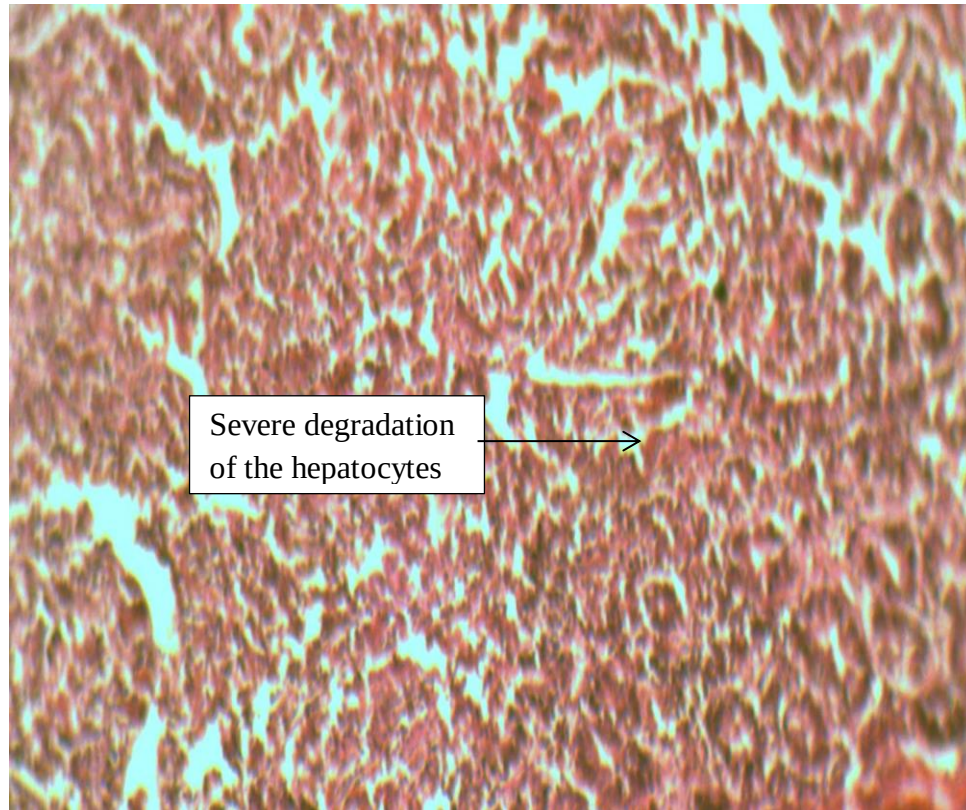


Plate v - Photomicrograph showing the liver of broilers fed 20% processed African star apple kernel meal using bentonite

H/E Stain Mag. X400

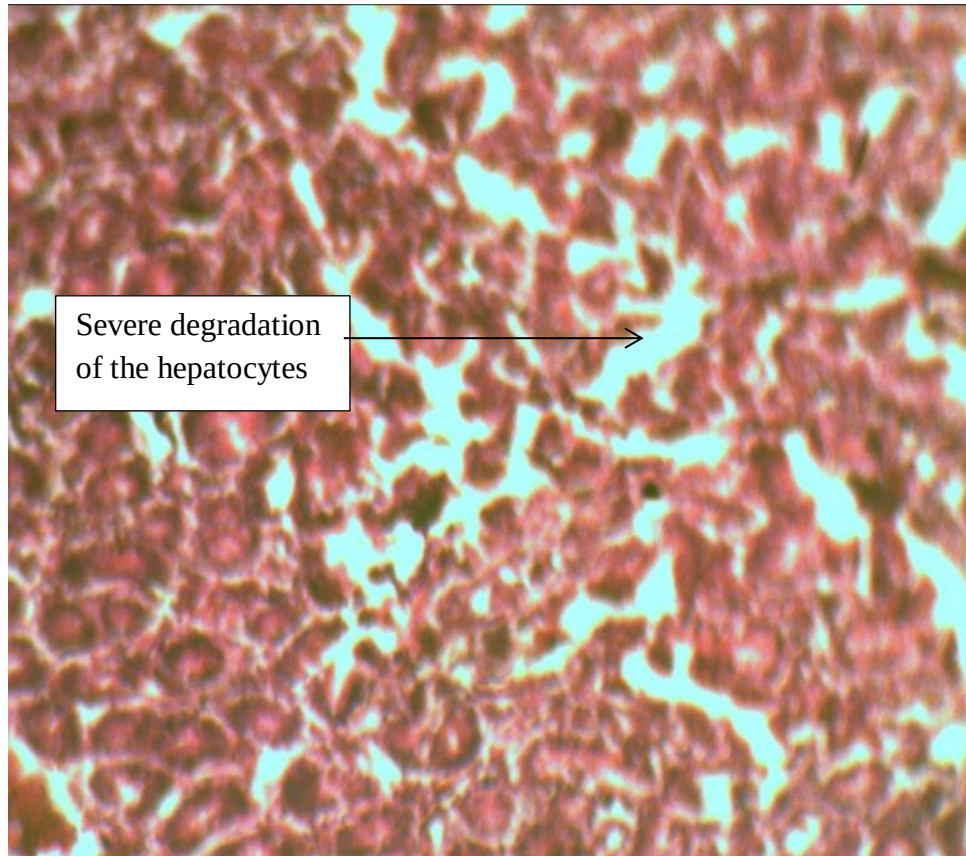


Plate vi - Photomicrograph showing the liver of broilers fed 25% processed African star apple kernel meal using bentonite

H/E Stain Mag. X400

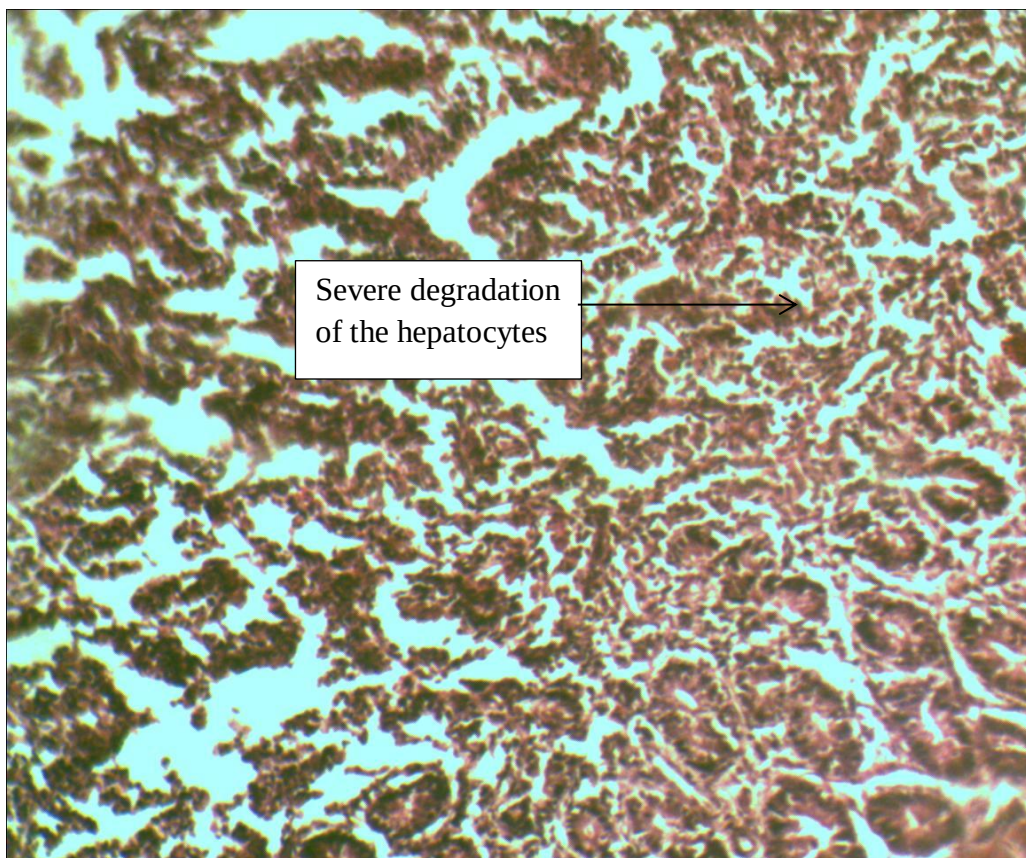


Plate vii - Photomicrograph showing the liver of broilers fed 30% processed African star apple kernel meal using bentonite

H/E Stain Mag. X400

Table 5.13: Profitability of broilers fed processed African star apple kernel meal using bentonite for dietary replacement of maize

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Total feed intake (g/bird)	5,551.17 ^a	4,589.55 ^b	4,230.94 ^c	3,590.33 ^d	3,478.00 ^e	3,417.37 ^f	3,333.71 ^g	0.38	0.0001
Total weight gain (g/bird)	1,905.75 ^a	1,315.71 ^b	955.71 ^c	735.72 ^d	695.72 ^d	684.22 ^e	665.72 ^f	3.47	0.0001
Final live weight (g/bird)	2,028.50 ^a	1,438.46 ^b	1,078.46 ^c	858.47 ^d	818.47 ^d	806.97 ^e	788.47 ^d	3.47	0.0001
Cost of feed/kg (₦)	106.00	104.30	102.70	101.10	99.40	97.70	96.10	-	-
(a) Cost of DOC/Medication	160.00	160.00	160.00	160.00	160.00	160.00	160.00	-	-
(b)Cost of feeding /bird = FC x TFI (₦)	588.31	478.92	434.60	362.95	345.92	334.32	320.70	-	-
Total cost of production/bird = (a+b) (₦)	748.31	638.92	594.60	522.95	505.92	494.32	480.70	-	-
Revenue = Fnwt x sales/kg	1,724.23	1,222.69	916.69	729.70	695.70	685.92	670.20	-	-
Profit (₦) = Revenue – TC	975.91	583.77	322.09	206.75	189.78	191.60	189.50	-	-
Sale's price/kg (₦)	850	850	850	850	850	850	850	-	-

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant. DOC= Day Old Chicks; FC= Feed Cost; TFI= Total Feed Intake; Fnwt=Final live weight; TC=Total cost of production58; Naira=₦

ASAK^{BN} meal. There was a mild improvement in the birds fed the processed ASAK^{BN} meal over the group fed the raw ASAK meal. The returns on investment for the dietary treatment of 10-30% processed ASAK^{BN} meal may not justify the total cost of production.

5.6 Discussion

Growth performance characteristics: The increased feed intake and the average daily weight gains of the birds fed the processed ASAK^{BN} meal over those fed the raw ASAK meal is in line with the findings of Southern *et al.* (1994) who reported 5% supplementation of bentonite in the diet given to chickens enhanced the feed intake and weight gains in the chickens. The decreased feed intake values recorded as the processed ASAK^{BN} meal increased in the diet in relation to the birds on the control diet could be supported by the findings of Douglas *et al.* (1993), who reported that tannins reduces dry matter intake due to reduced palatability.

The decreased final live weight and average daily weight gains in the birds fed beyond 5% inclusion level of the processed ASAK^{BN} meal is mainly attributed to the presence of the phytochemicals present in the ASAK even after treatment. These antinutritional factors may have constituted a hindrance to the bio-availability of nutrients to the birds. The non availability of the nutrients to the animal's body might have impacted negatively on the feed conversion ratio. The increasing cost per kg weight gains as the processed ASAK^{BN} meal increased in the diet despite the reduction in the feed cost were as a result of the poor feed conversion ratio, as the birds will have to consume more to attain a kilogram in body weight.

Previous authors (Grant and Phillips, 1998; Phillips *et al.* 2002) reported that bentonite act as gut protectants (enterosorbents) which rapidly and preferentially bind toxins (aflatoxins) from the digestive tract and thus reduce their absorption into the organism, this might have enhanced the improvements on the use of the processed ASAK^{BN} meal on the performance characteristics of the birds over their counterpart fed the raw ASAK^{BN} meal, its effect on the ANFs in the ASAK meal was more effective than activated charcoal but not effective for the enhanced growth performance characteristics of the birds probably at the pretreatment level of the ASAK meal at 20g/kg. Hassan *et al.* (2003) and Katsumata *et al.* (2003) also reported the excellent adsorptive potentials of bentonite for toxic and anti-nutritive agents. An increase in the pretreatment level of ASAK with bentonite may probably enhance the growth performance characteristics of the broiler chickens.

Carcass characteristics: The decrease in the live weights, dressing percentage, carcass weights and its components as the inclusion level of the processed ASAK^{BN} meal increased in the diets of the birds was as a result of the reduced final live weights and poor feed conversion ratio of the birds fed between 10 and 30% processed ASAK^{BN} meal inclusion levels. The effect of the processed ASAK^{BN} meal on the internal organs of the heart, liver, kidney and proventriculus except for the lungs could be as a result of the relative weights of the birds when these organs were expressed as percentages of the live weights of the birds due to the effect of the phytochemicals on the performance characteristics which were not reasonably alleviated by the absorbent (bentonite) in the animal's body at higher dietary intake.

Serum biochemical indices: The increase in the serum sodium, calcium and potassium levels as the processed ASAK^{BN} meal increased in the diet of the birds were ascribed to the appreciable levels of these minerals in the seed. This corroborates the findings of Ukana *et al.* (2012), who reported the high mineral content in the star apple seed. The elevation in the blood glucose of the birds fed the processed ASAK^{BN} meal over those on the control diet might perhaps be ascribed to the influence of the ASAK in the diet which probably increased the energy content and enhanced the glucose level in the birds. A similar effect in the serum blood glucose was also observed in the broilers fed the raw ASAK meal suggesting that, the blood glucose of broilers would be elevated when fed ASAK irrespective of treatment method applied or not. Ogbuewu *et al.* (2011) had earlier reported that, concentration of serum glucose is directly associated with energy utilization and metabolism in the animal's body.

The increase in the serum urea as the dietary inclusion level of the processed ASAK^{BN} meal over their counterpart on the control diet might perhaps be associated with the breakdown of the body tissues, since the nitrogen and energy supplied in the diet was not accessible resulting to damaged tissues, thereby increasing the serum urea levels of the birds on the test diets. This is in conformity with the report of Omoikhoje *et al.* (2003), that urea is an indirect measure of protein utilization in the animals. The significant ($p < 0.05$) decrease in the creatinine levels in relation to those on the control diet suggest the level of muscle damage. The creatinine values in this study did not exceed the normal range of 0.6 to 2.5mg/dl reported by Taiwo and Ogunsanmi (2003), however the creatinine values (0.20 to 0.69mg/dl) of the birds fed 5-30% processed ASAK^{BN} meal fall below the normal range, this suggest the tendency of muscle wastage, hence the reduced

weights of the birds on the test diet. This is in line with the findings of Ogbuewu *et al.* (2010), that the level of serum creatinine signals the extent of muscle damage.

The decline in the total cholesterol, high density lipid, low density lipid and triglyceride as the dietary inclusion level of the processed ASAK^{BN} meal increased in the diet compared with their counterpart on the control diet do not impact negatively on the birds as the range in the values (38.33-63.37mg/dl) obtained for the total cholesterol were within the normal values (30.15-85.05mg/dl) reported by Waziri *et al.* (2010). The increase in the total protein, albumin and globulin values observed as the dietary inclusion level of the processed ASAK^{BN} meal increased could be attributed to interference in protein synthesis from the phytochemicals in the ASAK meal limiting the bioavailability of protein for the animal's use.

The linear increase in the AST, ALT and ALP as the dietary inclusion levels of the processed ASAK meal using bentonite increased in the diet of the birds indicated that the broiler chickens have a challenge in handling the digestion of the star apple seed kernels irrespective of whether fed raw or treated. Sodipo *et al.* (2009) had earlier reported that saponins inhibit enzyme activities and nutrient absorption. The presence of saponins and other phytochemicals not completely detoxified by the bentonite may have increased the enzyme activities of AST, ALT and ALP in the liver of the birds on the test diet compared to those fed the control diets.

Haematology indices: The red blood cell, packed cell volume and haemoglobin of the broilers fed the raw ASAK meal were affected whereas only the red blood cell of the broilers fed the processed ASAK^{BN} meal was significantly affected, this implies that, the

bentonite may have altered the PCV and Hb values of the broilers fed the processed ASAK^{BN} meal. The PCV values of 31.39-34.60% obtained for the birds fed processed ASAK^{BN} meal were still within the normal range of 23-55% for healthy birds reported by Maxwell *et al.* (1990) which showed that the birds were not anaemic. PCV is an index of toxicity, any reduction in its concentration in the blood usually suggests the presence of toxic factors which has adverse effect on blood formation (Oyawoye and Ogunkunle, 1998). The haemoglobin values (8.90-9.69g/dl) obtained for the birds on the processed ASAK^{BN} meal were within the recommended haemoglobin concentration of 7-18.6g/dl for healthy birds reported by Aiello and Mays (1998). This implies the safety of bentonite for the processing of ASAK meal and its inclusion in the diet of the birds. The values obtained for the red blood cells of the experimental birds may suggest nutritional adequacy of the test diets.

The values obtained for the mean cell volume (124.91-130.02fl) of the birds on the processed ASAK^{BN} meal were within the normal range of 115-127fl reported by Swenson (1993). The MCV of the broilers fed the processed ASAK^{BN} meal were enhanced compared to the broilers fed raw ASAK meal with lower MCV of 51.28-60.75fl affirming the suitability of bentonite for the processing of ASAK meal with regard to the blood indices. The higher values of 35.00-36.77pg obtained for the MCH and 27.81-28.34 for the MCHC compared with the values of 25-27pg and 21-23g/dl reported by Swenson (1993) for the MCH and MCHC respectively for healthy birds suggest that, the birds were not anaemic. The values obtained for the mean cell volume, mean cell haemoglobin and mean cell haemoglobin concentration were within the normal range reported for avian species suggesting that, the treatment of the ASAK meal improved the

blood parameters and attests to the nutritional adequacy of the diets and safety of the test ingredient for broilers. The non significant effect of the white blood cells observed in the birds fed the processed ASAK^{BN} meal suggest that the absorbent (bentonite) may have impacted positively on the immune system of the birds thus ruling out the possibility of any infection attributed from feeding the test ingredient to the birds. The birds fed the raw ASAK meal were significantly affected and accompanied with an increase in the white blood cells which may be attributed to the high concentration of the phytochemicals in the raw ASAK meal.

Nutrient retention: The decrease in the dry matter, crude protein, ether extract and soluble carbohydrate retention of the birds fed the increasing inclusion levels of the processed ASAK^{BN} meal were as a result of the incomplete detoxification of the antinutritional factors particularly tannins, saponins and phytate still present in the processed ASAK^{BN} meal. Saponins have been shown to bind to the cells of the small intestine thereby affecting the absorption of nutrients across the intestinal wall in the reports of Annongu, (2012). Phillips *et al.* (2002) had earlier reported that bentonite act as an enterosorbent which preferentially bind toxins and reduce their absorption in the digestive tract, the effect of saponins exerted on the intestinal walls may have limited the absorption of the available nutrients from the feed probably the dosage of the bentonite for pretreatment of the ASAK meal might be inadequate coupled with the low dry matter intake attributed to the astringent taste of the feed from tannins was responsible for the poor dry matter, crude protein, ether extract and soluble carbohydrate retention. This assertion could also be supported by the findings of Ravindran *et al.* (2006), that tannins in poultry diets reduce dry matter intake, body weight gain, feed efficiency and nutrient digestibility.

Although the nutrient retention of the birds fed the processed ASAK^{BN} meal were fairer than those fed the raw ASAK meal and those fed processed ASAK using activated charcoal meal. There is the need to increase the dosage for the pretreatment of ASAK meal with bentonite to enhance the nutrient retention of the birds.

Histology of the Liver: The severe hepatocyte degradation and inflammation of the bile duct observed in the liver of the birds fed beyond 10% inclusion level of processed ASAK^{BN} meal were as a result of the undetoxified phytochemicals present in the feed. The reports of Grant and Phillips (1998) gives credence to this study, the authors opined that, bentonite in animal diet act as gut protectants (enterosorbents) which preferentially bind toxins from the digestive tract and reduce their absorption into the animal's body. This implies that, the bentonite in the diet was insufficient to bind the toxins in the digestive tract to prevent impairment of the liver hepatocyte. In that manner, in a related study, the adverse effect of aflatoxins on efficiency and liver function was minimized by addition of bentonite (Santurio *et al.*, 1999).

The profitability of replacing maize with processed ASAK^{BN} meal: The replacement of maize with the processed ASAK^{BN} meal do not justify its use for all the inclusion levels, as there was a higher revenue and profit from the birds fed the control diet despite the reduction in feed cost per kilogram of the diets formulated with increasing inclusion level of the processed ASAK^{BN} meal. This is attributed to the poor palatability of the feed and its utilization by the birds. The implies that, the investor or farmer will have higher returns on capital investment from the use of maize compared to its replacement with the processed African star apple kernel meal with bentonite in the diet of the broilers.

It is concluded that using bentonite for the processing of ASAK meal revealed an improvement on the growth performance characteristics over the birds fed the raw ASAK and processed ASAK using activated charcoal meal respectively with regard to the growth performance characteristics, however the birds on the processed ASAK^{BN} meal performed poorly in relation to the birds on the control diet. The nutrient retention, serum biochemical and haematology parameters were enhanced by the processed ASAK^{BN} meal. The histology of the liver were severely affected beyond 10% inclusion level of the test diet attributed to the mild effect of low dosage of bentonite used in pretreating the ASAK meal.

CHAPTER SIX

6.0 Experiment Four: The effect of replacing maize with processed African star apple kernel meal using phytase in broilers

6.1 Introduction

The addition of enzymes to poultry diets in order to enhance the nutrient utilisation and performance by inhibiting the side effects of the targeted substrates has gained relevance in the last two decades. Most of the poultry diets are often formulated with maize-soybean as the main feed ingredients. The increasing prices and limited-availability of this conventional feedstuff is a major challenge for researchers in the field of nutrition to proffer alternative feed stuff or agro-industrial by products for feeding animals. Although, there is a wide range of alternative feed resources, their inclusion in poultry diets remains a challenge as a result of the antinutritional factors present in this novel feedstuff such as phytate and non-starch polysaccharides which lowers the nutritive value of the feedstuffs. The lack of endogenous enzymes to hydrolyse phytate makes phosphorus biologically not available to poultry. In order to mitigate against the adverse effect of these antinutrients, enzymes are added to the diet to improve their biological value and at the same time enhance profitability and also reduce environmental pollution. Some feeding trials have revealed that addition of phytase to broilers diet often enhance the availability of phosphorus bound by phytate in the feedstuff and enhance the utilization by the animals (Ravindran *et al.*, 1995; Selle *et al.*, 2000). There seems to be no information on the use of phytase enzyme for the treatment of African star apple kernels for feeding broilers.

6.2 Objective

This objective of this experiment was to evaluate the potential of phytase enzyme for the processing of African star apple kernels to enhance its utilization by the birds.

6.3 Materials and Methods

6.3.1 Experimental site

The experiment was carried out in the Poultry Unit of the Teaching and Research Farm, Landmark University, Omu-Aran, Kwara State.

6.3.2 Source of experimental birds

A total of 210, day-old Cobb breed of broiler birds were obtained from Zartech farms at Ibadan, Oyo State, Nigeria.

6.3.3 Collection of African star apple seeds

The fruits of *C. albidum* for this study were collected from the various star apple plantations in Osun state, Nigeria. The seeds were obtained from the fruit, thoroughly washed to remove the foreign materials, properly sun dried to a constant weight and were further dehulled to obtain the kernels.

6.3.4 Experimental diet

The kernels obtained from the seed were soaked for 12 hours, boiled for 30 minutes and sun dried. The sun dried kernels were milled, pretreated with phytase at 5g/kg and placed in tightly sealed containers for seven days before inclusion in the diet. Seven experimental diets were formulated made of a corn-soy reference diet and six other diets containing processed African star apple kernel using phytase (ASAK^P) meal for replacement maize in the diet of the birds at graded levels of 0, 5, 10, 15, 20, 25 and 30%

corresponding to diets 1, 2, 3, 4, 5, 6 and 7 respectively. The composition of the experimental diets for the broiler starter and finisher phases on as fed basis are presented on Tables 6.1 and 6.2, respectively. The proximate composition of the broiler starter phase and finisher are presented on Table 6.3 and 6.4 respectively. The proximate composition and the phytochemical analysis of the processed ASAK^P meal are presented on Table 6.5 and 6.6 respectively.

6.3.5 Management of experimental birds and data collection

A total of 210, day-old broiler chicks were used for the trial. The chicks were fed for one week on a standard broiler starter diet before the commencement of the experiment for both the starter and finisher phases. The experiment was designed as a complete randomized design. The dietary treatments contained three replicates with 10 chicks per replicate. All the birds were raised under similar management practices (brooding, lighting, feeding and watering) throughout the eight week experimental period for both the starter and finisher phase except for the diets offered that differed. The birds were given feed and water *ad-lib* and weighed weekly. Routine vaccinations and medications were carried out as at when due.

6.3.6 Data collection/response criteria

In the course of the experiment, data were collected on the performance characteristics: (a) feed consumption, (b) daily weight gain, (c) growth rate, (d) feed conversion ratio, (e) survival rate, (f) Carcass evaluation. At the end of the eight weeks study period, three birds per treatment were randomly selected based on the group average and were weighed, slaughtered and eviscerated for carcass evaluation. The birds were fasted for

Table 6.1: Composition of the experimental diets for broiler starter processed with phytase enzyme (Kg/100Kg)

Diets	T1	T2	T3	T4	T5	T6	T7
CKM levels %	0	5	10	15	20	25	30
Maize	56.46	53.63	50.81	47.99	45.17	42.34	39.52
CKM	0.00	2.83	5.65	8.47	11.29	14.12	16.94
SBM	38.04	38.04	38.04	38.04	38.04	38.04	38.04
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Limestone	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
V. premix	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100	100	100	100	100	100	100

Calculated analysis of the diets

Feed cost/Kg(₦)	105.98	104.72	103.46	102.19	100.93	99.64	98.41
ME kcal/kg	3132.74	3118.63	3104.57	3090.52	3076.46	3062.35	3077.62
CP (%)	22.99	22.63	22.40	22.18	21.95	21.73	21.50
Fat (%)	3.74	3.63	3.52	3.40	3.29	3.18	3.06
C. fibre (%)	4.02	3.95	3.87	3.79	3.72	3.64	3.57
Ash (%)	1.07	1.04	1.00	0.96	0.93	0.89	0.85
Calcium (%)	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Phosphorus	0.54	0.53	0.52	0.52	0.51	0.50	0.49
Lysine	1.25	1.24	1.23	1.23	1.22	1.21	1.20
Methionine	0.57	0.56	0.55	0.55	0.54	0.54	0.53
Phytase/g (₦)	-	0.12	0.12	0.12	0.12	0.12	0.12

CKM= Chrysophyllum kernel meal; ME=Metabolizable energy; CP=Crude protein; C.fibre= Crude fibre

Table 6.2: Composition of the experimental diets for broiler finisher processed with phytase enzyme (Kg/100Kg)

Diets	T1	T2	T3	T4	T5	T6	T7
CKM levels %	0	5	10	15	20	25	30
Maize	63.91	60.71	57.52	54.32	51.13	47.93	44.74
CKM	0.00	3.20	6.39	9.59	12.78	15.98	19.17
SBM	30.19	30.19	30.19	30.19	30.19	30.19	30.19
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bone meal	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Limestone	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
V. premix	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100	100	100	100	100	100	100

Calculated analysis of the diets

Feed cost/Kg(₦)	105.98	104.72	103.46	102.19	100.93	99.64	98.41
ME kcal/kg	3153.71	3137.76	3121.86	3105.90	3089.99	3074.04	3058.14
CP (%)	20.00	19.74	19.49	19.23	18.97	18.71	18.60
Fat (%)	3.77	3.64	3.51	3.38	3.25	3.13	3.00
C. fibre (%)	3.71	3.63	3.54	3.46	3.37	3.28	3.20
Ash (%)	1.17	1.13	1.09	1.05	1.00	0.96	0.92
Calcium (%)	1.16	1.16	1.16	1.16	1.16	1.16	1.16
Phosphorus	0.65	0.64	0.63	0.62	0.61	0.60	0.59
Lysine	1.08	1.07	1.06	1.05	1.05	1.04	1.03
Methionine	0.54	0.53	0.53	0.52	0.51	0.51	0.50
Phytase/g (₦)	-	0.12	0.12	0.12	0.12	0.12	0.12

CKM= Chrysophyllum kernel meal; ME=Metabolizable energy; CP=Crude protein; C.fibre= Crude fibre.

Table 6.3: Analysed nutrient content of experimental diets for broiler starter

	D		I	E	T	S	
Parameters	T1	T2	T3	T4	T5	T6	T7
Dry matter (%)	89.25	89.47	89.23	89.28	89.76	89.29	89.18
Crude protein (%)	22.97	21.69	22.19	21.76	22.55	22.40	22.76
Ether extract (%)	2.45	2.38	2.35	2.33	2.29	2.19	2.10
Crude fibre (%)	2.61	2.59	2.28	2.74	2.74	3.08	3.03
Ash (%)	8.55	8.03	8.27	8.36	8.15	8.24	8.43
NFE (%)	56.85	56.15	55.00	54.39	55.30	53.93	54.14

Table 6.4: Analysed nutrient content of experimental diets for broiler finisher

	D		I	E	T	S	
Parameters	T1	T2	T3	T4	T5	T6	T7
Dry matter (%)	88.17	88.45	88.41	88.43	89.41	88.26	88.37
Crude protein (%)	20.10	20.30	20.90	21.37	21.35	21.46	21.28
Ether extract (%)	2.29	2.24	2.23	2.19	2.13	2.11	2.07
Crude fibre (%)	2.06	2.58	2.97	3.12	3.22	3.31	3.36
Ash (%)	6.87	7.18	7.31	7.36	7.41	7.45	7.52
NFE (%)	56.85	56.15	55.00	54.39	55.30	53.93	54.14
Gross energy (kcal/g)	1,082.41	932.71	911.34	875.74	759.55	679.19	498.88

Table 6.5: Proximate composition of processed African star apple kernel meal using phytase

Parameters	%
Dry matter	89.37
Crude protein	11.44
Ether extract	1.86
Ash	4.42
Crude fibre	5.91
Soluble carbohydrate	65.74
Gross energy (kcal/g)	3.85

Table 6.6: Phytochemical analysis of processed African star apple kernel using phytase

Parameters	mg/kg
Saponin	1.01
Phytate	0.34
Tannins	8.78
Oxalate	0.38
Glycoside	4.10×10^{-3}

12 hours before slaughtering, bled and the slaughter weight taken. The birds were also defeathered manually using hot water and eviscerated. The live weight and carcass weight were recorded. The dressing percentage was calculated. Organ weights and the major primal carcass parts were expressed as percentages of the live weight.

6.3.7 Nutrient digestibility trial

The study on apparent nutrient digestibility was carried out at the end of the 8th week of the experimental period. Three birds per treatment were randomly selected and transferred to clean metabolic cages and fed the corresponding treatment diets. The trial lasted for eight days. The first four days were considered as adaptation period and the last four days as experimental period. Records of feed intake and faeces voided were taken during the last four days. The droppings were oven dried, bulked and representative samples were taken for chemical analysis. The samples were analyzed for proximate composition according to the methods of AOAC (1990).

$$\text{Apparent Nutrient Retention} = \frac{\text{Nutrient intake} - \text{Nutrient in faeces}}{\text{Nutrient intake}} \times 100$$

6.3.8 Serum biochemical and haematology analysis

At the end of the experiment, one broiler per replicate in all the treatments was taken at random and blood collected by decapitation. Blood for serum biochemical indices was collected in bottles without EDTA for the analysis of the biochemical parameters of (a) blood electrolytes: Ca, Na, K, Cl, and bicarbonate, (b) blood glucose level, (c) total protein, (d) albumin, (e) globulin, (f) albumin/globulin ratio (g) total cholesterol (h) creatinine (i) urea (j) lipid profile (HDL and LDL), (k) transaminase activities- AST,

ALT ALP etc. The samples were spun in the centrifuge at 3,000 rpm and the clearer portion (serum) decanted after centrifugation into another set of plain bottles and were placed in an ice bath and taken to the laboratory.

The blood samples for haematology parameters were pretreated with ethylene diamine tetra-acetate (EDTA), an anti-coagulant and were placed in the refrigerator (4°C) immediately before taken to the laboratory. Haematology indices examined include white blood cell (WBC) and its differential counts (neutrophils, lymphocyte, monocyte, eosinophil and basophils), red blood cell (RBC), packed Cell Volume (PCV), haemoglobin (Hb). The mean cell volume (MCV), mean cell haemoglobin (MCH) and the mean cell haemoglobin concentration (MCHC) were calculated from the values of the RBC, PCV and Hb respectively.

$$\text{MCV} = \frac{\text{PCV}}{\text{RBC}} \times 10 \qquad \text{MCH} = \frac{\text{Hb}}{\text{RBC}} \times 10 \qquad \text{MCHC} = \frac{\text{Hb}}{\text{PCV}} \times 100$$

6.3.9 Histology of the liver

Three birds were selected per treatment at the end of the feeding trial and sacrificed to obtain the liver. Sections were obtained from the anterior lobe of the liver, preserved in 90% saline + 10% formalin solution. The liver tissues from each replicate were processed for histological studies using haematoxylin and eosin stains. Photomicrographs were taken using a digital microscope with a magnification of 400. The analysis was carried out at the histopathological laboratory of Central Research Laboratory, Tanke, Ilorin.

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6.4 Statistical analysis

Data collected on the response criteria were subjected to analysis of variance according to the completely randomized design model and differences between treatment means were separated using the Duncan's multiple range test (Steel and Torrie, 1980).

6.5 Results

6.5.1 Growth performance characteristics of broilers fed processed African star apple kernel meal using phytase

Table 6.7 presents the growth performance characteristics of broilers fed processed African star apple kernel using phytase (ASAK^P) meal. The growth performance characteristics of the birds fed processed ASAK^P meal were enhanced compared with the birds fed the raw ASAK meal, however there was a corresponding decrease in the performance characteristics of the birds as the dietary level of the processed ASAK^P meal increased in the diet in relation to those on the control diet. The final live weighs, average daily weight gains and the feed intake values of the birds significantly ($p < 0.05$) decreased as the processed ASAK^P meal increased in the diet of the birds for replacement of maize as energy source. The feed conversion ratio favoured the birds on the control diet compared to those on the test feedstuff. There was an increased poor feed conversion ratio as the processed ASAK^P meal increased in the diets. The results of the cost per kg weight gains also followed the same trend with the feed conversion ratios. There was a decrease in the feed cost N/kg of the birds as the dietary replacement of maize with the processed CKM increased in the diets of the birds. The percent mortality of the birds was not significantly ($p > 0.05$) affected by the dietary inclusion of the processed ASAK^P meal in the diet of the birds.

Table 6.7: Growth performance characteristics of broiler birds fed processed African star apple kernel meal using phytase

Parameters	T1	T2	T3	T4	T5	T6	T7	SEM	Pvalue
	(0%)	(5%)	(10%)	(15%)	(20%)	(25%)	(30%)		
Initial live weight (g/bird)	126.45	126.45	126.45	126.45	126.45	126.45	126.45	-	-
Final live weights (g/bird)	2024.80 ^a	1084.76 ^b	964.77 ^c	874.77 ^d	784.77 ^e	694.77 ^f	534.78 ^g	3.12	0.0001
Daily weight gains (g/bird/day)	40.39 ^a	20.38 ^b	17.83 ^c	15.92 ^d	14.00 ^e	12.09 ^f	8.68 ^g	0.07	0.0001
Feed intake (g/bird/day)	118.34 ^a	97.95 ^b	92.69 ^c	77.33 ^d	76.11 ^e	71.58 ^f	67.77 ^g	0.49	0.0001
Feed conversion ratio	2.94 ^f	4.80 ^e	5.19 ^d	4.85 ^e	5.43 ^c	5.92 ^b	7.83 ^a	0.04	0.0001
Cost per kg weight gain (₦)	311.58 ^g	502.65 ^e	536.95 ^d	495.62 ^f	548.04 ^c	589.86 ^b	770.55 ^a	3.83	0.0001
Cost of feed/kg (₦)	105.98	104.72	103.46	102.19	100.93	99.64	98.41	-	-
% Mortality	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-

SEM= Standard error of mean;LOS= Level of Significance,*=P<0.05;^{a,b,c,d,e,f,g}Means with different superscript along the same rows are significant (P<0.05);NS=Non Significant (P>0.05)

The phytochemical dietary intake of the processed ASAK^P meal is presented on Table 6.8. The incomplete detoxification of the phytochemicals in the diets further attest to the poor growth performance characteristics observed in the birds fed from 5-30% inclusion level of the processed ASAK^P meal.

6.5.2 Carcass characteristics of broilers fed processed African star apple kernel meal using phytase

The carcass characteristics of broilers fed processed ASAK^P meal is presented on Table 6.9. The result of the carcass characteristics of the birds fed the processed ASAK^P meal were fairer than when fed raw to the birds, though far below the optimum for the birds on the control diet. The differences in the live weights, carcass weights and the dressing percentage were significantly ($p<0.05$) affected across the treatment groups fed the processed ASAK^P meal. There was a corresponding decrease in the live weights, carcass weights and dressing percentage of the birds as the processed ASAK^P meal increased in the diets of the birds. The weights of the carcass components for the neck, wings, thigh, drumstick, shank, breast, back expressed as percentages of the live weights were lower in all the dietary groups fed the processed ASAK^P meal compared with the control group except the head that was lower in the control group. The weights of the heart, liver, kidney, proventriculus and the gizzard were significantly ($p<0.05$) affected except the lungs that was not significantly ($p>0.05$) affected. There was a significant ($p<0.05$) decrease in the lengths of the small and large intestines as dietary replacement of corn with processed ASAK^P meal increased in the diets of the birds compared to the birds on the control diet.

Table 6.8: Dietary phytochemical intake of broilers fed processed African star apple kernel meal using phytase

Parameters	T1	T2	T3	T4	T5	T6	T7	SEM	P value
	(0%)	(5%)	(10%)	(15%)	(20%)	(25%)	(30%)		
Saponins (mg/bird/day)	0.00 ^g	0.32 ^f	0.60 ^e	0.75 ^d	0.98 ^c	1.16 ^b	1.31 ^a	0.51	0.0001
Phytate (mg/bird/day)	0.00 ^g	0.11 ^f	0.20 ^e	0.25 ^d	0.33 ^c	0.39 ^b	0.44 ^a	4.28	0.0001
Tannins (mg/bird/day)	0.00 ^g	2.75 ^f	5.20 ^e	6.51 ^d	8.54 ^c	10.04 ^b	11.41 ^a	3.81	0.0001
Oxalate (mg/bird/day)	0.00 ^g	0.12 ^f	0.22 ^e	0.28 ^d	0.37 ^c	0.43 ^b	0.49 ^a	0.03	0.0001
Glycoside (mg/bird/day)	0.00 ^g	1.3x10 ^{-3f}	2.4x10 ^{-3e}	3.0x10 ^{-3d}	4.0x10 ^{-3c}	5.3x10 ^{-3b}	8.9x10 ^{-3a}	0.03	0.0001

Table 6.9: Carcass characteristics of broilers fed processed African star apple kernel meal using phytase

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Live weight (g/bird)	2,024.80 ^a	1,084.76 ^b	964.77 ^c	874.77 ^d	784.77 ^e	694.77 ^f	534.78 ^g	3.12	0.0001
Carcass weights (g/bird)	1,315.30 ^a	685.19 ^b	595.70 ^c	534.63 ^d	440.40 ^e	390.52 ^f	297.50 ^g	6.09	0.0001
Dressing percentage (%)	64.95 ^a	63.16 ^b	61.74 ^c	61.11 ^c	56.11 ^d	56.20 ^d	55.62 ^d	0.33	0.0001
Prime cut and Organ weights	Expressed as % of live weight								0.0001
Head	2.43 ^g	2.99 ^f	3.30 ^e	3.36 ^d	3.47 ^c	3.55 ^b	3.91 ^a	0.01	0.0001
Thigh	10.89 ^a	9.12 ^c	8.97 ^{de}	9.48 ^b	9.03 ^d	8.97 ^{de}	8.90 ^e	0.05	0.0001
Breast	20.95 ^a	17.96 ^b	17.93 ^b	17.36 ^c	14.88 ^d	13.60 ^e	12.45 ^f	0.07	0.0001
Wings	8.20 ^a	8.14 ^d	8.24 ^c	8.29 ^b	8.46 ^a	8.38 ^a	7.96 ^e	0.04	0.0001
Shank	4.26 ^a	4.20 ^{ab}	4.22 ^a	4.17 ^{ab}	4.12 ^b	3.98 ^c	3.85 ^d	0.05	0.0001
Neck	5.45 ^a	5.33 ^d	5.42 ^b	5.39 ^{bc}	5.26 ^e	5.01 ^f	5.36 ^{cd}	0.02	0.0001
Drumstick	8.62 ^a	8.51 ^b	8.45 ^{bc}	8.37 ^c	8.33 ^d	8.14 ^e	7.75 ^f	0.04	0.0001
Back	11.21 ^a	10.75 ^b	10.65 ^c	10.59 ^c	10.22 ^d	10.16 ^d	10.04 ^e	0.03	0.0001
Heart	0.35 ^c	0.36 ^b	0.35 ^c	0.34 ^d	0.36 ^b	0.37 ^a	0.37 ^a	0.01	0.0027
Lungs	0.53	0.51	0.54	0.55	0.56	0.52	0.52	0.03	0.2937
Liver	3.09 ^d	3.01 ^e	3.01 ^e	3.21 ^c	3.40 ^a	3.36 ^b	2.54 ^f	0.01	0.0001
Kidney	0.53 ^a	0.47 ^b	0.44 ^{bc}	0.42 ^c	0.39 ^d	0.35 ^e	0.34 ^e	0.02	0.0001
Proventriculus	0.40 ^f	0.51 ^e	0.53 ^d	0.55 ^c	0.59 ^b	0.60 ^b	0.65 ^a	0.01	0.0001
Gizzard	1.78 ^g	2.17 ^f	2.34 ^e	2.36 ^d	2.43 ^c	2.51 ^b	2.76 ^a	0.01	0.0001
Small intestine length (cm)	142.11 ^a	129.45 ^b	103.08 ^c	77.46 ^d	54.02 ^e	47.97 ^e	38.65 ^f	4.06	0.0001
Large intestine length (cm)	68.28 ^a	61.51 ^b	53.10 ^c	39.80 ^d	26.62 ^e	25.56 ^e	23.33 ^e	2.10	0.0001

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d,e,f,g}Means with different superscript along the same rows are significant (P<0.05);NS=Non Significant (P>0.05)

6.5.3 Serum biochemical indices of broilers fed processed African star apple kernel meal using phytase

Table 6.10 presents the serum biochemical indices of the broiler chickens fed processed ASAK^P meal. The pattern in the values of the serum biochemical indices of the birds fed the processed ASAK^P meal were fairer in relation to the birds fed the increasing inclusion level of the raw ASAK meal for replacing maize in the diet of the birds. There was a significant ($p<0.05$) linear increase in the serum potassium levels as the processed ASAK^P meal increased in the diet of the birds. The patterns in the serum sodium and calcium levels were irregular. The blood glucose and serum urea levels significantly ($p<0.05$) increased with an increasing inclusion level of the processed ASAK^P meal in the diet of the birds. There was a significant ($p<0.05$) decrease in the creatinine levels of the birds as the inclusion level of the processed ASAK^P meal increased in the diet of the birds.

There were significant ($p<0.05$) differences for the total cholesterol, high density lipid (HDL) cholesterol, low density lipid (LDL) cholesterol and triglyceride respectively with a linear decrease in their values as the dietary inclusion level of the processed ASAK^P meal increased in the diet of the birds. The serum total protein, albumin and globulin were significantly ($p<0.05$) affected and accompanied by a corresponding increase as the dietary inclusion level of the processed ASAK^P meal increased in the diet of the birds.

The serum AST, ALT and ALP levels of the birds on the processed ASAK^P meal were significantly ($p<0.05$) affected. The AST, ALT and ALP activities increased as dietary inclusion of the processed ASAK^P meal increased in the diet. The values obtained for AST and ALP in the birds fed the processed ASAK^P meal were higher than the

Table 6.10: Serum biochemical indices of broilers fed processed African star apple kernel meal using phytase

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Glucose (mg/dl)	96.73 ^d	103.39 ^{cd}	107.57 ^{cd}	111.56 ^c	114.98 ^b	121.12 ^{ab}	128.81 ^a	2.14	0.0005
Calcium (ppm)	11.26 ^{ab}	11.45 ^a	11.24 ^{ab}	11.41 ^a	11.20 ^{ab}	10.10 ^{bc}	9.60 ^c	0.62	0.0137
Sodium (mEq/l)	111.93 ^{ab}	119.88 ^a	118.25 ^{ab}	112.25 ^{ab}	108.29 ^{ab}	115.35 ^{ab}	106.30 ^b	6.41	0.1685
Potassium (mg/dl)	18.05 ^d	20.33 ^c	22.31 ^{bc}	21.23 ^c	24.20 ^{ab}	25.14 ^a	25.41 ^a	1.28	0.0001
Urea (mg/dl)	28.00 ^e	36.82 ^d	41.12 ^c	42.92 ^{bc}	44.67 ^b	46.34 ^{ab}	48.36 ^a	2.39	0.0001
Creatinine (mg/ml)	0.74 ^a	0.54 ^b	0.48 ^c	0.40 ^d	0.35 ^e	0.27 ^f	0.21 ^g	0.03	0.0001
Total cholesterol (mg/dl)	70.84 ^a	66.22 ^{ab}	62.94 ^b	55.65 ^c	49.72 ^d	44.65 ^{de}	40.30 ^e	3.23	0.0001
HDL Cholesterol (mg/dl)	11.77 ^a	10.99 ^{ab}	10.43 ^b	9.19 ^c	8.19 ^d	7.32 ^{de}	6.58 ^e	0.55	0.0001
LDL Cholesterol (mg/dl)	57.51 ^a	53.67 ^{ab}	50.94 ^b	44.90 ^c	39.97 ^d	35.76 ^{de}	32.16 ^e	2.68	0.0001
Triglyceride (mg/dl)	13.03 ^a	10.35 ^b	9.57 ^{bc}	9.20 ^c	8.81 ^c	7.28 ^d	5.97 ^e	0.53	0.0001
Total protein (mg/dl)	15.05 ^c	13.23 ^d	13.87 ^{cd}	15.38 ^c	15.52 ^c	21.24 ^b	24.30 ^a	0.99	0.0001
Albumin (g/l)	0.31 ^b	0.24 ^c	0.31 ^b	0.30 ^b	0.31 ^b	0.33 ^{ab}	0.34 ^a	0.02	0.0002
Globulin (g/l)	14.74 ^{cd}	12.99 ^d	13.56 ^{cd}	15.08 ^c	15.21 ^c	20.90 ^b	23.95 ^a	0.97	0.0001
Albumin-Globulin ratio	0.02	0.01	0.02	0.01	0.02	0.01	0.01	-	0.0001
Aspartate Aminotransaminase (u/l)	10.89 ^e	23.46 ^c	19.88 ^d	21.93 ^{cd}	26.01 ^b	27.54 ^{ab}	29.07 ^a	1.33	0.0001
Alanine Aminotransaminase (u/l)	16.11 ^a	8.77 ^e	8.97 ^e	10.40 ^{de}	11.01 ^d	19.78 ^b	26.31 ^a	0.89	0.0001
Alkaline phosphate (u/l)	0.93 ^d	1.87 ^c	2.34 ^b	2.81 ^a	2.81 ^a	2.74 ^a	2.81 ^a	0.14	0.0001

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05,^{a,b,c,d,e,f}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant (P>0.05); HDL=High Density Lipid;LDL=Lipid Density Lipid.

values obtained for those on the control diet whereas the ALT activity was higher in the birds fed the control diet compared with its counterpart fed 5, 10, 15 and 20% processed ASAK^P meal.

6.5.4 Haematology indices of broilers fed processed African star apple kernel meal using phytase

The haematology indices of the birds fed the processed ASAK^P meal is presented on Table 6.11. The red blood cell of the birds fed the processed ASAK^P meal was significantly ($p < 0.05$) affected, there was an increase in the red blood cells as the processed ASAK^P meal increased in the diet of the birds compared with the birds on the control diet. The haemoglobin and the packed cell volume were not significantly ($p > 0.05$) affected by the processed ASAK^P meal unlike in the birds that were fed the raw ASAK meal, although there was a linear increase in the values but not statistically significant. There were significant ($p < 0.05$) differences in the mean cell volume, mean cell haemoglobin and mean cell haemoglobin concentration with a corresponding decrease as the processed ASAK^P meal increased in the diet. The values obtained were lower compared with the birds on the control diet except for treatment 2 that was higher than treatment 1 for the MCV. The white blood cells of the birds was not significantly ($p > 0.05$) affected by the processed ASAK^P meal unlike the broilers fed the raw ASAK meal but the trend revealed an increase which was statistically insignificant.

6.5.5 Nutrient retention of broilers fed processed African star apple kernel meal using phytase

Table 6.12 presents the nutrient retention of the broilers fed processed ASAK^P meal. The nutrient retention of the dry matter, crude protein, ether extract and soluble carbohydrate were significantly ($p < 0.05$) affected with a linear decrease as the processed

Table 6.11: Haematology indices of broilers fed processed African star apple kernel meal using phytase

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Red Blood Cell (x 10 ¹² /l)	2.27 ^c	2.28 ^b	2.35 ^{abc}	2.40 ^{abc}	2.48 ^{abc}	2.54 ^{ab}	2.60 ^a	0.13	0.0680
Haemoglobin (g/dl)	8.36	8.36	8.55	8.68	8.83	8.93	9.11	0.49	0.4746
Packed Cell Volume (%)	29.51	29.70	30.36	31.11	31.57	32.11	32.52	1.76	0.3147
Mean Cell Volume (fl)	129.83 ^{ab}	130.07 ^a	128.65 ^c	129.24 ^b	127.32 ^d	125.91 ^e	125.09 ^f	0.36	0.0001
Mean Cell Haemoglobin (pg)	36.80 ^a	36.64 ^a	36.25 ^b	36.08 ^b	35.63 ^c	35.01 ^d	35.05 ^d	0.10	0.0001
Mean Cell Hae. Conc (g/dl)	28.34 ^a	28.17 ^b	28.18 ^b	27.92 ^e	27.98 ^d	27.81 ^f	28.02 ^c	0.01	0.0001
White Blood Cell (x 10 ⁹ /l)	229.46	230.87	234.54	236.41	237.54	239.32	240.92	4.41	0.9131

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05,^{a,b,c,d,e,f}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant (P>0.05);Mean Cell Hae. Conc= Mean Cell Haemoglobin Concentration.

Table 6.12: Nutrient retention of broilers fed processed African star apple kernel meal using phytase

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Dry matter	88.50 ^a	74.40 ^b	68.53 ^c	58.46 ^d	56.16 ^d	53.33 ^d	52.83 ^d	1.16	0.0001
Crude protein	87.23 ^a	76.91 ^b	75.76 ^b	74.27 ^b	73.65 ^b	73.60 ^b	72.81 ^b	3.62	0.0558
Ether extract	82.22 ^a	74.43 ^b	63.77 ^c	63.54 ^c	57.10 ^d	52.20 ^d	48.45 ^e	2.92	0.0064
Soluble carbohydrate	63.80 ^a	59.88 ^b	55.27 ^c	53.32 ^d	52.43 ^d	51.21 ^d	49.27 ^e	0.63	0.0001

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d} Means with different superscript along the same rows are significantly (P<0.05).

ASAK^P meal increased in the diet of the birds in relation to the birds on the control diet. The trend in the nutrient retention of the birds fed the processed ASAK^P meal was fairer compared to their counterpart fed the raw ASAK meal.

6.5.6 Histology of the liver of broilers fed processed African star apple kernel meal using phytase

The photomicrographs showing the liver of the birds fed the processed ASAK^P meal are presented on plates 1-7. The sections of the liver revealed a distortion in the architecture of the liver as the processed ASAK^P meal increased in the diet of the birds. The birds on the control diet and those fed 5% processed ASAK^P meal had normal hepatocyte, while birds fed 10% inclusion level also had normal hepatocyte with clear central vein. An increase in the dietary intake at 15% was accompanied with ducticular inflammation and mild hepatocyte perturbation while higher levels from 20 to 30% inclusion levels resulted in ducticular inflammation and severe hepatocyte perturbation.

6.5.7 Profitability of broilers fed processed African star apple kernel meal using phytase for dietary replacement of maize

Table 6.13 shows the profitability of replacing maize with processed ASAK^P meal in broiler's diet. The total feed intake, total weight gain and total cost of production per bird were higher in the birds fed the control diet, although there was a decrease in the feed cost per kg as the replacement of maize with processed ASAK^P meal increased in the diet. The reduction in the prices could not inturn enhance the profit on investment. The highest profit was obtained from the birds fed the control diet and the lowest obtained in the group fed 30% inclusion level of processed ASAK^P meal. There was a mild improvement in the birds fed the processed ASAK^P meal over the group fed the raw

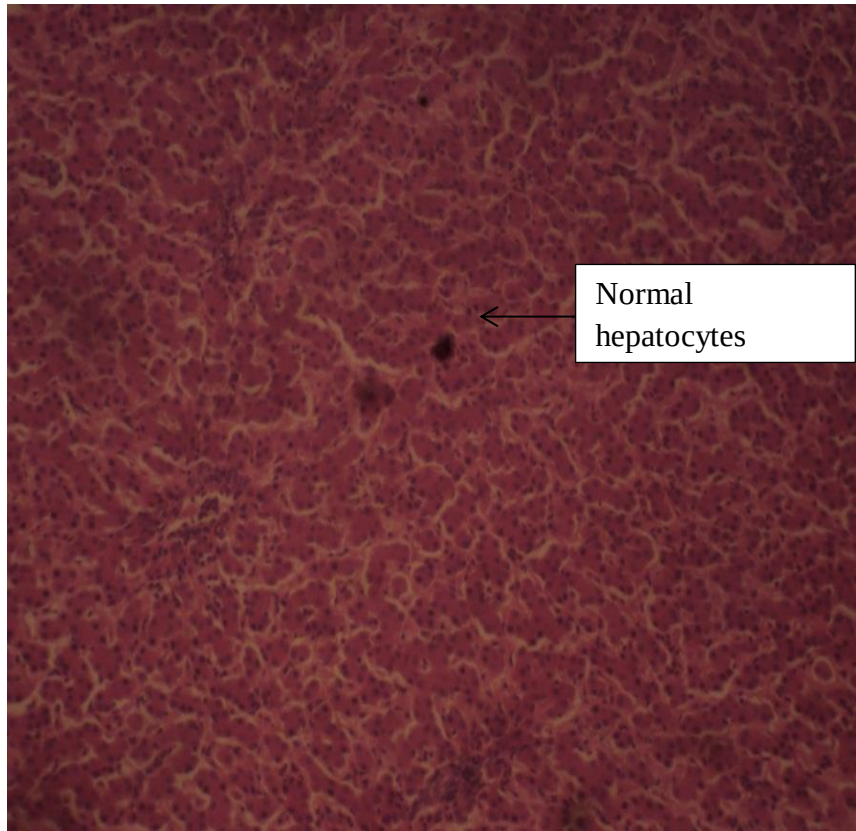


Plate i - Photomicrograph showing the liver of broilers fed the control diet

H/E Stain Mag. X400

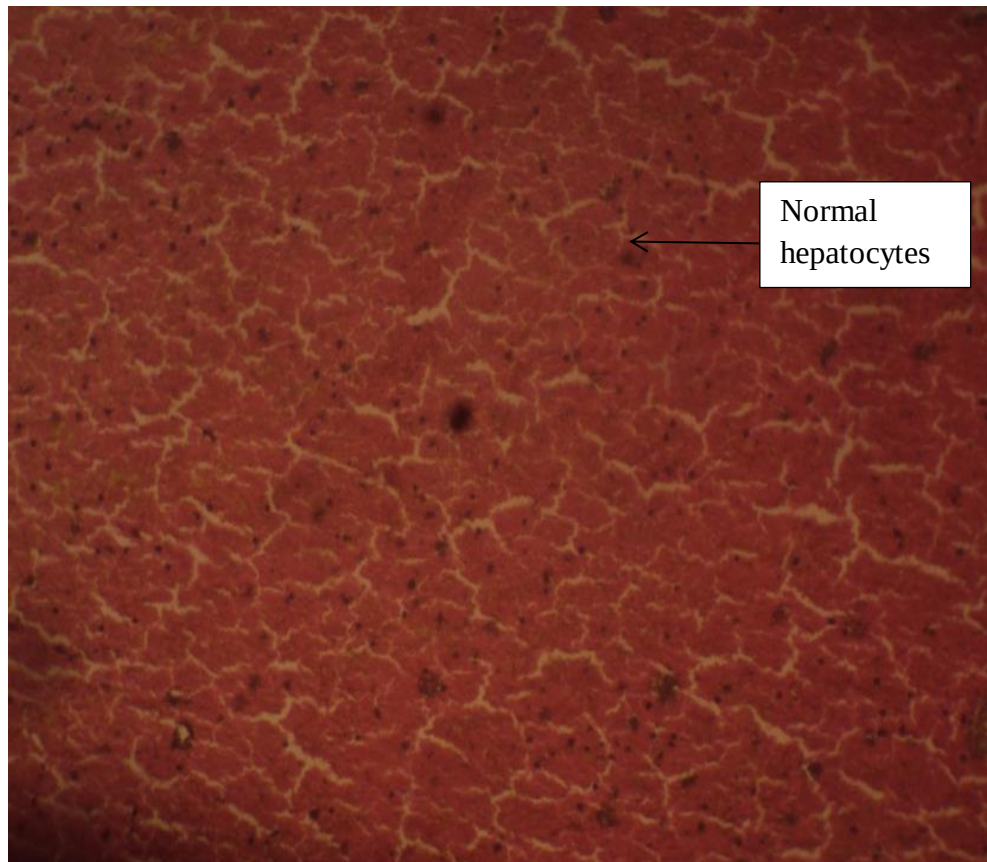


Plate ii - Photomicrograph showing the liver of broilers fed 5% processed African star apple kernel meal using phytase

H/E Stain Mag. X400

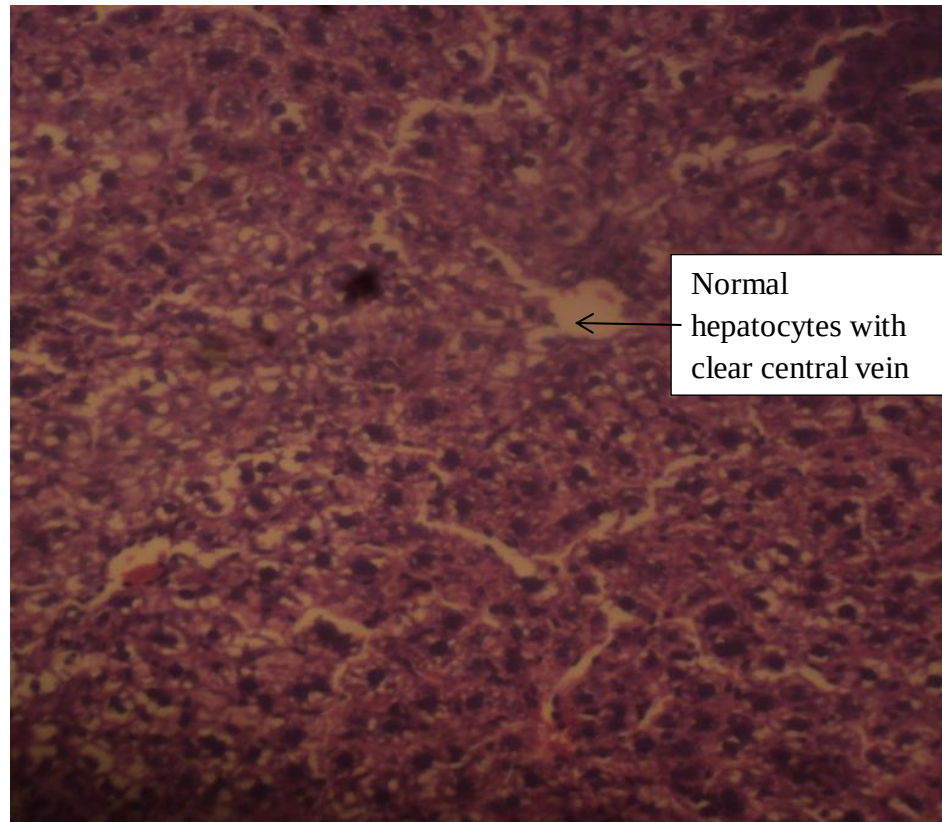


Plate iii - Photomicrograph showing the liver of broilers fed 10% processed African star apple kernel meal using phytase

H/E Stain Mag. X400

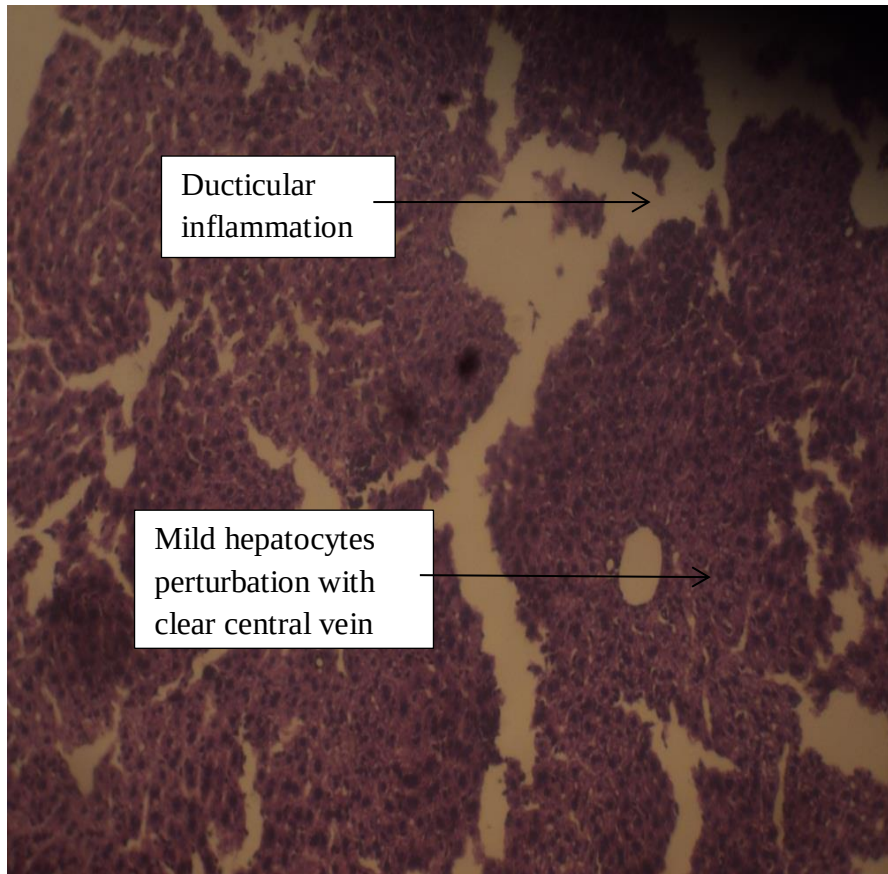


Plate iv - Photomicrograph showing the liver of broilers fed 15% processed African star apple kernel meal using phytase

H/E Stain Mag. X400

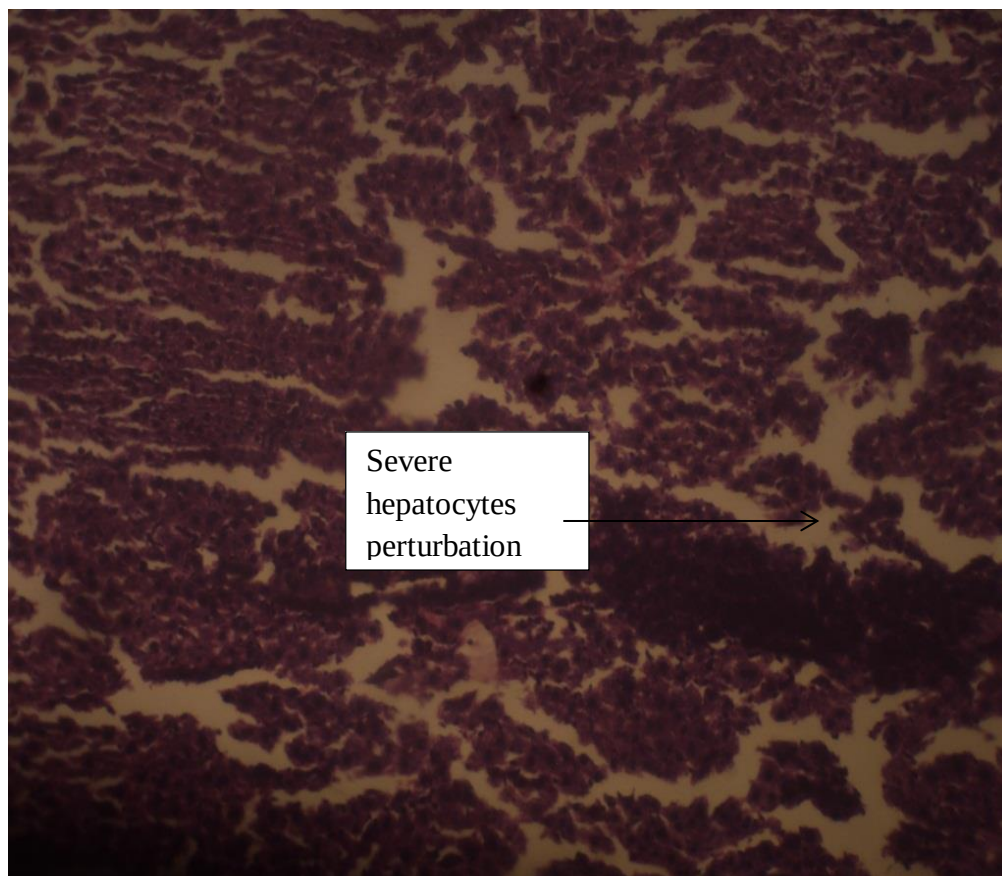


Plate v - Photomicrograph showing the liver of broilers fed 20% processed African star apple kernel meal using phytase

H/E Stain Mag. X400

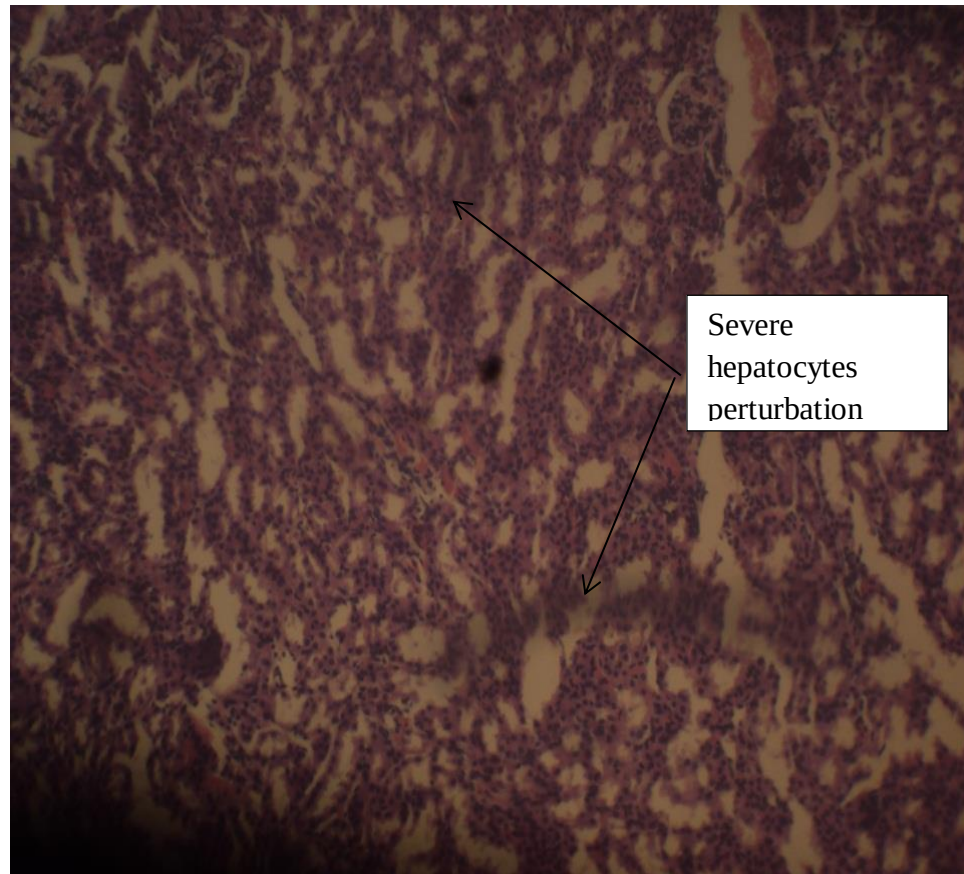


Plate vi - Photomicrograph showing the liver of broilers fed 25% processed African star apple kernel meal using phytase

H/E Stain Mag. X400

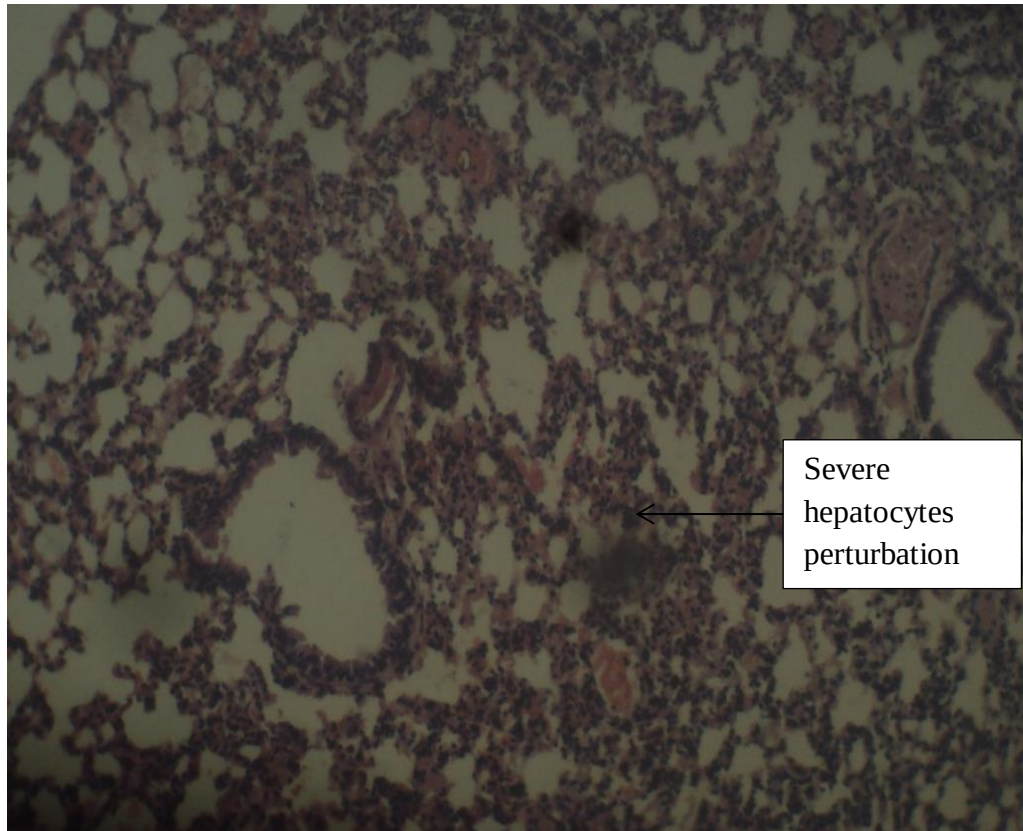


Plate vii - Photomicrograph showing the liver of broilers fed 30% processed African star apple kernel meal using phytase

H/E Stain Mag. X400

Table 6.13: Profitability of broilers fed processed African star apple kernel meal using phytase for dietary replacement of maize in broilers

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Total feed intake (g/bird)	5,561.98 ^a	4,603.65 ^b	4,356.43 ^c	3,634.51 ^d	3,577.17 ^e	3,364.26 ^f	3,185.19 ^g	4.35	0.0001
Total weight gain (g/bird)	1,898.35 ^a	958.31 ^b	838.32 ^c	748.32 ^d	658.32 ^d	568.32 ^e	408.33 ^f	3.12	0.0001
Final live weight (g/bird)	2,024.80 ^a	1,084.76 ^b	964.77 ^c	874.77 ^d	784.77 ^d	694.77 ^e	534.78 ^d	3.12	0.0001
Cost of feed/kg (₦)	106.00	104.30	102.70	101.10	99.40	97.70	96.10	-	-
(a) Cost of DOC/Medication	160.00	160.00	160.00	160.00	160.00	160.00	160.00	-	-
(b)Cost of feeding /bird = FC x TFI (₦)	589.46	482.09	450.72	371.41	361.04	335.21	313.45	-	-
Total cost of production/bird = (a+b) (₦)	749.46	642.09	610.72	531.41	521.04	495.21	473.45	-	-
Revenue = Fnwt x sales/kg	1,721.08	922.05	820.05	743.55	667.05	590.55	454.56	-	-
Profit (₦) = Revenue – TC	971.62	279.95	209.34	212.14	146.01	95.34	-18.89	-	-
Sale's price/kg (₦)	850	850	850	850	850	850	850	-	-

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant. DOC= Day Old Chicks; FC= Feed Cost; TFI= Total Feed Intake; Fnwt=Final live weight; TC=Total cost of production; Naira=₦

ASAK meal. The returns on investment for the dietary treatment of 10-30% processed ASAK^P meal may not justify the total cost of production.

6.6 Discussion

Growth performance characteristics: The decline in the growth performance characteristics (final live weight, average daily weight gains and feed intake values) of the birds fed beyond 5% inclusion level of the processed ASAK^P meal compared with their counterpart fed the control diet even though superior to the broilers fed the raw ASAK meal may be attributed to the presence of phytate in the processed ASAK^P meal even after treatment. Phytic acid acts as a strong chelator, forming protein and mineral phytic acid complexes; the net result being reduced protein and mineral bioavailability (Khare, 2000). The report of Khare (2000) that phytic acid inhibits the action of gastrointestinal tyrosinase, trypsin, pepsin and amylase may have affected the growth performance of the birds. Enzymes are added to diets on the basis that they will enhance the digestibility of economically interesting nutrients. These digestibility modifying influences are not static and are related to the concentration of substrate and the inherent digestibility of the focal nutrient *per se* as well as several other factors such as animal's age, species, disease status according to Cowieson and Bedford (2009). This implies that the concentration of the ANFs in the ASAK may have suppressed the processed ASAK^P meal making the nutrients unavailable since phytate is not the only phytochemical present in the kernels. The report of Cowieson *et al.* (2016) gives credence to the findings of this study with regard to the minimal effect of phytase enzyme on the growth performance characteristics of the birds, who reported that removing the nutritional impediments that phytate introduces and even liberating *myo*-inositol may not necessarily result in

enhanced live performance unless digestible amino acid and energy concentrations are suitable to promote further growth. The author affirmed that adding more phytase to a diet will not guarantee a beneficial response in the animal, therefore exploitation of 'supra-nutritional' concentrations of phytase should be combined in other to optimize responses. The antinutritional factors may have constituted a hindrance to the bio-availability of nutrients to the birds. The non availability of the nutrients to the animal's body might have impacted negatively on the feed conversion ratio. The increasing cost per kg weight gains as the processed ASAK^P meal increased in the diet despite the reduction in the feed cost were as a result of the poor feed conversion ratio, as the birds will have to consume more to attain a kilogram in body weight.

Carcass characteristics: The decrease in the live weights, dressing percentage, carcass weights and its components as the processed ASAK^P meal inclusion levels increased in the diets of the birds were as a result of the reduced final live weights and poor feed conversion ratio of the birds fed 10 to 30% processed ASAK^P meal inclusion levels. The effect of the processed ASAK^P meal on the internal organs of the heart, liver, kidney and proventriculus except for the lungs could be as a result of the relative weights of the birds when these organs were expressed as percentages of the live weights of the birds due to the effect of the phytochemicals on the performance characteristics which were not reasonably alleviated by the phytase enzyme in the animal's body.

Serum biochemical indices: The increase in the serum potassium levels as the processed ASAK^P meal increased in the diet of the birds were ascribed to the appreciable mineral content in the seed. This corroborates the findings of Ukana *et al.* (2012), who reported the high mineral content in the star apple seed. The irregular trend observed for the

sodium and calcium values as the processed ASAK^P meal increased in the diet do not suggest nutritional inadequacy as the birds fed 5 and 15% processed ASAK^P meal had higher sodium and calcium values compared to those fed the control diet. The elevation in the blood glucose of the birds fed the processed ASAK^P meal over those on the control diet might perhaps be ascribed to the influence of the ASAK in the diet which probably increased the energy content and enhanced the glucose level in the birds. A similar effect in the serum blood glucose was also observed in the broilers fed the raw ASAK meal suggesting that, the blood glucose of broilers would be elevated when fed ASAK meal irrespective of treatment method applied or not. Ogbuewu *et al.* 2011) had earlier reported that, concentration of serum glucose is directly associated with energy utilization and metabolism in the animal's body.

The increase in the serum urea as the dietary inclusion level of the processed ASAK^P meal increased in relation their counterpart on the control diet might perhaps be associated with the breakdown of the body tissues, since the nitrogen and energy supplied in the diet was not accessible resulting to damaged tissues, thereby increasing the serum urea levels of the birds on the test diets. This is in conformity with the report of Omoikhoje *et al.* (2003), that urea is an indirect measure of protein utilization in the animals. The decrease in the creatinine levels in relation to those on the control diet suggests the level of muscle damage. The creatinine values in this study did not exceed the normal range of 0.6 to 2.5mg/dl reported by Taiwo and Ogunsanmi (2003), however the creatinine values (0.21 to 0.54mg/dl) of the birds fed 5-30% processed ASAK^P meal fell below the normal range, this suggest the tendency of muscle wastage, hence the

reduced weights of the birds on the test diet. This is in line with the findings of Ogbuewu *et al.* (2010), that the level of serum creatinine signals the extent of muscle damage.

The decline observed in the total cholesterol, high density lipid, low density lipid and triglyceride as the dietary inclusion level of the processed ASAK^P meal increased in the diet compared with their counterpart on the control diet do not impact negatively on the birds as the range in the values (40.30-70.74mg/dl) obtained for the total cholesterol were within the normal values (30.15-85.05mg/dl) reported by Waziri *et al.* (2010). The increase in the total protein, albumin and globulin values observed as the dietary inclusion level of the processed ASAK^P meal increased could be attributed to interference in protein synthesis from the phytochemicals in the ASAK limiting the bioavailability of protein for the animal's use.

The linear increase in the AST, ALT and ALP as the dietary inclusion levels of the processed ASAK^P meal increased in the diet of the birds indicated that the broiler chickens have a challenge in handling the digestion of the African star apple kernels irrespective of whether fed raw or processed. Khare, (2000) had earlier reported that phytate inhibit digestion of proteins by forming complexes with them. Similarly, phytic acid has a negative effect on amino acid digestibility thereby posing problems to non ruminant animals due to insufficient amount of intrinsic phytase necessary to hydrolyse the phytic complex (Turner, 2006). This phytic complex formed may have increased the enzyme activities of AST, ALT and ALP in the liver of the birds fed the processed ASAK^P meal compared to those fed the control diets.

Haematology indices: The red blood cell, packed cell volume and haemoglobin of the broilers fed the raw ASAK meal were affected whereas only the red blood cell of the broilers fed the processed ASAK^P meal was significantly affected, this implies that, the phytase enzyme may have altered the PCV and Hb values of the broilers fed the processed ASAK^P meal. The PCV values of 29.70-32.52% obtained for the birds fed processed ASAK^P meal were still within the normal range of 23-55% for healthy birds reported by Maxwell *et al.* (1990) which showed that the birds were not anaemic. PCV is an index of toxicity, any reduction in its concentration in the blood usually suggests the presence of toxic factors which has adverse effect on blood formation (Oyawoye and Ogunkunle, 1998). The haemoglobin values (8.36-9.11g/dl) obtained for the birds on the processed ASAK^P meal were within the recommended haemoglobin concentration of 7-18.6g/dl for healthy birds reported by Aiello and Mays (1998). This implies the safety of phytase for processing of ASAK meal and its inclusion in the diet of the birds. The values obtained for the red blood cells of the experimental birds may suggest nutritional adequacy of the test diets.

The values obtained for the mean cell volume (125.09-130.07fl) of the birds on the processed ASAK^P meal were within the normal range of 115-127fl reported by Swenson (1993). The MCV of the broilers fed the processed ASAK^P meal were enhanced compared to the broilers fed raw ASAK meal with lower MCV of 51.28-60.75fl affirming the suitability of phytase for the processing of ASAK meal with regard to the blood indices. The higher values of 35.01-36.64pg obtained for the MCH and 27.81-28.17 for the MCHC compared with the values of 25-27pg and 21-23g/dl reported by Swenson (1993) for the MCH and MCHC respectively for healthy birds suggest that, the birds

were not anaemic. The insignificant effect of the white blood cells observed in the birds fed the processed ASAK^P meal suggest that the phytase enzyme may have impacted positively on the immune system of the birds thus ruling out the possibility of any infection attributed from feeding the test ingredient to the birds. The birds fed the raw ASAK meal were significantly affected and accompanied with an increase in the white blood cells which may be attributed to the high concentration of the phytochemicals in the raw ASAK meal.

Nutrient retention: The decrease in the dry matter, crude protein, ether extract and soluble carbohydrate retention of the birds fed the increasing inclusion levels of the processed ASAK^P meal were as a result of the incomplete detoxification of the ANFs particularly tannins, saponins and phytate still present in the processed ASAK^P meal. Saponins have been shown to bind to the cells of the small intestine thereby affecting the absorption of nutrients across the intestinal wall (Annongu, 2012).

Histology of the liver: The severe hepatocyte degradation and ducticular inflammation observed in the liver of the birds fed beyond 10% inclusion level of processed ASAK^P meal were as a result of the undetoxified phytochemicals present in the feed. The phytic complex formed may have inhibited absorption thus responsible for the impaired histology of the liver.

The profitability of replacing maize with processed ASAK^P meal: The replacement of maize with the processed ASAK^P meal do not justify its use for all the inclusion levels, as there was a higher revenue and profit from the birds fed the control diet despite the reduction in feed cost per kilogram of the diets formulated with increasing inclusion level

of the processed ASAK^P meal. This is attributed to the poor palatability of the feed and its utilization by the birds. This implies that, the investor or farmer will have higher returns on capital investment from the use of maize compared to its replacement with the processed ASAK^P meal in the diet of the broilers.

It is concluded that a combination of soaking, boiling and phytase enzymes for the treatment of ASAK meal revealed an improvement on the growth performance characteristics and nutrient retention over the birds fed the raw ASAK meal, however the birds on the test ingredient performed poorly in relation to the birds on the control diet. The values obtained for the haematology and some serum biochemical indices were within the normal range reported by previous authors except for the serum urea, creatinine and enzyme activities of AST, ALP and ALT. The histology of the liver revealed severe impairment from 15-30% inclusion levels mainly attributed to the effect of tannins and saponins. Therefore, the pretreatment of ASAK meal using phytase enzyme at 5g/kg, preceded by soaking (12 hours) and boiling (30 minutes) may not be efficient for the reasonable detoxification of the phytochemicals in the kernels for optimum utilization in broilers.

CHAPTER SEVEN

7.0 Experiment Five: The effect of replacing maize with processed African star apple kernel meal using polyethylene glycol in broilers

7.1 Introduction

The major impediment towards increasing livestock production in the developing countries is the scarcity and inadequate availability of conventional feedstuff through out the year. In other to meet the increasing demand of livestock and its products, there is need for effective utilization of novel feed resources which do not compete with humans (Besharati *et al.*, 2008). Tannin is ranked higher among the antinutritional factors in alternative feed resources. The constrain in the use of these novel feed resources attributed to tannins could be ameliorated using tannin-binding agent such as polyethylene glycol (PEG) without compromising the nutritional value of the formulated diet (Getachew *et al.*, 2000). PEG could be administered in the water given to the animals or mixing a small amount of the feed stuff with polyethylene glycol to neutralize the effects of tannins present in the feed on the animals. The animal diet could be pelletized along with polyethylene glycol for feed stuff containing tannins (Makkar, 2003). It was observed that the digestion of carbohydrate was affected by the presence of tannins in the diet which inturn altered bioavailability of glucose to the animals (Al-mamary *et al.*, 2001). Reports by Mc Sweeney *et al.* (2001) revealed that addition of polyethylene glycol to diets containing tannins prevented the formation of complexes which eventually enhanced digestion and absorption of nutrients. There is no information on the use of polyethylene glycol for the processing of *C. albidum* kernels in the diet of broilers.

7.2 Objective

This objective of this experiment was to evaluate the detoxification potentials of polyethylene glycol in processing of African star apple kernels to enhance its utilization by the birds.

7.3 Materials and Methods

7.3.1 Experimental site

The experiment was carried out in the Poultry Unit of the Teaching and Research Farm, Landmark University, Omu-Aran, Kwara State.

7.3.2 Source of Experimental birds

A total of 210-day old Cobb breed of broiler birds were obtained from Zartech farms at Ibadan, Oyo State, Nigeria.

7.3.3 Collection of Star apple seeds

The fruits of *C. albidum* for this study were collected from the various star apple plantations in Osun state, Nigeria. The seeds were obtained from the fruit, thoroughly washed to remove the foreign materials, properly sun dried to a constant weight and were further dehulled to obtain the kernels.

7.3.4 Experimental diet

The kernels obtained from the seed were soaked for 12 hours, boiled for 30 minutes and sun dried. The sun dried kernels were milled, pretreated with polyethylene glycol at 20g/kg and placed in tightly sealed containers for seven days before inclusion in the diet. Seven experimental diets were formulated made of a corn-soy reference diet and six other diets containing processed African star apple kernel using polyethylene glycol

(ASAK^{PEG}) meal for replacing maize in the diet of the birds at graded levels of 0, 5, 10, 15, 20, 25 and 30% corresponding to diets 1, 2, 3, 4, 5, 6 and 7 respectively. The composition of the experimental diets for the broiler starter and finisher phases on as fed basis are presented on Tables 7.1 and 7.2, respectively. The proximate composition of the broiler starter phase and finisher are presented on Table 7.3 and 7.4 respectively. The proximate composition and the phytochemical analysis of the processed ASAK^{PEG} meal are presented on Table 7.5 and 7.6 respectively.

7.3.5 Management of experimental birds and data collection

A total of 210, day-old broiler chicks were used for the trial. The chicks were fed for one week on a standard broiler starter diet before the commencement of the experiment for both the starter and finisher phases. The experiment was designed as a complete randomized design. The dietary treatments contained three replicates with 10 chicks per replicate. All the birds were raised under similar management practices (brooding, lighting, feeding and watering) throughout the eight week experimental period for both the starter and finisher phase except for the diets offered that differed. The birds were given feed and water *ad-lib* and weighed weekly. Routine vaccinations and medications were carried out as at when due.

7.3.6 Data collection/response criteria

In the course of the experiment, data were collected on the performance characteristics: (a) feed consumption, (b) daily weight gain, (c) growth rate, (d) feed conversion ratio, (e) survival rate, (f) Carcass evaluation. At the end of the eight weeks study period, three

Table 7.1: Composition of the experimental diets for broiler starter processed with polyethylene glycol (Kg/100Kg)

Diets	T1	T2	T3	T4	T5	T6	T7
CKM levels %	0	5	10	15	20	25	30
Maize	56.46	53.63	50.81	47.99	45.17	42.34	39.52
CKM	0.00	2.83	5.65	8.47	11.29	14.12	16.94
SBM	38.04	38.04	38.04	38.04	38.04	38.04	38.04
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Limestone	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
V. premix	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100	100	100	100	100	100	100

Calculated analysis of the diets

Feed cost/Kg (₦)	105.98	104.88	103.78	102.67	101.57	100.43	99.37
ME kcal/kg	3132.74	3118.63	3104.57	3090.52	3076.46	3062.35	3077.62
CP (%)	22.99	22.63	22.40	22.18	21.95	21.73	21.50
Fat (%)	3.74	3.63	3.52	3.40	3.29	3.18	3.06
C. fibre (%)	4.02	3.95	3.87	3.79	3.72	3.64	3.57
Ash (%)	1.07	1.04	1.00	0.96	0.93	0.89	0.85
Calcium (%)	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Phosphorus	0.54	0.53	0.52	0.52	0.51	0.50	0.49
Lysine	1.25	1.24	1.23	1.23	1.22	1.21	1.20
Methionine	0.57	0.56	0.55	0.55	0.54	0.54	0.53
PEG/g (₦)	-	0.17	0.17	0.17	0.17	0.17	0.17

CKM= Chrysophyllum kernel meal; ME=Metabolizable energy; CP=Crude protein; C.fibre= Crude fibre; PEG=Polyethylene glycol.

Table 7.2: Composition of the experimental diets for broiler finisher processed with polyethylene glycol (Kg/100Kg)

Diets	T1	T2	T3	T4	T5	T6	T7
CKM levels	0	5	10	15	20	25	30
%							
Maize	63.91	60.71	57.52	54.32	51.13	47.93	44.74
CKM	0.00	3.20	6.39	9.59	12.78	15.98	19.17
SBM	30.19	30.19	30.19	30.19	30.19	30.19	30.19
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bone meal	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Limestone	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
V. premix	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100	100	100	100	100	100	100

Calculated analysis of the diets

Feedcost/Kg(₦)	105.98	104.88	103.78	102.67	101.57	100.43	99.37
ME kcal/kg	3153.71	3137.76	3121.86	3105.90	3089.99	3074.04	3058.14
CP (%)	20.00	19.74	19.49	19.23	18.97	18.71	18.60
Fat (%)	3.77	3.64	3.51	3.38	3.25	3.13	3.00
C. fibre (%)	3.71	3.63	3.54	3.46	3.37	3.28	3.20
Ash (%)	1.17	1.13	1.09	1.05	1.00	0.96	0.92
Calcium (%)	1.16	1.16	1.16	1.16	1.16	1.16	1.16
Phosphorus	0.65	0.64	0.63	0.62	0.61	0.60	0.59
Lysine	1.08	1.07	1.06	1.05	1.05	1.04	1.03
Methionine	0.54	0.53	0.53	0.52	0.51	0.51	0.50
PEG/g (₦)	-	0.17	0.17	0.17	0.17	0.17	0.17

CKM= Chrysophyllum kernel meal; ME=Metabolizable energy; CP=Crude protein; C.fibre= Crude fibre; PEG=Polyethylene glycol.

Table 7.3: Analysed nutrient content of experimental diets for broiler starter

	D		I	E	T	S	
Parameters	T1	T2	T3	T4	T5	T6	T7
Dry matter (%)	89.97	90.09	89.95	90.00	90.49	90.01	89.90
Crude protein (%)	23.15	22.91	22.37	22.78	22.56	23.03	22.95
Ether extract (%)	2.47	2.45	2.40	2.26	2.29	2.33	2.35
Crude fibre (%)	2.63	2.59	2.68	2.75	2.77	3.04	3.18
Ash (%)	8.51	8.49	8.56	8.54	8.59	8.56	8.61
NFE (%)	53.21	53.65	53.94	53.67	54.28	53.05	52.81

Table 7.4: Analysed nutrient content of experimental diets for broiler finisher

	D		I	E	T	S	
Parameters	T1	T2	T3	T4	T5	T6	T7
Dry matter (%)	88.88	89.16	89.30	89.32	89.30	89.15	89.26
Crude protein (%)	20.56	21.07	20.41	21.01	20.77	21.11	20.95
Ether extract (%)	2.32	2.30	2.19	2.22	2.18	2.14	2.09
Crude fibre (%)	2.17	2.43	2.65	3.01	3.19	3.28	3.36
Ash (%)	6.92	7.10	7.24	7.86	7.59	7.91	8.02
NFE (%)	56.91	56.25	56.81	55.22	55.57	54.71	54.84
Gross energy (kcal/g)	1,083.51	992.95	802.96	719.16	623.33	479.49	435.79

Table 7.5: Proximate composition of processed African star apple kernel meal using polyethylene glycol

Parameters	%
Dry matter	88.43
Crude protein	11.12
Ether extract	1.78
Ash	4.48
Crude fibre	5.92
Soluble carbohydrate	65.14
Gross energy (kcal/g)	3.79

Table 7.6: Phytochemical analysis of proceesed African star apple kernel using polyethylene glycol meal

Parameters	mg/kg
Saponin	1.98
Phytate	0.37
Tannins	8.37
Oxalate	0.44
Glycoside	2.91×10^{-2}

birds per treatment were randomly selected based on the group average and were weighed, slaughtered and eviscerated for carcass evaluation. The birds were fasted for 12 hours before slaughtering, bled and the slaughter weight taken. The birds were also defeathered manually using hot water and eviscerated. The live weight and carcass weight were recorded. The dressing percentage was calculated. Organ weights and the major primal carcass parts were expressed as percentages of the live weight.

7.3.7 Nutrient digestibility trial

The study on apparent nutrient digestibility was carried out at the end of the 8th week of the experimental period. Three birds per treatment were randomly selected and transferred to clean metabolic cages and fed the corresponding treatment diets. The trial lasted for eight days. The first four days were considered as adaptation period and the last four days as experimental period. Records of feed intake and faeces voided were taken during the last four days. The droppings were oven dried, bulked and representative samples were taken for chemical analysis. The samples were analyzed for proximate composition according to the methods of AOAC (1990).

$$\text{Apparent Nutrient Retention} = \frac{\text{Nutrient intake} - \text{Nutrient in faeces}}{\text{Nutrient intake}} \times 100$$

7.3.8 Serum biochemical and haematology analysis

At the end of the experiment, one broiler per replicate in all the treatments was taken at random and blood collected by decapitation. Blood for serum biochemical indices was collected in bottles without EDTA for the analysis of the serum biochemical parameters of (a) blood electrolytes: Ca, Na, K, Cl, and bicarbonate, (b) blood glucose level, (c) total

protein, (d) albumin, (e) globulin, (f) albumin/globulin ratio (g) total cholesterol (h) creatinine (i) urea (j) lipid profile (HDL and LDL), (k) transaminase activities- AST, ALT and ALP. The samples were spun in the centrifuge at 3,000 rpm and the clearer portion (serum) decanted after centrifugation into another set of plain bottles and were placed in an ice bath and taken to the laboratory.

The blood samples for haematology parameters were pretreated with ethylene diamine tetra-acetate (EDTA), an anti-coagulant and were placed in the refrigerator (4°C) immediately before taken to the laboratory. Haematology indices examined include white blood cell (WBC) and its differential counts (neutrophils, lymphocyte, monocyte, eosinophil and basophils), red blood cell (RBC), packed Cell Volume (PCV), haemoglobin (Hb). The mean cell volume (MCV), mean cell haemoglobin (MCH) and the mean cell haemoglobin concentration (MCHC) were calculated from the values of the RBC, PCV and Hb respectively.

$$\text{MCV} = \frac{\text{PCV}}{\text{RBC}} \times 10 \qquad \text{MCH} = \frac{\text{Hb}}{\text{RBC}} \times 10 \qquad \text{MCHC} = \frac{\text{Hb}}{\text{PCV}} \times 100$$

7.3.9 Histology of the liver

Three birds were selected per treatment at the end of the feeding trial and sacrificed to obtain the liver. Sections were obtained from the anterior lobe of the liver, preserved in 90% saline + 10% formalin solution. The liver tissues from each replicate were processed for histological studies using haematoxylin and eosin stains. Photomicrographs were taken using a digital microscope with a magnification of 400. The analysis was carried out at the histopathological laboratory of Central Research Laboratory, Tanke, Ilorin.

7.4 Statistical analysis

Data collected on the response criteria were subjected to analysis of variance according to the completely randomized design model and differences between treatment means were separated using the Duncan's multiple range test (Steel and Torrie, 1980).

7.5 Results

7.5.1 Growth performance characteristics of broilers fed processed African star apple kernel meal using polyethylene glycol

Table 7.7 presents the growth performance characteristics of the broilers fed the processed African star apple kernel using polyethylene glycol (ASAK^{PEG}) meal. The growth performance characteristics of the broilers fed the processed ASAK^{PEG} meal were enhanced compared with the birds fed the raw ASAK meal, however there was a corresponding decrease in the growth performance characteristics of the birds as the dietary level of the processed ASAK^{PEG} meal increased in the diet in relation to those on the control diet. The final live weights, average daily weight gains and the feed intake values of the birds significantly ($p < 0.05$) decreased as the processed ASAK^{PEG} meal increased in the diet of the birds. The feed conversion ratio favoured the birds on the control diet compared to those on the processed ASAK^{PEG} meal. There was an increased poor feed conversion ratio as the processed ASAK^{PEG} meal increased in the diets. The results of the cost per kg weight gains also followed the same trend with the feed conversion ratios. There was a decrease in the feed cost N/kg of the birds as the dietary replacement of maize with the processed ASAK^{PEG} meal increased in the diets of the birds. The percent mortality of the birds was not significantly ($p > 0.05$) affected by the dietary inclusion of the processed ASAK^{PEG} meal in the diet of the birds.

Table 7.7: Growth performance characteristics of broilers fed processed African star apple kernel meal using polyethylene glycol

Parameters	T1	T2	T3	T4	T5	T6	T7	SEM	Pvalue
	(0%)	(5%)	(10%)	(15%)	(20%)	(25%)	(30%)		
Initial live weight (g/bird)	128.13	128.13	128.13	128.13	128.13	128.13	128.13	-	-
Final live weights (g/bird)	2023.13 ^a	1323.09 ^b	863.10 ^c	733.11 ^d	698.11 ^e	683.11 ^f	673.10 ^g	3.17	0.0001
Daily weight gains (g/bird/day)	40.31 ^a	25.42 ^b	15.63 ^c	12.87 ^d	12.12 ^e	11.80 ^f	11.59 ^g	0.06	0.0001
Feed intake (g/bird/day)	118.29 ^a	95.39 ^b	92.13 ^c	79.30 ^d	75.72 ^e	73.15 ^f	70.48 ^g	0.79	0.0001
Feed conversion ratio	2.93 ^e	3.75 ^d	5.89 ^c	6.16 ^{ab}	6.24 ^a	6.19 ^a	6.08 ^b	0.04	0.0001
Cost per kg weight gain (₦)	310.52 ^e	393.65 ^d	611.26 ^c	632.78 ^a	634.13 ^a	621.99 ^b	604.17 ^c	4.97	0.0001
Cost of feed/kg (₦)	105.98	104.88	103.78	102.67	101.57	100.43	99.37	-	0.0001
% Mortality	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-

SEM= Standard error of mean;LOS= Level of Significance,*=P<0.05;^{a,b,c,d,e,f,g}Means with different superscript along the same rows are significant (P<0.05);NS=Non Significant (P>0.05)

The phytochemical dietary intake of the processed ASAK^{PEG} meal is presented on Table 7.8. The incomplete detoxification of the phytochemicals in the diets further attest to the poor growth performance characteristics observed in the birds fed from 15-30% inclusion level of the processed ASAK^{PEG} meal.

7.5.2 Carcass characteristics of broilers fed processed African star apple kernel meal using polyethylene glycol

The carcass characteristics of broilers fed processed ASAK^{PEG} meal is presented on Table 7.9. The result of the carcass characteristics of the birds fed the processed ASAK^{PEG} meal were fairer than when fed raw to the birds, though far below the optimum for the birds on the control diet. The differences in the live weights, carcass weights and the dressing percentage were significantly ($p < 0.05$) affected across the treatment groups fed the processed ASAK^{PEG} meal. There was a corresponding decrease in the live weights, carcass weights and dressing percentage of the birds as the polyethylene glycol processed ASAK increased in the diets of the birds. The weights of the carcass components for the neck, wings, thigh, drumstick, shank, breast, back expressed as percentages of the live weights were lower in all the dietary groups fed the processed ASAK^{PEG} meal compared with the control group except the head that was lower in the control group. The weights of the heart, liver, kidney, proventriculus and the gizzard were significantly ($p < 0.05$) affected except the lungs that was not significantly ($p > 0.05$) affected. There was a significant ($p < 0.05$) decrease in the lengths of the small and large intestines as dietary replacement of corn with processed ASAK^{PEG} meal increased in the diets of the birds compared with birds on the control diet.

Table 7.8: Dietary phytochemical intake of broilers fed processed African star apple kernel meal using polyethylene glycol

Parameters	T1	T2	T3	T4	T5	T6	T7	SEM	P value
	(0%)	(5%)	(10%)	(15%)	(20%)	(25%)	(30%)		
Saponins (mg/bird/day)	0.00 ^g	0.60 ^f	1.17 ^e	1.51 ^d	1.92 ^c	2.31 ^b	2.68 ^a	0.51	0.0001
Phytate (mg/bird/day)	0.00 ^g	0.11 ^f	0.22 ^e	0.28 ^d	0.35 ^c	0.43 ^b	0.49 ^a	4.28	0.0001
Tannins (mg/bird/day)	0.00 ^g	2.55 ^f	4.93 ^e	6.37 ^d	8.10 ^c	9.78 ^b	11.31 ^a	3.81	0.0001
Oxalate (mg/bird/day)	0.00 ^g	0.14 ^f	0.26 ^e	0.34 ^d	0.43 ^c	0.52 ^b	0.60 ^a	0.03	0.0001
Glycoside (mg/bird/day)	0.00 ^g	8.9x10 ^{-3f}	1.7x10 ^{-2e}	2.21x10 ^{-2d}	2.82x10 ^{-2c}	3.4x10 ^{-2b}	3.93x10 ^{-2a}	0.03	0.0001

Table 7.9: Carcass characteristics of broilers fed processed African star apple kernel meal using polyethylene glycol

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Live weight (g/bird)	2023.13 ^a	1323.09 ^b	863.10 ^c	733.11 ^d	698.11 ^e	683.11 ^f	673.10 ^g	3.17	0.0001
Carcass weights (g/bird)	1320.12 ^a	852.40 ^b	515.20 ^c	425.10 ^d	402.70 ^e	387.99 ^f	342.80 ^g	5.90	0.0001
Dressing percentage (%)	65.25 ^a	64.42 ^b	59.69 ^c	57.98 ^d	57.68 ^d	56.79 ^e	50.92 ^e	0.32	0.0001
Prime cut and Organ weights expressed as % of live weight									0.0001
Head	2.44 ^f	3.20 ^e	3.35 ^d	3.84 ^a	3.68 ^b	3.53 ^c	3.53 ^c	0.02	0.0001
Thigh	10.89 ^a	10.15 ^b	10.06 ^c	8.51 ^d	8.46 ^d	8.31 ^e	8.09 ^f	0.02	0.0001
Breast	20.97 ^a	18.53 ^b	17.13 ^c	16.23 ^d	15.62 ^e	15.64 ^e	13.29 ^f	0.05	0.0001
Wings	7.72 ^b	7.84 ^a	7.69 ^b	7.42 ^c	7.43 ^c	7.05 ^d	6.41 ^e	0.03	0.0001
Shank	4.26 ^c	4.57 ^a	4.26 ^c	4.44 ^b	4.19 ^d	4.05 ^e	3.84 ^f	0.01	0.0001
Neck	5.46 ^b	5.53 ^a	5.36 ^d	5.42 ^c	5.18 ^e	5.06 ^f	4.65 ^g	0.02	0.0001
Drumstick	8.63 ^a	8.16 ^c	8.14 ^c	8.28 ^b	8.03 ^c	7.58 ^d	6.72 ^e	0.06	0.0001
Back	11.22 ^b	11.35 ^a	9.05 ^c	9.75 ^d	9.64 ^e	9.10 ^f	8.63 ^g	0.04	0.0001
Heart	0.35 ^c	0.35 ^c	0.35 ^c	0.37 ^a	0.36 ^b	0.35 ^c	0.35 ^c	0.01	0.0036
Lungs	0.54	0.53	0.56	0.57	0.55	0.54	0.54	0.02	0.5858
Liver	3.09 ^a	2.39 ^e	2.52 ^d	2.60 ^c	2.64 ^b	2.59 ^c	2.62 ^{bc}	0.02	0.0001
Kidney	0.54 ^a	0.48 ^b	0.45 ^c	0.43 ^{cd}	0.40 ^d	0.36 ^e	0.35 ^e	0.02	0.0001
Proventriculus	0.40 ^d	0.51 ^{bc}	0.55 ^a	0.56 ^a	0.54 ^a	0.52 ^b	0.49 ^c	0.01	0.0001
Gizzard	1.78 ^e	2.59 ^d	3.09 ^a	3.08 ^a	3.06 ^a	3.01 ^b	2.90 ^c	0.02	0.0001
Small intestine length (cm)	143.50 ^a	130.72 ^b	104.09 ^c	78.22 ^d	54.55 ^e	48.44 ^e	39.04 ^f	4.29	0.0001
Large intestine length (cm)	68.95 ^a	62.11 ^b	53.62 ^c	40.19 ^d	26.87 ^e	25.81 ^e	21.29 ^f	2.11	0.0001

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d,e,f,g}Means with different superscript along the same rows are significant (P<0.05);NS=Non Significant (P>0.05)

7.5.3 Serum biochemical indices of broilers fed processed African star apple kernel meal using polyethylene glycol

Table 7.10 presents the serum biochemical indices of the broiler chickens fed processed ASAK^{PEG} meal. The pattern in the values of the serum biochemical indices of the birds fed the processed ASAK^{PEG} meal were fairer in relation to the birds fed the increasing inclusion level of the raw ASAK meal for replacing maize in the diet of the birds. There was a significant ($p<0.05$) linear increase in the serum potassium levels as the processed ASAK^{PEG} meal increased in the diet of the birds. The patterns in the serum sodium and calcium levels were irregular. The blood glucose and serum urea levels significantly ($p<0.05$) increased with an increasing inclusion level of the processed ASAK^{PEG} meal in the diet of the birds. There was a significant ($p<0.05$) decrease in the creatinine levels of the birds as the inclusion level of the processed ASAK^{PEG} meal increased in the diet of the birds.

There were significant ($p<0.05$) differences for the total cholesterol, high density lipid (HDL) cholesterol, low density lipid (LDL) cholesterol and triglyceride respectively with a linear decrease in their values as the dietary inclusion level of the processed ASAK^{PEG} meal increased in the diet of the birds. The serum total protein, albumin and globulin were significantly ($p<0.05$) affected and accompanied by a corresponding increase as the dietary inclusion level of the processed ASAK^{PEG} meal increased in the diet of the birds. The serum aspartate transaminase, alanine transaminase and alkaline phosphate levels of the birds on the processed ASAK^{PEG} meal were significantly ($p<0.05$) affected. The trend in the serum alanine transaminase were irregular as the birds on the control diet had higher value compared with its counterpart fed 5, 10, 15 and 20% processed ASAK^{PEG} meal but lower than those fed 25 and 30% inclusion levels. There were

Table 7.10: Serum biochemical indices of broilers fed processed African star apple kernel meal using polyethylene glycol

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Glucose (mg/dl)	91.04 ^d	97.31 ^{cd}	101.25 ^{cd}	105.01 ^{bc}	108.21 ^{bc}	114.00 ^{ab}	121.23 ^a	2.01	0.0005
Calcium (ppm)	10.59 ^{ab}	10.78 ^a	10.58 ^{ab}	10.73 ^a	10.55 ^{ab}	9.51 ^{bc}	9.04 ^c	0.58	0.0137
Sodium (mEq/l)	105.35 ^{ab}	112.82 ^a	111.30 ^{ab}	105.65 ^{ab}	101.92 ^{ab}	108.56 ^{ab}	100.05 ^b	2.01	0.1685
Potassium (mg/dl)	16.99 ^d	19.13 ^c	21.00 ^b	19.98 ^c	22.78 ^{ab}	23.66 ^a	23.92 ^a	1.21	0.0001
Urea (mg/dl)	25.85 ^e	33.99 ^d	37.95 ^c	39.62 ^{bc}	41.23 ^b	42.77 ^{ab}	44.64 ^a	2.20	0.0001
Creatinine (mg/ml)	0.68 ^a	0.49 ^b	0.44 ^c	0.37 ^d	0.32 ^e	0.25 ^f	0.20 ^g	0.02	0.0001
Total cholesterol (mg/dl)	66.67 ^a	62.33 ^{ab}	59.24 ^b	52.38 ^c	46.80 ^d	42.02 ^{de}	37.93 ^e	3.04	0.0001
HDL Cholesterol (mg/dl)	11.08 ^a	10.34 ^{ab}	9.82 ^b	8.65 ^c	7.70 ^d	6.89 ^{de}	6.19 ^e	0.51	0.0001
LDL Cholesterol (mg/dl)	54.12 ^a	50.51 ^{ab}	47.94 ^b	42.25 ^c	37.62 ^d	33.66 ^{de}	30.26 ^e	2.52	0.0001
Triglyceride (mg/dl)	12.26 ^a	9.74 ^b	9.01 ^{bc}	8.66 ^c	8.29 ^c	6.85 ^d	5.62 ^e	0.50	0.0001
Total protein (mg/dl)	14.17 ^c	12.45 ^d	13.05 ^{cd}	14.48 ^c	14.61 ^c	19.99 ^b	22.87 ^a	0.93	0.0001
Albumin (g/l)	0.29 ^b	0.22 ^c	0.28 ^b	0.28 ^b	0.28 ^b	0.31 ^{ab}	0.32 ^a	0.02	0.0002
Globulin (g/l)	13.87 ^{cd}	12.22 ^d	12.77 ^{cd}	14.19 ^c	14.32 ^c	19.67 ^b	22.54 ^a	0.91	0.0001
Albumin-Globulin ratio	0.02	0.01	0.02	0.01	0.01	0.01	0.01	-	0.0001
Aspartate Aminotransaminase (u/l)	10.25 ^e	22.08 ^c	18.71 ^d	20.64 ^{cd}	24.48 ^b	25.92 ^{ab}	27.36 ^a	1.25	0.0001
Alanine Aminotransaminase (u/l)	11.17 ^c	8.25 ^e	8.45 ^e	9.79 ^{de}	10.36 ^d	18.62 ^b	24.76 ^a	0.84	0.0001
Alkaline phosphate (u/l)	0.88 ^d	1.76 ^c	2.20 ^b	2.64 ^a	2.64 ^a	2.58 ^a	2.64 ^a	0.13	0.0001

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05,^{a,b,c,d,e,f}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant (P>0.05); HDL=High Density Lipid;LDL=Lipid Density Lipid.

increasing AST and ALP activities in the birds as the inclusion level of the processed ASAK^{PEG} meal increased in the diet of the birds compared with those on the control diet.

7.5.4 Haematology indices of broilers fed processed African star apple kernel meal using polyethylene glycol

The haematology indices of broilers fed processed ASAK^{PEG} meal is presented on Table 7.11. The red blood cell of the birds fed the processed ASAK^{PEG} meal was significantly ($p<0.05$) affected, there was an increase in the red blood cells as the processed ASAK^{PEG} meal increased in the diet of the birds compared with the birds on the control diet. The haemoglobin and the packed cell volume were not significantly ($p>0.05$) affected by the processed ASAK^{PEG} meal unlike in the birds that were fed the raw ASAK meal, although there was a linear increase in the values but not statistically significant. There were significant ($p<0.05$) differences in the mean cell volume, mean cell haemoglobin and mean cell haemoglobin concentration with a corresponding decrease as the processed ASAK^{PEG} meal increased in the diet. The values obtained were lower compared with the birds on the control diet. The white blood cell of the broilers on the processed ASAK^{PEG} meal were not significantly ($p>0.05$) affected, although there was a linear increase in the white blood cells as the processed ASAK^{PEG} meal increased in the diet of the birds unlike in the birds fed the raw ASAK meal that were significantly ($p<0.05$) affected.

Table 7.11: Haematology indices of broilers fed processed African star apple kernel meal using polyethylene glycol

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Red Blood Cell (x 10 ¹² /l)	2.37 ^c	2.38 ^b	2.45 ^{ab}	2.50 ^{ab}	2.58 ^{ab}	2.65 ^{ab}	2.71 ^a	0.14	0.0680
Haemoglobin (g/dl)	8.72	8.72	8.91	9.05	9.21	9.31	9.50	0.51	0.4674
Packed Cell Volume (%)	30.76	30.96	31.65	32.43	32.91	33.47	33.90	1.84	0.3143
Mean Cell Volume (fl)	129.84 ^{ab}	130.10 ^a	128.67 ^c	129.37 ^b	127.25 ^d	126.00 ^e	124.96 ^f	0.33	0.0001
Mean Cell Haemoglobin (pg)	36.79 ^a	36.63 ^b	36.26 ^c	36.12 ^c	35.60 ^d	35.04 ^e	35.02 ^d	0.08	0.0001
Mean Cell Hae. Conc (g/dl)	28.33 ^a	28.16 ^b	28.18 ^b	27.92 ^e	27.97 ^d	27.81 ^f	28.02 ^c	0.01	0.0001
White Blood Cell (x 10 ⁹ /l)	239.22	240.69	244.52	246.47	247.65	249.50	251.17	2.12	0.9310

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d,e,f}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant (P>0.05);Mean Cell Hae. Conc= Mean Cell Haemoglobin Concentration.

7.5.5 Nutrient retention of broilers fed processed African star apple kernel meal using polyethylene glycol

Table 7.12 presents the nutrient retention of broilers fed processed ASAK^{PEG} meal. The nutrient retention of the dry matter, crude protein, ether extract and soluble carbohydrate were significantly ($p < 0.05$) affected with a linear decrease as the processed ASAK^{PEG} meal increased in the diet of the birds in relation to the birds on the control diet. The trend in the nutrient retention of the birds fed the processed ASAK^{PEG} meal were fairer compared to their counterpart fed the raw ASAK meal.

7.5.6 Histology of the liver of broilers fed processed African star apple kernel meal using polyethylene glycol

The photomicrographs showing the liver of the broilers processed ASAK^{PEG} meal are presented on plates 1-7. The sections of the liver revealed a distortion in the architecture of the liver as the processed ASAK^{PEG} meal increased in the diet of the birds. The birds on the control diet had normal hepatocyte. Mild hepatocyte perturbation was observed in the liver of the birds fed 5-25% processed ASAK^{PEG} meal. An increase in the inclusion level of the processed ASAK^{PEG} meal from 25 to 30% led to severe hepatocyte perturbation.

7.5.7 Profitability of broilers fed processed African star apple kernel meal for dietary replacement of maize

Table 7.13 shows the profitability of replacing maize with processed ASAK^{PEG} meal in broilers. The total feed intake, total weight gain and total cost of production per bird were higher in the birds fed the control diet, although there was a decrease in the feed cost per kg as the replacement of maize with processed ASAK^{PEG} meal increased in the diet. The reduction in the prices could not inturn enhance the profit on investment.

Table 7.12: Nutrient retention of broilers fed processed African star apple kernel meal using polyethylene glycol

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Dry matter	87.96 ^a	72.61 ^b	71.78 ^b	62.30 ^c	58.80 ^c	57.52 ^c	56.49 ^c	3.33	0.0002
Crude protein	86.98 ^a	80.56 ^b	78.33 ^{bc}	76.23 ^{bc}	74.40 ^{cd}	72.05 ^d	70.43 ^d	2.07	0.0565
Ether extract	82.37 ^a	71.39 ^b	61.05 ^{bc}	58.52 ^{bc}	57.72 ^{bc}	55.67 ^c	48.85 ^d	3.42	0.0358
Soluble carbohydrate	63.19 ^a	59.55 ^b	55.83 ^c	52.99 ^d	52.95 ^d	51.10 ^e	49.21 ^f	0.63	0.0001

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d} Means with different superscript along the same rows are significantly (P<0.05).

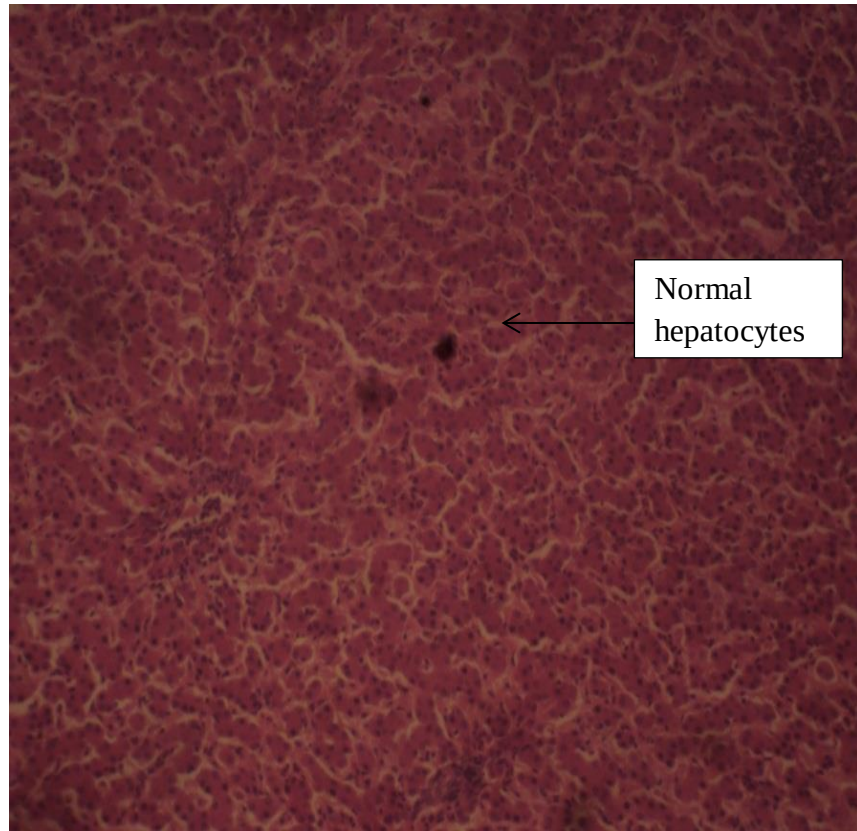


Plate i - Photomicrograph showing the liver of broilers fed the control diet
H/E Stain Mag. X400

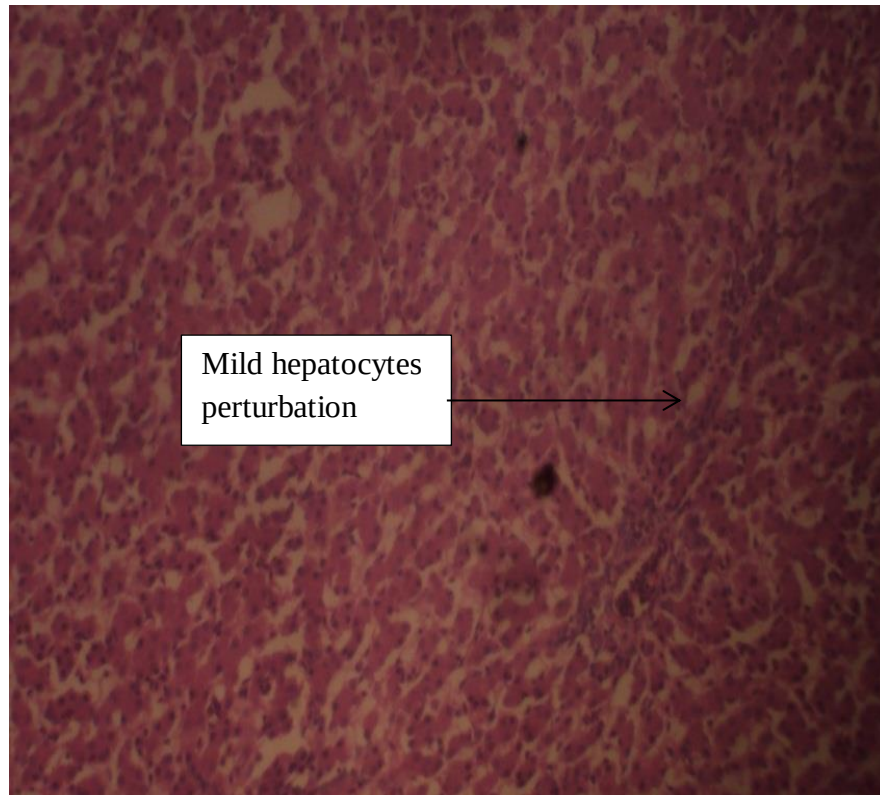


Plate ii - Photomicrograph showing the liver of broilers fed 5% processed African star apple kernel meal using polyethylene glycol

H/E Stain Mag. X400

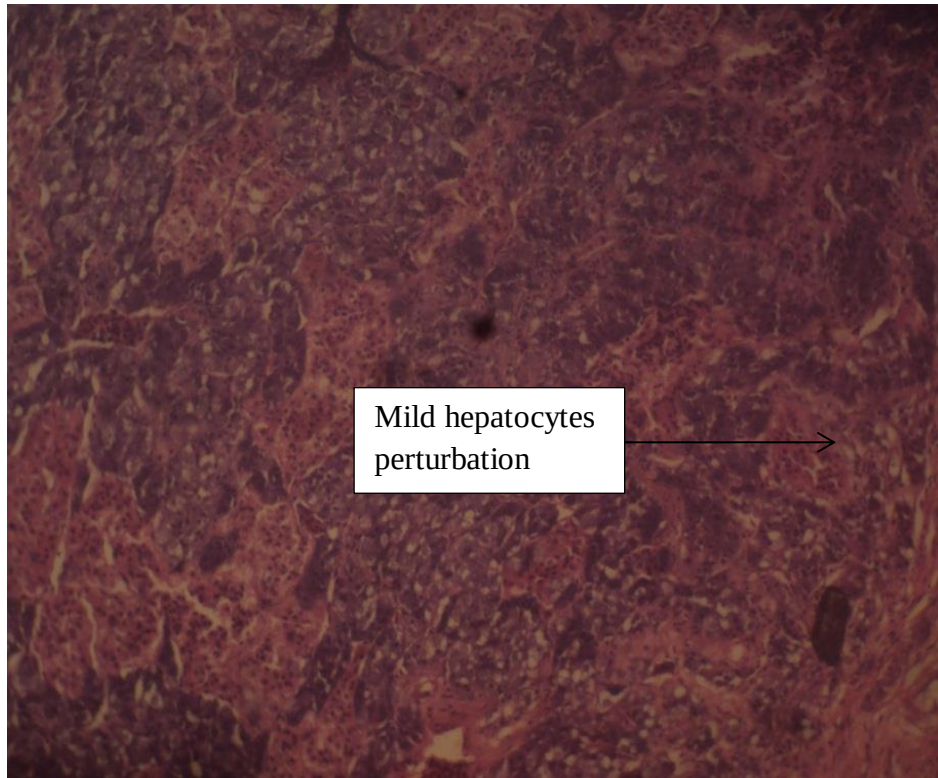


Plate iii: Photomicrograph showing the liver of broilers fed 10% processed African star apple kernel meal using polyethylene glycol

H/E Stain Mag. X400

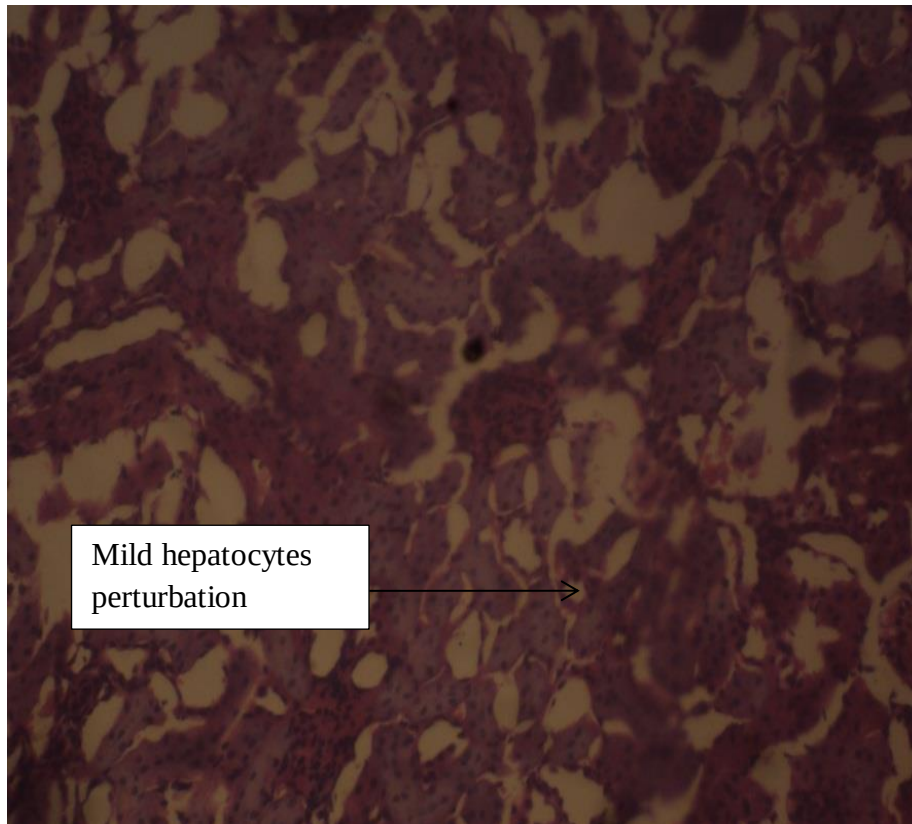


Plate iv: Photomicrograph showing the liver of broilers fed 15% processed African star apple kernel using meal polyethylene glycol

H/E Stain Mag. X400

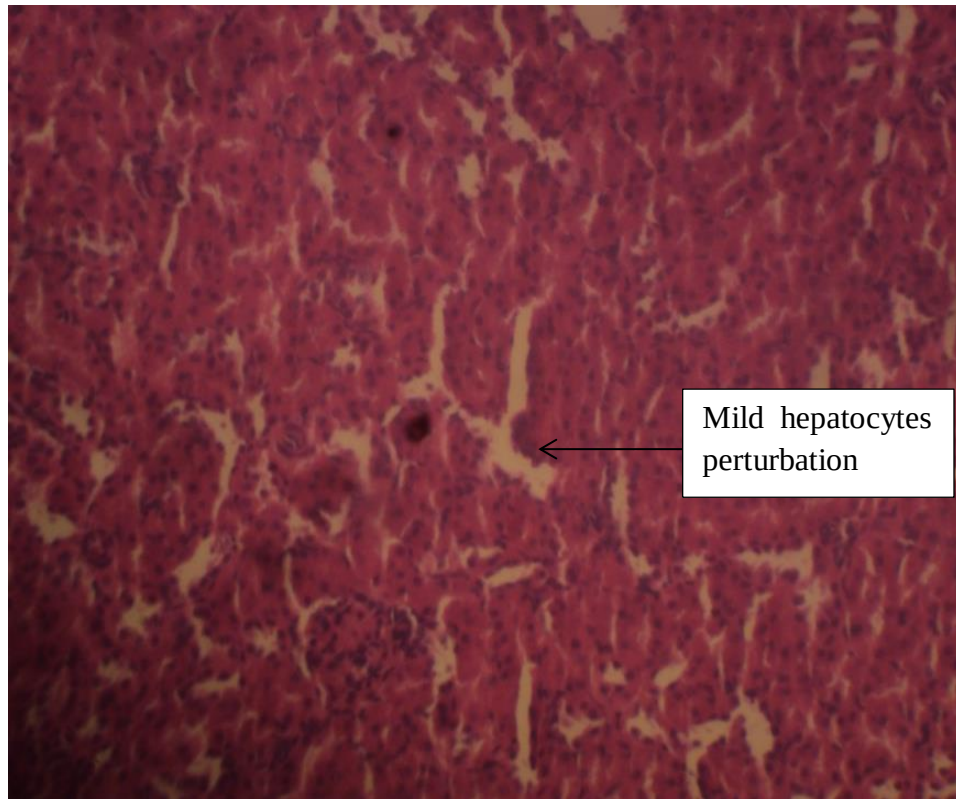


Plate v: Photomicrograph showing the liver of broilers fed 20% processed African star apple kernel meal using polyethylene glycol

H/E Stain Mag. X400

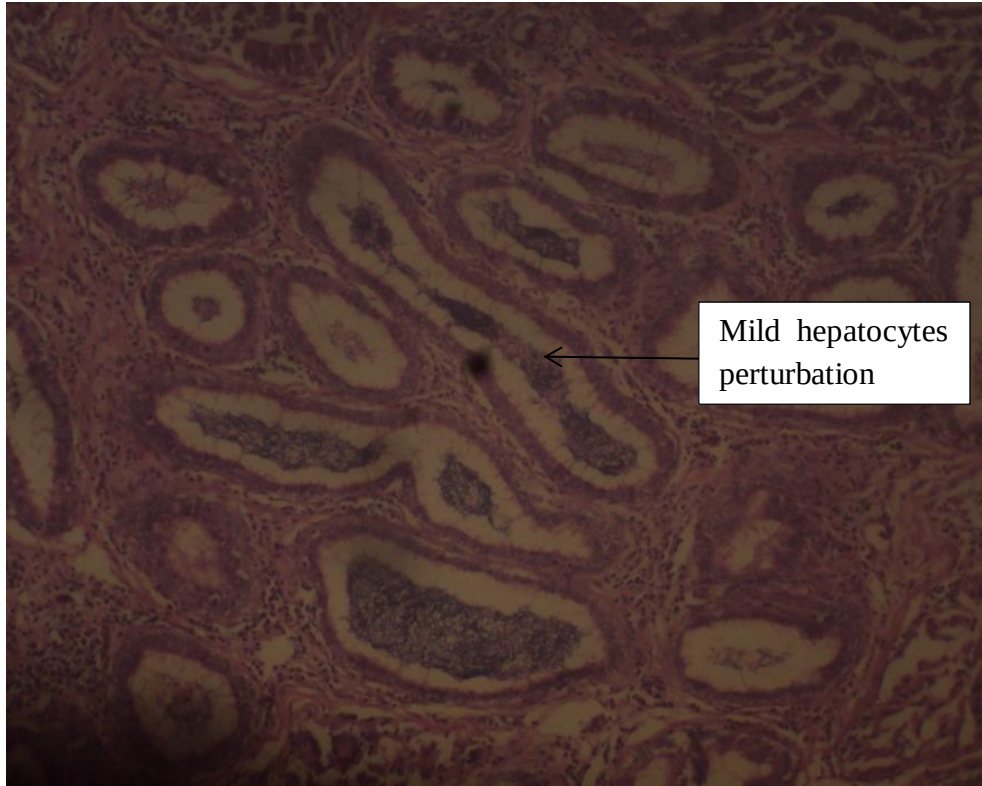


Plate vi: Photomicrograph showing the liver broilers fed 25% processed African star apple kernel meal using polyethylene glycol

H/E Stain Mag. X400

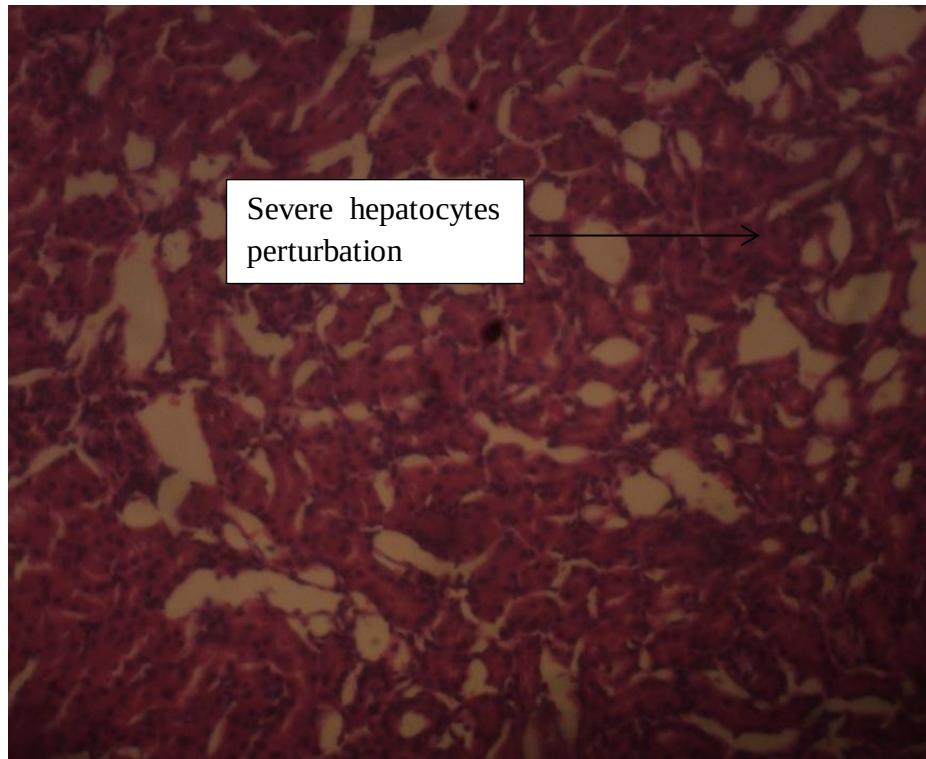


Plate vii: Photomicrograph showing the liver of broilers fed 30% processed African star apple kernel meal using polyethylene glycol

H/E Stain Mag. X400

The highest profit was obtained from broilers fed the control diet and the lowest obtained in the group fed 30% inclusion level of processed ASAK^{PEG} meal. There was a mild improvement in the birds fed the processed ASAK^{PEG} meal over the group fed the raw ASAK meal. The returns on investment for the dietary treatment of 10-30% processed ASAK^{PEG} meal may not justify the total cost of production.

Table 7.13: Profitability of broilers fed processed African star apple kernel meal using polyethylene glycol for dietary replacement of maize

Parameters	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)	T7 (30%)	SEM	Pvalue
Total feed intake (g/bird)	5,559.63 ^a	4,483.33 ^b	4,330.11 ^c	3,727.10 ^d	3,558.84 ^e	3,438.05 ^f	3,312.56 ^g	4.35	0.0001
Total weight gain (g/bird)	1,895.00 ^a	1,194.96 ^b	734.97 ^c	604.98 ^d	569.98 ^e	554.98 ^f	544.97 ^g	3.17	0.0001
Final live weight (g/bird)	2,023.13 ^a	1,323.09 ^b	863.10 ^c	733.11 ^d	698.11 ^e	683.11 ^f	673.10 ^g	3.17	0.0001
Cost of feed/kg (₦)	106.00	104.30	102.70	101.10	99.40	97.70	96.10	-	-
(a) Cost of DOC/Medication	160.00	160.00	160.00	160.00	160.00	160.00	160.00	-	-
(b)Cost of feeding /bird = FC x TFI (₦)	589.21	470.21	449.38	382.66	361.47	345.28	329.17	-	-
Total cost of production/bird = (a+b) (₦)	749.21	630.21	609.38	542.66	521.47	505.28	489.17	-	-
Revenue = Fnwt x sales/kg	1,719.66	1,124.63	733.64	623.14	593.39	580.64	572.14	-	-
Profit (₦) = Revenue – TC	970.45	494.41	124.26	80.48	71.92	75.36	82.97	-	-
Sale's price/kg (₦)	850	850	850	850	850	850	850	-	-

SEM= Standard error of mean;LOS= Level of Significance;*=P<0.05;^{a,b,c,d}Means with different superscript along the same rows are significantly (P<0.05);NS=Non Significant. DOC= Day Old Chicks; FC= Feed Cost; TFI= Total Feed Intake; Fnwt=Final live weight; TC=Total cost of production; Naira=₦

7.6 Discussion

Growth performance characteristics: The decline in the growth performance characteristics (final live weight, daily weight gains and feed intake) of broilers fed beyond 5% inclusion level of the processed ASAK^{PEG} meal compared with their counterpart fed the control diet even though superior to the broilers fed the raw ASAK meal may partly be attributed to the presence of tannins in the processed ASAK^{PEG} meal even after processing. Douglas *et al.* (1993) earlier reported that tannins reduces feed intake due to reduced palatability. The pretreatment of the ASAK with polyethylene glycol (PEG) may have enhanced the feed intake of the broilers fed the processed ASAK^{PEG} meal compared with their counterpart fed raw ASAK meal. In this study, tannins remain a serious challenge to the use of ASAK for broilers diet. The phytochemical analysis of the ASAK meal revealed tannins to be quantitatively higher than other phytochemicals, while there was an appreciable decline in the initial physical treatment of soaking and boiling that preceded the treatment of the raw ASAK meal for saponins, phytate, glycoside, there was rather an increase in the tannin content (Table 3.15). This severely impacted negatively on the growth performance characteristics of the broilers fed the processed ASAK^{PEG} meal. This assertion is in line with the reports of Elkin *et al.* (1990) who reported depressed growth rate and reduced feed efficiency in poultry fed diets containing tannins. The non availability of the nutrients to the animal's body impacted negatively on the feed conversion ratio as the dietary inclusion of processed ASAK^{PEG} meal increased. The increasing cost per kg weight gains as the processed ASAK^{PEG} meal increased in the diet despite the reduction in the feed cost were

as a result of the poor feed conversion ratio, as the birds will have to consume more to attain a kilogram in body weight.

Carcass characteristics: The decrease in the live weights, dressing percentage, carcass weights and its components as the processed ASAK^{PEG} meal inclusion levels increased in the diets of the birds were as a result of the reduced final live weights and poor feed conversion ratio of the birds fed 10 to 30% processed ASAK^{PEG} meal inclusion levels. The effect of the processed ASAK^{PEG} meal on the internal organs of the heart, liver, kidney and proventriculus except for the lungs could be as a result of the relative weights of the birds when these organs were expressed as percentages of the live weights of the birds due to the effect of the phytochemicals on the performance characteristics which were not reasonably alleviated by the absorbent (PEG) in the animal's body.

Serum biochemical indices: The increase in the serum potassium levels as the processed ASAK^{PEG} meal increased in the diet of the birds were ascribed to the appreciable mineral content in the seed. This corroborates the findings of Ukana *et al.* (2012), who reported the high mineral content in the star apple seed. The irregular trend observed for the sodium and calcium values as the processed ASAK^{PEG} meal increased in the diet do not suggest nutritional inadequacy as the birds fed 10-30% processed ASAK^{PEG} meal were statistically similar with those fed the control diet. The elevation in the blood glucose of the birds fed the processed ASAK^{PEG} meal over those on the control diet might perhaps be ascribed to the influence of the ASAK meal in the diet which probably increased the energy content and enhanced the glucose level in the birds. A similar effect in the serum blood glucose was also observed in the broilers fed the raw ASAK meal suggesting that, the blood glucose of broilers would be elevated when fed ASAK irrespective of treatment

method applied or not. Ogbuewu *et al.* (2011) had earlier reported that, the concentration of serum glucose is directly associated with energy utilization and metabolism in the animal's body.

The increase in the serum urea as the dietary inclusion level of the processed ASAK^{PEG} meal increased in relation to their counterpart on the control diet might perhaps be associated with the breakdown of the body tissues, since the nitrogen and energy supplied in the diet was not accessible resulting to damaged tissues, thereby increasing the serum urea levels of the birds on the test diets. This is in conformity with the report of Omoikhoje *et al.* (2003), that urea is an indirect measure of protein utilization in the animals. The decrease in the creatinine levels in relation to those on the control diet suggest the level of muscle damage. The creatinine values in this study did not exceed the normal range of 0.6 to 2.5mg/dl reported by Taiwo and Ogunsanmi (2003), however the creatinine values (0.20 to 0.49mg/dl) of the birds fed 5-30% processed ASAK^{PEG} meal fell below the normal range, this suggest the tendency of muscle wastage, hence the reduced weights of the birds on the test diet. This is in line with the findings of Ogbuewu *et al.* (2010), that the level of serum creatinine signals the extent of muscle damage.

The decline in the total cholesterol, high density lipid, low density lipid and triglyceride as the dietary inclusion level of the processed ASAK^{PEG} meal increased in the diet compared with their counterpart on the control diet do not impact negatively on the birds as the range in the values (40.30-70.74mg/dl) obtained for the total cholesterol were within the normal values (30.15-85.05mg/dl) reported by Waziri *et al.* (2010). In a related study, Imik and Gunlu (2011) reported that, the feed additives used in detoxifying tannins from sorghum may act differently on lipid digestion. Complexes formed between

PEG and tannins may probably tie hydrophobic compounds such as triglycerides leading to the reduction of their hydrolysis by lipases to the impairment of the fatty acid absorption by the small intestine and finally decrease the circulating triglyceride concentrations amplified by a low synthesis of hepatic lipoproteins. The increase in the total protein, albumin and globulin values observed as the dietary inclusion level of the processed ASAK^{PEG} meal increased could be attributed to interference in protein synthesis from the phytochemicals in the ASAK meal limiting the bioavailability of protein for the animal's use.

The linear increase in the AST, ALP and the irregular trend observed for ALT as the dietary inclusion levels of the processed ASAK^{PEG} meal increased in the diet of the birds indicated that the broiler chickens have a challenge in handling the digestion of the star apple kernels irrespective of whether fed raw or treated. The increased activities of AST, ALP and irregular trend in the ALT observed as the processed ASAK^{PEG} meal increased in the diet could be supported by the findings of Al-mamary *et al.* (2001) that tannins in sorghum negatively affected nitrogen and energy digestion, increased the chymotrypsin and lipase activities, decreased trypsin, maltase and γ -glutamyl transferase activities in pigs.

Haematology indices: The red blood cell, packed cell volume and haemoglobin of the broilers fed the raw *C. albidum* kernel meal were affected whereas only the red blood cell of the broilers fed the processed ASAK meal using polyethylene glycol was significantly affected, this implies that, the polyethylene glycol may have altered the PCV and Hb values of the broilers fed the processed ASAK meal using polyethylene glycol.

The PCV values of 30.96-33.90% obtained for the birds fed processed ASAK^{PEG} meal were still within the normal range of 23-55% for healthy birds reported by Maxwell *et al.* (1990) which showed that the birds were not anaemic. PCV is an index of toxicity, any reduction in its concentration in the blood usually suggests the presence of toxic factors which has adverse effect on blood formation (Oyawoye and Ogunkunle, 1998). The haemoglobin values (8.72-9.50g/dl) obtained for the birds fed the processed ASAK^{PEG} meal were within the recommended haemoglobin concentration of 7-18.6g/dl for healthy birds reported by Aiello and Mays (1998). This implies the safety of polyethylene glycol for the treatment of ASAK meal and its inclusion in the diet of the birds. The values obtained for the red blood cells of the experimental birds suggest nutritional adequacy of the test diets.

The values obtained for the mean cell volume (124.96-130.10fl) of the birds fed the processed ASAK^{PEG} meal were within the normal range of 115-127fl reported by Swenson (1993). The MCV of the broilers fed the processed ASAK^{PEG} meal were enhanced compared to the broilers fed raw ASAK meal with lower MCV of 51.28-60.75fl affirming the suitability of polyethylene glycol for the treatment of ASAK meal with regard to the blood indices. The higher values of 35.02-36.63pg obtained for the MCH and 27.81-28.16 for the MCHC compared with the values of 25-27pg and 21-23g/dl reported by Swenson (1993) for the MCH and MCHC respectively for healthy birds suggest that, the birds were not anaemic. The insignificant effect of the white blood cells observed in the birds fed the processed ASAK^{PEG} meal suggest that the absorbent may have impacted positively on the immune system of the birds thus ruling out the possibility of any infection attributed from feeding the test ingredient to the birds. The

birds fed the raw ASAK meal were significantly affected and accompanied with an increase in the white blood cells which may be attributed to the high concentration of the phytochemicals in the raw ASAK meal.

Nutrient retention: The decrease in the dry matter, crude protein, ether extract and soluble carbohydrate retention of the birds fed the increasing inclusion levels of the processed ASAK^{PEG} meal were as a result of the incomplete detoxification of the ANFs particularly tannins, saponins and phytate still present in the processed ASAK^{PEG} meal. The reports of Lizardo *et al.* (1995) that tannins negatively affect nitrogen and energy digestion give credence to the findings of this study.

Histology of the liver: The severe hepatocyte degradation and ducticular inflammation observed in the liver of the birds fed beyond 10% inclusion level of processed ASAK^{PEG} meal were as a result of the undetoxified phytochemicals particularly tannins present in the feed. The complexes formed between PEG and tannins may have impaired the absorption of nutrients in the small intestine and consequently led to the decrease in the circulating triglyceride and eventual hepatocyte degradation.

The economics of production: The replacement of maize with the processed ASAK^{PEG} meal do not justify its use for all the inclusion levels, as there was a higher revenue and profit from the birds fed the control diet despite the reduction in feed cost per kilogram of the diets formulated with increasing inclusion level of the processed ASAK^{PEG} meal. This is attributed to the poor palatability of the feed and its utilization by the birds. This implies that, the investor or farmer will have higher returns on capital investment from

the use of maize compared to its replacement with processed ASAK^{PEG} meal in the diet of the broilers.

It is concluded that the use of PEG for the processing of African star apple kernel meal revealed an improvement on the growth performance characteristics over the birds fed the raw ASAK meal with regard to the growth performance characteristics, however the birds on the processed ASAK^{PEG} meal performed poorly in relation to the birds on the control diet due to the high concentration of tannins which defiled all processing methods applied at higher dietary inclusion levels of the ASAK meal. The nutrient retention, serum biochemical and haematology indices were enhanced by the processed ASAK^{PEG} meal. The histology of the liver revealed severe impairment mainly attributed to tannins. From this study, the pretreatment of ASAK meal at 20g/kg do not efficiently detoxify the phytochemicals in the kernels, hence the need to increase the pretreatment level.

8.0 Conclusion

From this study, broilers fed processed ASAK meal performed better than those fed raw ASAK, while those fed the control diet performed significantly better than those fed the raw and processed ASAK meal, respectively. Tannins and saponins were the critical antinutritional factors for its use in poultry diet. The pretreatment levels of bentonite and PEG at 20g/kg preceded by soaking and boiling for 12 hours and 30 minutes respectively was insufficient to detoxify the phytochemicals in the ASAK. A low dietary inclusion level of the ASAK meal could favour erythropoeisis thereby enhancing the haematology indices of broilers and also help mitigate against the deposition of cholesterol in the liver of broilers. The profitability of replacing maize with ASAK meal does not favour its inclusion in broiler's diet. It can be concluded that, African star apple kernel meal is inferior to maize, based on the unavailability of the nutrients to the birds. The best result obtained from replacing maize with African star apple kernel was 5% inclusion level.

8.1 Recommendation

This study therefore recommends further studies that will unravel the best method to enhance the nutritive value of the ASAK meal in broilers diet. Studies on the combination of bentonite and PEG beyond 20g/kg for the processing of the African star apple kernel may be helpful to farmers who may insist on its use where there is abundant supply of it. This may be suitable for further detoxification of the phytochemicals in the ASAK meal to enhance its full utilization at 5% inclusion level and beyond in the diet of broilers.

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APPENDIX

MEDICATION AND VACCINATION SCHEDULE FOR BROILER CHICKENS

DAYS/WEEKS	TYPE OF MEDICATION/VACCINATION	ROUTE	TREATMENT
Day 1	On arrival, Administer glucose for 30 mins	Oral	To alleviate stress of transit
Day 1-5	Antibiotics + Multivitamins	Oral	To alleviate hatchery and post hatch diseases (CRD, Fowl typhoid)
Day 6	Multivitamins only		
Day 7 (1 week)	1 st dose of Gumboro vaccine (IBDV)	Oral	To prevent Infectious Bursa Disease (IBD)
Day 8	Multivitamins	Oral	To allow recuperation from stress involved with vaccine
Day 9&10	Anticoccidiostat (1 st dose)	Oral	To prevent Coccidiosis
Day 11	Multivitamins		
Day 12	Change the litter & administer multivitamins		To alleviate the stress of changing litter
Day 13	Administer 1 st dose of Lasota vaccine (NDV)	Oral	To prevent New Castle Disease
Day 14 (2 wks)	Multivitamins	Oral	To allow recuperation from stress involved with vaccine
Day 15-16	Anticoccidiostat (2nd dose)	Oral	To prevent Coccidiosis
Day 17	Multivitamins	Oral	
Day 18	Change litter + Multivitamins	Oral	
Day 19	Multivitamins		
Day 20	2 nd dose of Gumboro	Oral	To prevent Infectious Bursa Disease (IBD)
Day 21 (3 wks)	Multivitamins		
Day 22-24	Antibiotics + Multivitamins		
Day 27	2 nd dose of Lasota	Oral	
Day 28	Multivitamins		
Day 29	Change litter + Multivitamins		
Day 35	Change litter + Multivitamins		
Day 42	Change litter + Multivitamins		
Day 49	Processing for response criterias		

