`

UTILISATION OF CASHEW (*ANACARDIUM OCCIDENTALE* L.) APPLE POMACE AS A SOURCE OF ENERGY BY BROILER CHICKEN

BY

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CERTIFICATION

I certify that this work was carried out by Iyabode Kehinde YISA with Matriculation Number 40381 in the Agricultural Biochemistry and Nutrition Unit, Department of Animal Science, University of Ibadan, under my supervision.

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ABSTRACT

Cereals, the main energy source ingredients, usually constitute more than half of poultry feed. Maize, the most commonly used cereal is expensive and scarce. Cashew Apple Pomace (CAP) is a residue of cashew nut production with Gross Energy (GE) content similar to maize. However, information on CAP as an energy source in poultry diets is currently inadequate. Therefore, CAP as an energy source for broiler chickens was investigated.

Cashew apple was pressed, sun-dried and milled (2mm sieve size) to obtain Dry Cashew Apple Pomace (DCAP). Chemical composition and Apparent Metabolisable Energy (AME) of DCAP were determined using standard procedures. Five diets, in which maize was replaced with DCAP at 0% (T_1), 5% (T_2), 10% (T_3), 15% (T_4) and 20% (T_5), were fed at starter and finisher phases to 400 one-day-old Arbor Acre Plus Broiler Chicks (AAPBC) in eight replicates for 42 days using completely randomised design. Feed Intake-FI (g), Total Weight Gain-TWG (g) and Feed Conversion Ratio (FCR) were determined. Blood (3mL) was sampled and analysed for triglycerides. In another trial, maize in starter and finisher diets was replaced with DCAP at 0% (C_1, C_2), 15% (C_3, C_4) and 30% (C_5, C_6). Diets C_2, C_4 and C_6 had fibrolytic multienzyme complex inclusion at 350g/tonne. The diets were fed to 288 one-day old AAPBC in a 2x3 factorial arrangement. At day 42, FI, WG and FCR were determined. Two chickens per replicate were sacrificed to determine Relative Dressed Weight (RDW) and Abdominal Fat (AF). The DCAP was stored in Woven Polyethylene Sacks (WPS) and Plastic Container (PC) for 12 months and insect infestation was monitored. Data were analysed using descriptive statistics, orthogonal contrast and ANOVA at $\alpha_{0.05}$.

The DCAP contained 11.1±1.7% Crude Protein (CP), 23.4±1.0% available carbohydrate, 4,227.6±5 kCal/kg GE, 0.002mg/mg methionine, 0.005mg/mg lysine, 35.5% neutral detergent fibre, 23.3% acid detergent fibre, 18.8% acid detergent lignin and 2,146.8±2.4 kcal/kg AME. The total FI ranged from 2,566.8±111.9 (T_1) to 2,897.8±92.7 (T_5). The TWG ranged from 1,038.2±23.0 (T_5) to 1,136.8±25.0 (T_1). The FCR at starter phase ranged from 2.02 (T_1) to 2.36 (T_3). At finisher phase, FCR of T_1 (2.24) was similar to T_2 (2.46), T_3 (2.48) and T_4 (2.67) but differed significantly from T_5 (2.80). Triglycerides (mg/dL) ranged from 22.8±1.6 (T_5) to 27.1±1.7 (T_1). Enzyme inclusion significantly reduced FI in C_4 (903.8±25.4) against C_3 (1014.1±47.5) and increased WG in C_6 (464.0±40.4) against C_5 (410.5±26.1) at starter phase. Enzyme had no effect on FCR, RDW and AF at starter and finisher phases. The TWG was also not affected. However, maize replacement with DCAP increased: WG (C_3 - 443.5±20.1 and C_5 - 410.5±36.1 than C_1 - 361.7±46.2), FCR (C_5 - 2.99 than C_1 - 2.35) and reduced AF (C_5 - 0.40 than C_1 - 0.75). *Lasioderma serricorne* was identified as a pest in DCAP stored in PC and WPS within a year.

Dietary dry cashew apple pomace enhanced performance and lowered abdominal fat of broiler chicken up to 15% replacement in broiler diets. Dry cashew apple did not deteriorate after one year in storage.

Keywords: Cashew apple pomace, Broiler chicken, growth performance, Apparent metabolisable energy, Fibrolytic enzyme complex

Word count: 500

DEDICATION

To God, my Father who has loved me with eternal love, for His use, to bless Guinea- Bissau and other nations. Eyin nikan ni N'O ma sin, eyin nikan ni N'O ma bo.

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LIST OF ABBREVIATIONS

AIB Agro- Industrial by-products

AOAC Association of Analytical Chemists

ADF Acid Detergent Fibre

AME Apparent metabolisable energy

AMEn Nitrogen corrected apparent metabolisable energy

ANOVA Analysis of Variance

BD Bulk density

Ca Calcium

CAP Cashew apple pomace

CaOH Calcium Hydroxide

CBD Compact Bulk Density

CDS Corn Condensed Distillers Solubles

CNSL Cashew nut shell liquid

CP Crude Protein

DCAP Dry Cashew Apple Pomace

DDGS Distillers' Dry Grains with Solubles

DG Distillers' Grains

EDTA Ethylenediamine tetraacetic acid

EE Ether extract

ELISA Enzyme Linked Immunosorbent Assay

FAO Food and Agricultural Organisation

FCR Feed conversion ratio

Fe Iron

GE Gross energy

HB Haemoglobin

HDL-C High density lipoprotein cholesterol

HET Heterocyte

HPLC High Performance Liquid Chromatography

ICP-OES Inductively coupled plasma atomic emission spectroscopy

IITA International Institute of Tropical Agriculture

ISO International Organization for Standardization

LDL-C Low density lipoprotein cholesterol

LYM Lymphocyte

ME Metabolisable energy

Na Sodium

NaOH Sodium Hydroxide

NE No enzyme

NDF Neutral Detergent Fibre

NDL Neutral Detergent Lignin

NFE Nitrogen Free Extract

NH_4OH Ammonium Hydroxide

P Phosphorus

PCV Packed Cell Volume

PLAT Platelet

RBC Red Blood Cell

SPSS Statistical Package for Social Sciences

USA United States of America

USD United States Dollar

WBC White Blood Cell

WE With Enzyme

Zn Zinc

CHAPTER ONE

1.0 INTRODUCTION

Poultry feed is usually made up of several ingredients, each contributing nutrients such as carbohydrate, protein, fat, vitamins and minerals to the concentrate. A higher percentage (about 50-70%) of this is usually from cereals which include maize, sorghum, millet, wheat and triticale to mention a few which contribute the bulk of energy in such feeds. They are so needed because broiler chickens utilize concentrated energy in feed for rapid production of meat. In Africa, like most other places, the most common cereal used in feed formulation is maize (Dei, 2017)

Maize is a highly valued crop all over the world being used directly in human nutrition as food for different strata of human development ranging from babyhood to old age, as diets for the healthy, convalescing and sick. It also serves as an industrial raw material for manufacturing baby food, corn related adult food, malt and alcohols besides its use in biogas manufacture and as livestock feeI9d. The relative ease of its cultivation and adaptation to diverse climatic conditions supports the demand placed on its production Olaniyan (2015).

Due to its importance in many sectors and a consequent rise in demand, cost of maize is regularly on an ascending scale, thus bearing effect on the cost of production of broiler chicken feed which eventually limits affordability of broiler chicken by the population. The production of broiler chicken in Nigeria and other countries in Africa is greatly hampered by the escalating cost of feed which is highlighted by the importation of most of the maize used in the formulation of poultry feed. This has also led to importation of processed chickens which are cheaper than those produced in the country. A lot of effort is therefore being made to source possible alternative ingredients within the economy to reduce the cost of feed which usually accounts for up to 70% of the total cost of production. These alternative sources include crop wastes/residues and agro-industrial by-products.

Crop wastes and are left over/residues from the harvesting of crops. In cereals such as maize, millet, sorghum, rice, oats and wheat, after harvest, the leaves, stem, husk, cob, bran, middling, chaff and straws are usually left on the farm or the site of processing. In legumes such as groundnut, cowpea, soya beans, and melon leaves, stem, shell, pods and haulm are left as residues. In vegetable and fruit production leaves, stem, vines, bark, wounded fruits and nuts are left on the farm (Obi *et al.*, 2016).

Agro-industrial by-products constitute the bulk of alternative sources that could be easily incorporated into livestock feed. Ingredients from different classification of industries include

- Sugar, starch and confectionery industry by- products: molasses and sugar-cane bagasse,

-Oil industry by products: cotton seed cake, groundnut cake/ pellets, palm kernel meal and palm kernel cake,

- Cereal by-products: wheat bran/offal, rice husks, rice chaff maize and bran,

- Distilleries and breweries by-products: brewers dried grain, and brewers' bran.

-Roots, tubers and their by –products: yam peels and cassava peels,

-Fruit and vegetable by-products: these are products resulting from processing of fruits and vegetables such as peels, backs, kernels, pomace, and pulp or bagasse. Dried cashew apple pulp falls within this category (Iyayi and Aderolu, 2004; Makinde and Inuwa, 2015)

There is an abundance of crop residues and agro-industrial by-products all over the world and especially in developing countries where a large percentage of the population is usually agrarian. Global production of such is estimated to be about 998 million tonnes which is close to 30% of world agricultural products (Agamuthu, 2009; Ajila *et al*., 2012). The estimate of agricultural waste in Nigeria is rare as in most developing countries; however the volume obtained could be significant (Obi *et al*., 2016). It can therefore be postulated that a huge amount of residues is obtained from the agronomic section in Nigeria. The quantity of vegetable and fruit wastes/ residues generated all over the world is huge and there is hardly any adequate record. The fruits and vegetable wastes generated in the organized sector of India, Philippines, China and USA are estimated at 1.81, 6.53, 32.0 and 15million tonnes respectively (FAO, 2013).

These residues/ by-products are generally regarded to be deficient in protein and high in fibre and have been regarded as only useful in ruminant nutrition in the past. However recent research has proved based on their chemical compositions and potential feeding value the possibility of their inclusion in poultry feed formulations (Swain and Barbudhe, 2014). In order to enhance nutrient utilization in broilers, different methods have been used to boost digestibility of these alternative ingredients. These are physical, chemical and biological methods. The physical methods are exemplified by chopping, grinding, pelleting and extrusion while chemical methods are alkali treatment which includes the use of NaOH, urea, CaOH, supplementing with amino acids e.g.

lysine and methionine and biological methods such as ensiling, solid state fermentation and the use of exogenous enzymes.

Most of these by-products such as cabbage waste, cashew apple pulp, pineapple waste and mango peels can be fed as obtained particularly to ruminants but due to their high moisture content, relatively high total soluble sugars and crude protein, they are easily fermentable and highly perishable. There is need to conserve them in view of the available quantity and seasonality. Different methods that have been used for conservation include drying (thermal or sun-drying), conservation with poultry litter and ensiling.

The material used in this study, cashew apple is the edible soft part of the cashew fruit and forms the bulk by weight of the whole harvest. A higher percentage of cashew apple is wasted than used at all during the harvest due to its high degradability as it can only be stored for days in refrigerated conditions. Cashew apple pomace can be regarded as a crop residue or agro-industrial by-product (AIB) depending on whether it is sourced from the farm where it is left as a by-product of cashew nut harvest or from the production of cashew beverage after the extraction of the liquid from the apple. It is also grouped under the fruit and vegetable by-product, a group that is just attaining prominence in research as compared to grain, legumes and oil-seed by-products.

Due to enormous waste of cashew apple recorded during cashew apple season, it has been recommended that acceptable products be developed from cashew apple for further utilization (Ogunjobi and Ogunwolu, 2010); Adebowale *et al*., (2011). Drying cashew apple could enhance its utilization in poultry production; however the availability of such a product all year round will depend on its shelf life. The inclusion or replacement of this novel product in broiler feed is expected to reduce annual harvest loss, lower the pressure of demand on maize, reduce environmental pollution and lower the cost of broiler chicken production.

In spite of the several uses of dried cashew apple for wine constitution, there is paucity of information on its use as an animal feed ingredient. This study is therefore designed to evaluate the use of dry cashew apple pulp in replacement for maize as a source of energy in broiler chicken production.

1.1 Justification of the study

The continuous rise in the cost of broiler feed production, (about 70% of which lies on the energy supplying ingredients which is particularly maize, owing to its multiple competitive uses) has kindled interest to promote new energy source ingredients such as dried cashew apple pomace which is highly underutilized leaving a colossal waste. There is the need to increase animal protein availability in the continent because Africa is rated low in its consumption of animal protein, consuming only 62g of the 75g daily protein recommended for an adult male weighing 90kg (FAOSTAT, 2011). This can only be done rapidly by producing the most rapid converter to animal protein (broiler chickens) at affordable prices to the growing population.

There has been advocacy by cashew stakeholders for the effective use of its by-products, cashew apple, cashew nut discards and cashew nut shell. Cashew apple is the bulkiest of these by-products and the least used as about 90% of it is yet to attain any commercial value. The use of cashew apple pomace in broiler feed could add value to the otherwise left-to-rot quantity, thereby enhancing the income of cashew farmers and possibly increasing employment opportunity of cashew harvest force. This can also salvage the environmental effects of unused cashew apples which include air, soil and water pollution.

In this study, dry cashew apple pomace was used in replacement of maize in broiler diets as an energy source.

1.1 **Objectives of this study**

General objective

The aim of this study is to harness a fruit by-product/ waste (cashew apple) to replace energy source ingredients in broiler diet.

Specific objectives

i. To determine the chemical composition and metabolisable energy of Dry Cashew Apple Pomace (DCAP)
ii. To assess the utilisation of DCAP in broiler chicken finisher and broiler diets
iii. To evaluate the effect of exogenous enzyme on utilisation of DCAP
iv. To assess the shelf life of DCAP

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Maize as an energy source

Maize (*Zea mays*) is known to have originated from Mexico about 7000 years ago as a wild grass which has undergone several transformations to what otherwise is referred to as corn (Abbassian, 2009; Ranum *et al*., 2014).World production of maize was estimated at 1.06 billion `metric tonnes in 2016 (FAOSTAT, 2017). United States of America ranked first with 36.67% of total world production in 2016/2017 (Statista, 2018). The volume of maize produced in Africa and Nigeria in 2016 was 70,557,426 tonnes and 10,414,012 tonnes respectively (FAOSTAT 2017). Nigeria ranked second after South Africa as the biggest producer of maize in Africa and topped the list in Sub – Saharan Africa (FAOSTAT, 2012; Olaniyan, 2015). Table 2.1 shows maize production in Africa by country. Maize is produced generally in all the ecological zones of Nigeria and the yield is between 1.7-2.0 tons/ha against global average of 4.9- 5.1 tons/ha (Olaniyan, 2015).

The chemical composition of maize is at an average of moisture 10.36%, protein 9.55%, ether extract 4.14%, crude fibre 1.98%, NDF 15.5%, ADF 3.2%, ash 1.76%, carbohydrate 72.26%. According to Heuzé *et al*. (2017) in Feedipedia datasheet the gross energy of maize is reported to be between 3904.2kcal/kg and 5086.0Kcal/kg with an average of 4489.4±1.3kcal/kg in Sub-Saharan and East Africa. The high carbohydrate content makes it a formidable energy source for poultry production. Apparent metabolizable energy of about 3629.7kcal /kg in cockerel and 3534.2kcal/kg in broiler in Sub- Saharan Africa has been reported, although an ME of 3432kcal/kg or up to 3550kcal/kg for broilers is adopted in Nigeria (Heuzé and Tran, 2015; Ape *et al*., 2016). The average amino acid (protein) content of maize is as follows: Alanine 7.4, Arginine 4.5, Aspartic acid 6.5%, Cystine 2.3%, Glutamic acid 18.2, Glycine 3.7, Histidine 2.8, Isoleucine 3.5, Leucine 12.0, Lysine 3.1, Methionine 2.1, Phenylalanine 4.8, Proline 8.8, Serine 4.8, Threonine 3.6, Tryptophan 0.7, Tyrosine 3.7 and Valine 4.8.

Due to its high energy content, maize is a staple food for man, up to 15% of the total production is consumed by humans in different regions of the world particularly Latin America (Mexico taking lead), Asia and many countries in Africa (Abbassian, 2009). Maize is used as food in various forms such as in meals, snacks and beverages, sweeteners and oil (Akintoye and Olaniyan, 2012; Ranum *et al*., 2014). According to IITA (2009) reports, maize is a staple food for more than half (50%) of the population in Sub-Saharan Africa. In Nigeria, it is eaten in different forms such as whole grains fresh from the field as boiled or roasted on its cob and as popcorn when dry (IITA, 2019). Varieties of meals and snacks are made from milled (wet or dry) which include porridge, ogi, tuwo, massa, aadun, kokoro, egbo, elekute. Abari, donkwa, gwate and other fried and baked product. (Abiose and Ikujenlola, 2014; IITA 2009).

In the course of processing maize as food and for other industrial purposes, co-products or by-products which are used in livestock feed become available such as 'dusa', distillers' grains (DG), corn distillers grains with soluble (DDGS), corn condensed distillers solubles (CDS), maize gluten meal, maize gluten feed (Abbassian, 2009). The quantity obtained from this is little in comparison to the demand for maize grain in livestock feed particularly in broiler chicken production.

Africa consumes about 90% of maize produced as food and raw materials for industries thereby leaving little for livestock production. For this reason, Africa depends largely on the importation of maize to meet its need for livestock feed. America, Argentina and South Africa are the largest exporters of maize. In spite of the ease of cultivation and relative low cost, the recent trend of ethanol production which accounts for about 40% of maize produced in America has resulted in higher prices for maize due to increasing demand for its use (Ranum *et al*., 2014). The resultant high cost of broiler feed has led to procuring possible alternative ingredients which are available in hot climates with reduced prices though some could only be used in partial replacement of maize (Afolayan *et al*., 2012).

2.2 Alternative feed ingredients

Feed ingredients that are being developed or introduced into the livestock industry other than had been used in the past such as maize and soya bean meal, have been referred to as alternative or non- conventional sources (Swain *et al*., 2014).These are usually sources that are readily available locally and have not been considered as feed ingredient or have been sparingly used in livestock nutrition (Mabelebele *et al*., 2015). Plant source alternative ingredient are broadly divided into crop wastes/residues and agro- industrial by-products (AIB). An estimated quantity of about 998 million tonnes of agricultural waste is produced yearly in the developing countries (Agamuthu, 2009).

Table 2.1 Maize production in Africa by country (tonnes)

Country	2014	2015	2016
South Africa	14,250,000,	9,955,000	7,778,500
Nigeria	10,058,968	10,562,050	10,414,012
Ethiopia	7,234,955	7,882,444	7,847,175
Tanzania	6,737,197	5,902,776	5,875,560
Egypt	8,059,906	7,803,183	8,001,411
Malawi	3,978,123	2,776,277	2,369,493
Kenya	3,513,171	3,825,000	3,339,000
Zambia	3,350,671	2,618,221	2,873,052
Uganda	2,763,000	2,647,453	2,663,025
Ghana	1,762,000	1,691,644	1,721,910

Source: FAOSTAT, 2018a

2.2.1 Crop residues

This is agriculture's largest harvest as it incorporates more than 50% world's phytomass which include cereals and legume straws, in tops, stalks, leaves, and shoots of tubers, oil, sugar, and vegetable crops; and in prunings and litter of fruit and nut trees. Smil (1999), Onyeonagu and Njoku (2010) grouped crop residues into cereal crop residue (millet stover, rice husk, rice straw), root crop residues (yam peel, cassava peel, cocoyam peel, potatoes peel, potatoes vine) fruit crop residues (banana peel, plantain peel, orange peel) and leguminous residues (groundnut haulms, cowpea haulms, soyabean haulms). They are generally characterized by high fibre content, low digestibility and nitrogen content although vegetable and fruit wastes usually contain high moisture and some soluble sugars which make them suppliers of energy in livestock feed. Most of these are used as feed for ruminant livestock during the dry season (FAO, 2014; Sontakke *et al.,* 2014)

2.2.2 Agro-Industrial By-products (AIB)

The residue from the processing of agricultural products for human consumption and other uses is referred to as agro- industrial by-products. These can also be grouped according to the nutrients they supply in livestock feed which could be

(i) Protein source

a. low in fibre, high in nitrogen e.g. groundnut cake, cotton seed cake, sunflower cake and slaughter offals

b. high in fibre, high in nitrogen e.g. poultry litter, ruminants excreta, brewers grains

(ii) Energy source (low in fibre and low in nitrogen) e.g. molasses, citrus and pineapple pulps, apple pomace, reject bananas and other sugar, starch and confectionery by-products processing wastes (FAO, 2007)

2.2.3 Available quantity of crop residues and AIB world-wide/Nigeria

There is no accurate record of the amount of crop residues or accounting for its uses even in the developing countries (Smil 1999). AIB and crop residue is thought to be greater in quantity than actual crop production. AIB produced all over the world is about 1 billion tonnes which could represent up to 30% agricultural production (Agamuthu, 2009; Ajila *et al*., 2012), some information may be gleaned from statistics in countries like India, China, Philippines and America.

In West African sub- region, about 90 million tonnes of crop residues was produced by UEMOA countries in 2010 and about 500,000 tonnes of agro - industrial by- products in 1990 shared between molasses and wheat. (FAO, 2014).

2.2.4 Use of alternative feed ingredients in ruminant nutrition in other countries/Nigeria

In Uganda, and Kenya smallholder dairy farmers have used molasses, brewers spent grains, maize bran and cotton seed cake, green maize stover, vegetable wastes, bean haulms, sorghum and millet stovers and wheat straw in various quantities mostly during dry season depending on quantity, nearness to supply, extent of the knowledge of processing and preservation or storage method (Lukuyu *et al.,* 2011 and Atuhaire *et al.,* 2014). Onyeonagu and Njoku (2010) reported the all year use of crop residues and agro- industrial by-products by the communities found in Markurdi Local Government area of Benue State, Nigeria for feeding of small ruminants (sheep and goat).

2.2.5 Use of alternative feed ingredients in poultry feed and their constraints

Nonconventional ingredients used in poultry feed include cereals e.g. broken rice, triticale, brewers grains, rice husks, rice chaff, maize bran.(Iji *et al*., 2011, Swain *et al.,* 2014), grain legumes and leguminous leaves such as (*Vigna unguiculata* [L.] *Walp*) *Moringa oleifera* pigeon pea (*Cajanus cajan*), roots and tubers; cassava, cassava peel meal, (Sogunle, 2007; Iji *et al.,* 2011) fruit wastes mango waste, pineapple waste, avocado meal (Emshaw *et al.,* 2012; Skenjana, 2011) have been incorporated into feeds of quails, broilers, layers, cockerel turkey etc obtaining varying degrees of success.

The alternative feed ingredients have been used for as much as 100% replacement for maize such as triticale, which according to results obtained by Iji *et al.* (2011) could replace conventional cereal grains with no poorer performance. Low inclusion levels of alternative ingredients have been obtained for certain ingredients. Mandey *et al*. (2018) concluded that up to 20% of pineapple waste could be used in broiler feed when fermented by "ragi tape" and dried apple pomace could be used at 5% replacement for maize in broiler diets as opined by Ayhan *et al.* (2009). Cotton seed meal inclusion in the diets of broiler at the rate of 4% did not have significant difference on cholesterol and serum protein parameters with or without iron supplementation (Thirumalaisamy *et al.,* 2016).

There are several factors which limit the use of nonconventional feedstuffs. The most prominent among this is probably the lack of sufficient information on the nutrient or chemical composition of these rarely used ingredients in livestock feed (Iji *et al*., 2011; Mabelebele *et al*., 2015) such as dry cashew apple pulp. Others are their dry matter content and the presence of antinutritional factors in form of non starch polysaccharides (NSP), phytic acid, phytochemicals such as tannin, saponin, gossypol etc. (El- Deek et *al.,*2008; El-Deek *et al*., 2009; Glatz, 2012). The effects of these are shown by limiting feed intake, digestibility, and weight gain as well as adversely affecting haematological and serum parameters if they are indiscriminately added to animal feed (Swain *et al.,* 2014)

2.2.6 Ways of enhancing nonconventional feed ingredients

In the bid to incorporate nonconventional ingredients to livestock feed effectively to achieve best production performances and least cost formulations, several methods have been attempted with some success at improving these new sources. These include:

(i) physical methods like: pressing, boiling soaking, dehulling, autoclaving, toasting/ roasting, grinding, mealing, gamma irradiation and pelleting to increase density and improve intake (Medugu *et al.,* 2012; Dos Anjos, 2014). Gamma irradiation can reduce harmful substances such as tannin and phytic acid.

(ii) Chemical methods include the use of NaOH, urea , wood ash (Ben Salem *et al*., 2004).

(iii)Biological methods have also been used, examples of which are supplementation with molasses, fermentation, ensiling, solid state fermentation and supplementation with exogenous enzymes (Ben Salem *et al*., 2004; Mathur, 2015). Exogenous enzyme is readily available by manufacturers and is required in small quantities (100g/T – 1g/kg) and does not require more time of processing than direct mixing with feed or in water hence its choice in this study.

2.3 Use of exogenous enzyme in poultry nutrition

Exogenous enzymes have been used severally in the improvement of alternative source feed ingredients which are known to consist of non starch polysaccharides and sources of anti-nutritional factors (Ravrindran, 2013; Swain, 2015). Sources of enzymes include fungi, bacteria and yeast which are exemplified by *Asperigillus niger, Bacillus subtilis* and *Sacharomyces cerevisiae* respectively (Lee *et al.,* 2014). Enzymes, being biological catalysts have the capacity of increasing the rate of chemical reactions several times over for improved digestion and better performance of birds (Aehle, 2004; Ravindran, 2013).

The use of enzyme is targeted at improving the digestion of hitherto undigested or low digestion sites known as substrates. These substrates have the common characteristic of large molecular structures and belong to the groups known as nutrients and anti-nutrient factors such as cellulose, hemicelluloses, pectin, lignin and phytic acid (Ravindran, 2013; Martins *et al.,* 2011).

2.3.1 Types of enzymes in use

The types of enzymes that are produced include those targeting viscous cereals such as wheat and barley, non viscous cereals such as corn and sorghum, non cereals like soyabean canola, peas, lupin, beans and other grain legumes (Iji *et al.* 2011, Zou *et al.* 2013). They are produced as specific single enzymes such as β-glucanase, xylanase, cellulase, hemicellulase, alpha amylase, lipase and protease (Panda *et al.*, 2011).

There are also enzyme combinations known as enzyme cocktail in which the specific single enzymes are used together based on the knowledge of substrates targeted (Alemawor *et al*., 2009). Alemawor *et al.* 2009 in an in-vitro study mixed 0.8, 0.6 and 0.8% w/w respectively for Pentopan®MonoBG (xylanase), Viscozyme®L (beta- glucanase) and Pectinex®5XL (polygalactorunase and arabinase side activity) in different combinations to obtain best cocktail option to enhance utilisation of cocoa pod husk in poultry.

Multi-enzymes are prepared mixture of different specific enzymes whose use requires matching with feed with appropriate substrates. They contain different measures of activities of the combining enzymes. A common brand of multi-enzyme is Natuzyme® with different combinations. The constituents of the multi enzyme, Natuzyme (Bioproton Pty Ltd, Sunnybank, Australia) used in the evaluation of the product on laying hens by Lee *et al*. (2014) was as follows xylanase (10,000,000U kg^{-1}), cellulase 5,000,000U kg^{-1}), β-glucanase (1,000,000ukg^{-1}), pectinase (140,000Ukg^{-1}) from *Trichoderma reesei and Trichoderma longibrachiatum,* protease

(6,000Ukg^{-1}), phytase (500,000Ukg^{-1}) from *Aspergillus niger* and α-amylase (1,800,000kg^{-1}) from *Bacillus subtilis.* Mohammed *et al*. (2018) in studying the effects of different levels of multienzyme used a brand with the following activities Phytase – 300,000U kg^{-1}, β-glucanase – 1,000,000Ukg^{-1}, α-amylase at 750,000Ukg^{-1}, cellulase at 4.200, 000Ukg^{-1}, pectinase at 70,000Ukg^{-1}, xylanase at 5,000,000U kg^{-1} and protease at 3,000,000Ukg^{-1}. In this study, the same brand was used with differing enzymatic activities as shown in Chapter 3.

Dalólio *et al.* 2016, Alagawany *et al.* 2018 have reported improved productive performance while lowered feed cost was obtained by Yegani and Korver (2013) and Agunbiade *et al*. (2016).

2.3.2 Activities of exogenous enzymes in poultry nutrition

The use of exogenous enzyme in poultry feed is due to the fact that it expands opportunity for use of broader use of various ingredients by removing the constraint of poorly digested ingredients (Alemawor *et al*., 2009; Agunbiade *et al*., 2016). Metabolizable energy of the feed in use increases as more energy is released by the depolymerization of the complex structure of the present NSP. Improved digestion of protein and lipid is attained. Enzymes bring about improved gut health by stimulating the growth of beneficial bacteria. Improved performance in nutrient uptake, egg mass and egg shell qualities were reported by Abudabos (2012), Yohanna (2012) and Lee *et al.* (2014). Yohanna (2012) found no improvement in gain in body weight of chickens fed enzyme supplemented high and medium energy diets.

However, younger birds have been reported to react more positively to enzyme supplementation than older birds due to the fact that their endogenous enzyme capacity is not well developed. According to Abudabos (2012) and Ravindran (2013), starter broiler chickens showed improved weight gain when fed a complex enzyme supplemented diets against those fed diets without enzymes.

Most enzyme formulations have served mainly the corn/cereal-soybean meal diets while most other non-conventional feed stuff such as fruit wastes do not have enzymes so prepared (Iyayi and Davies, 2005). One hindrance to effective utilization of enzymes is the paucity of information on the basic quantities of the types of sugars which make up their NSP except for cereals (Ravindran 2014).

Another reason for the use of AIBPs and crop residues is to reduce the negative impact on the environment.

2.4 Environmental effect

Crop wastes and industrial by- products due to the large quantity available universally have been source of pollution to air and water. There is also the problem of soil contamination, global warming and negative effect to human health as a result of disease transmission through flies breeding on such wastes (Laufenberg *et al*., 2003; Dang and Nguyen, 2010). This is caused by colossal deposition at inconvenient locations, burning and other means of disposal which are not conducive to the environment. Akinbami and Momodu (2013) alleged that certain agricultural practices such as the handling of different forms of waste from cassava and oil palm processing have earned Nigeria a poor rating in global environmental performance. Huge loss to the tune of ninety percent of cashew apple produced in different countries has been recorded during cashew harvest (Filgueiras *et al.,*1999). This is deposited haphazardly on and around the farm consequently contaminating the environment (Kasapidou *et al.,* 2015).

2.5 Cashew and its origin

Cashew (*Anacardium occidentale* L.) is one of the versatile cultivated crops whose usefulness has only been exploited to a very small extent. Cashew (*A. occidentale*) which is known to have originated from Brazil is a tropical evergreen tree which can grow as tall as 6 – 14meters (Morton 1987; Adeigbe *et al.,*2015). The seed being transported by Portuguese sailors, missionaries, traders or colonists is now widely cultivated in Asia, South America and Africa because it thrives well in tropical conditions where it was initially introduced for the control of erosion. Nigeria, Tanzania, Mozambique, Ivory Coast, Guinea- Bissau are some of the countries that produce cashew in Africa. It is now cultivated on commercial basis in Vietnam, Nigeria, India, Ivory Coast, Guinea- Bissau, Brazil and other countries (FAOSTAT, 2013).

2.5.1 Production of Cashew in Africa

Major cashew producing centres in Africa had been Mozambique and Tanzania. In the recent past, greater percentage of the continental production has come from West Africa with countries like Ivory –Coast, Guinea- Bissau and Nigeria in the front line. Table 2.2 shows top ten cashew producers in Africa.

Table 2.2 Ten top cashew producing countries in Africa (tonnes)

Country	2014	2015	2016
Nigeria	903327	931094	958860
Cote d'Ivoire	532132	569198	607300
Benin	201818	225230	125728
Guinea Bissau	156620	152396	153888
United Republic of Tanzania	130124	197933	195140
Burkina Faso	81196	70626	78533
Mali	72009	103827	164185
Mozambique	63080	81240	104179
Ghana	50000	50000	78268

Source: FAOSTAT 2018b

2.5.2 Production of cashew in Nigeria

The introduction of cashew to Nigeria about 600 years ago was by Portuguese traders, however did not attain commercial status for a very long time (Aliyu 2012). Government farms sprung up in Eastern and Western Nigeria between 1950 and 1953. Cultivation for commercial purposes actually started at Iwo, Eruwa and Upper Ogun in the defunct Western Nigeria (Togun, 1977) whereas in the Eastern region cashew was planted principally for nuts, afforestation and prevention of erosion (Akinwale and Esan, 1989).

Cashew nut production has increased from 7000Mt in 1961 to 894,368Mt in 2014 and the production is likely to increase due to the awareness of its economical value by farmers, improved seed and growing research for improvement of cashew and the increasing promotion of non-oil export commodities by the Federal Government of Nigeria.

Cashew has been described as a foreign exchange earning commodity in Nigeria, second only to cocoa and with a high potential to increase in the next coming years. Cashew is now named as one of the 13 National Strategic Products (NSEPs) that will be used to diversify the economy away from oil in view of the present national economic predicament due to the unstable price of oil which had been the major stay of Nigerian economy (Faseru, 2015) . Cashew is now planted in all the 36 states in Nigeria though only 19 states plant in commercial quantity (Adeigbe *et al*., 2015).

2.5.3 Products of cashew

2.5.3.1 Cashew fruit

Cashew fruit is a controversial word in many quarters as different people refer to different parts of cashew as the fruit. The fleshy juicy part is known as an accessory fruit/pseudocarp or false fruit and the nut which is kidney shaped is often referred to as the true fruit (Morton, 1987).Cashew is produced primarily because of its nuts known as the true fruits in many parts of the world though Brazil is known to prefer the succulent apple to the nut (Jostock, 1996).

2.5.3.2 Cashew nut

Cashew nut is the most popular part of cashew and in many places the only thing known as cashew. What is known in the world market is actually the seeds and is like those for all tree seeds referred to as nuts. World production in the year 2015 was estimated at 788,861Mt as kernels with West Africa contributing about 46% of the above mentioned quantity (Nuts and Dried Fruits, Global Statistical Review, 2015). Different products are obtained from the nut/ or kernel.

2.5.3.3 Cashew seed

This is obtained by different forms of processing which may include roasting and breaking of the shell. This is then used as snacks and in culinary activities as found in India, China, Thailand, Indonesia, Mozambique and some West African countries in garnishing making sauces and dessert. It is used either in whole or the ground form. It could also be included in cuisines in the raw or cooked form (INC, 2016; Personal communications).

2.5.3.4 Cashew oil

Cashew oil is made from pressing the nut and is yellow in colour. Cashew cheese or butter is also made from the seed. Cashew milk is also made from the seed as an alternative to dairy milk (Osborn, 2015).

2.5.3.5 Cashew shell oil

This is otherwise referred to as cashew nut shell liquid (CNSL). This is released during the roasting of cashew but is now known to be useful in many things such as drugs, antioxidants, fungicides, biomaterials, insecticides/ pesticide and folk medicine (Hamad and Mubofu, 2015). The end product usually depend on the method of processing which could be cold solvent extracted, hot extraction followed by distillation producing CNSL with different percentages of cardol and cardanol, the latter being used to produce resins, coatings and frictional materials (Orwa *et al*. 2009, Hamad and Mubofu, 2015) .

2.5.3.6 Cashew apple

Cashew apple otherwise known as the pseudofruit or accessory fruit can be yellow, red or red-and-yellow colour, it is fleshy, juicy, sweet and somewhat astringent in taste (Orwa et al., 2009, Morton, 1987). Cashew apple is 5-10 times by weight of cashew nut or nearly 90% of cashew (Filgueiras *et al*.1999). It is the most important product in South America and West Indies where the nuts are known to be discarded due to the belief that it is poisonous because of the gaseous emission during roasting.

2.5.3.6.1 Uses of cashew apple

Cashew apple is usually consumed as plucked like other fruits though its astringent taste, clothes staining effect and high rate of fermentation limits this use. Sweet and alcoholic beverages, wines, liquor, jams chutneys, preserves and candies are also made from the apples. They are sometimes dried for reconstitution into wine. Use in animal feed include the fresh form used simply or combined with other things in making silage and dried form in concentrates.

The use of cashew apple globally in spite of its chemical composition and potentials has been declared as not more than 10% (Filgueras *et al*., 1999).The remaining is left to rot on the farm as most cashew producing countries harvest cashew nuts as major crop while cashew apples are rejected as waste (Rocha *et al*., 2007).

2.5.3.6.2 Cashew apple in livestock feed

Cashew apple has been fed to animals in locations where it is cultivated for a long time as animals in free range such as chickens, pigs, goats, sheep and cattle have always fed voluntarily during the harvest season. The research into its use may have been generated from this and the enormous waste that takes place in each planting season.

Milk yield in dairy cattle was not modified in India when cashew apple baggasse was used in 50% replacement of GNC (Sundaram, 1986). In Vietnam, Kinh *et al*. (1996) found that ensiling 90% whole cashew apple/ cashew apple waste was suitable as feed to cattle though whole cashew apple/cashew apple waste could be ensiled alone for the same result.

Okpanachi *et al*. (2016) reported that up to 30% inclusion of dried cashew pulp meal in the diets of West African Dwarf goats did not adversely affect performance parameters in Nigeria.

In Ghana, Oddoye *et al*. (2009) fed growing pigs with different levels in their diets and concluded that up to 200g/kg produced no deleterious effects on the performance of the pigs. Fanimo *et al*. (2003) fed dried cashew apple / bagasse to rabbits using up to 30% inclusion in replacement for groundnut and maize and concluded that cashew apple reduced cost though lower digestibility was observed.

In an eight week trial feeding one week-old Khaki Campbell ducks, Song and Seng (2008) reported no adverse effect in the inclusion of up to 15% dehydrated cashew baggasse in the duck diets.

2.5.3.6.3 Dried cashew apple pomace in broiler feed

Swain *et al*. (2007) reported the detrimental effect on performance characteristics when cashew apple waste was fed to broilers replacing maize weight for weight at 5, 10, 15 and 20% level. In the same study however, carcass characteristics and weight of organs showed no adverse effects. Bhamare *et al.* (2016) concluded that only 5 % replacement for maize would not lower performance as lower feed intake and significantly lower weight gain were was observed at other levels. The previous studies are not in accord with Yisa *et al.* (2018) who observed that up to 10% replacement of maize produced no negative effect on performance characteristics, carcass characteristics and haematological parameters of broiler chickens. The limitation in the use of cashew pulp in poultry diet could be due to its fibre content characterized by carbohydrate polymers. These polymers are made up of cellulose, hemicelluloses, resistant starch and indigestible oligosaccharides, this is shown in Fig. 2.1. For effective utilization in poultry feed, the use of exogenous enzyme which is known to break down polymers into component units easier to assimilate has been recommended. The activity of exogenous enzymes on NSP is shown in Fig. 2.2

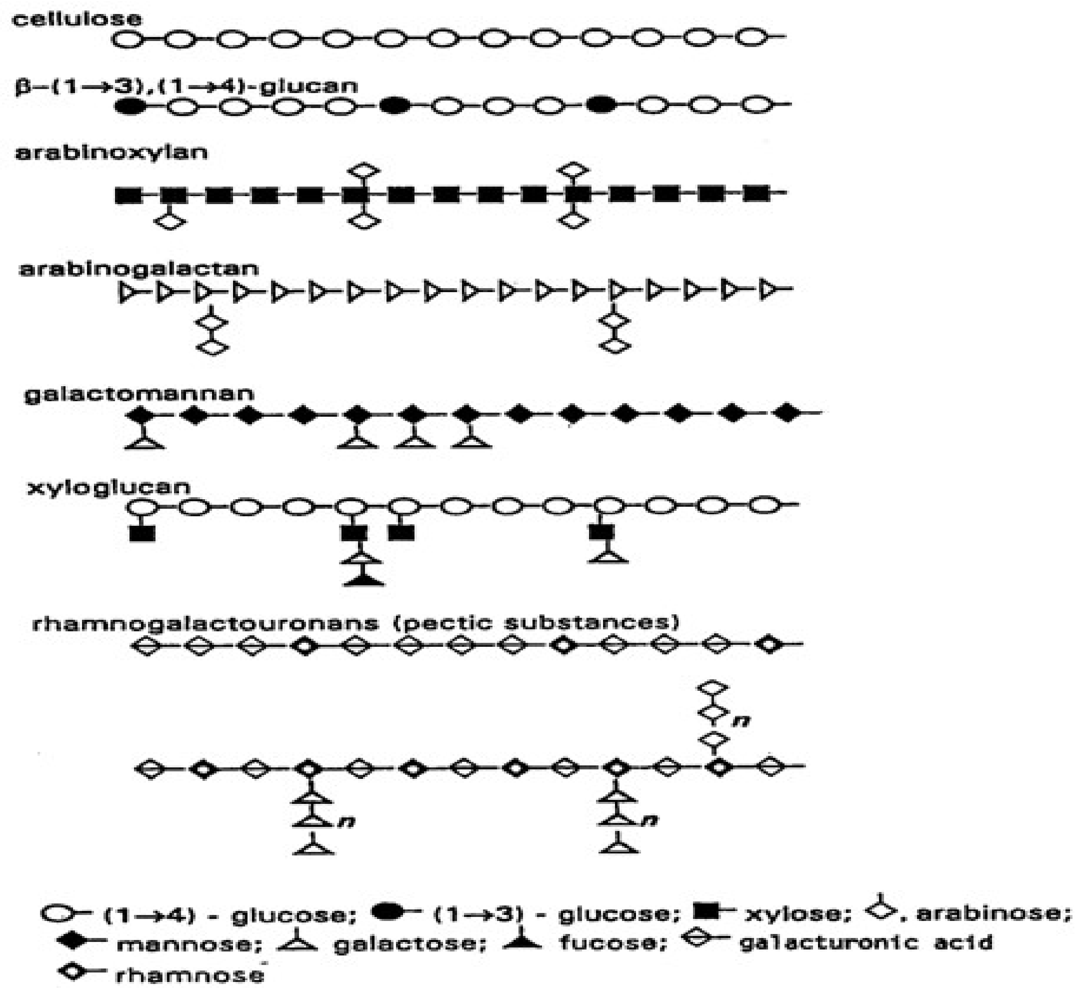

Figure 2.1 Structures of polysaccharides commonly found in feed ingredients of plant origin (de Lange, 2000).

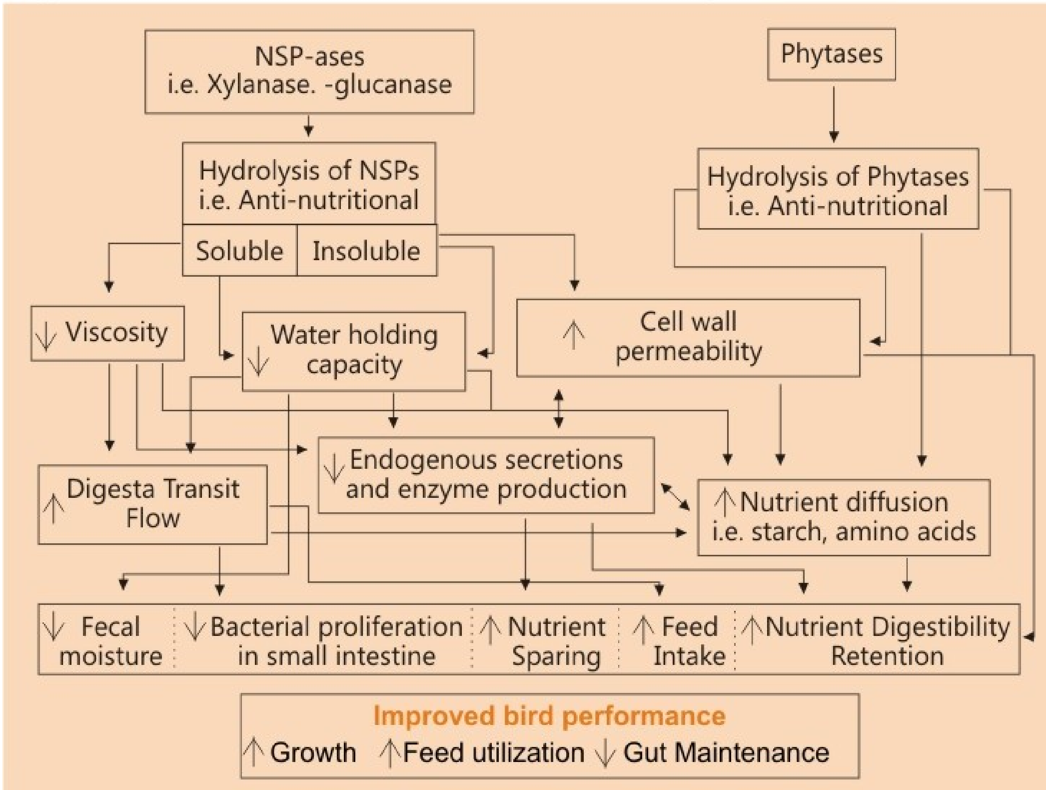

Figure 2.2 Effect of exogenous enzymes on non-starch polysaccharides and phytates

Source: http/benisonmedia.com/wp.contentuploads2017/07g.jpg Accessed 8/4/2018

2.5.3.6.4 Dried cashew apple in broiler feed and exogenous enzyme

There is paucity of information on the use of exogenous enzyme in dried cashew apple pulp in poultry feed, however very little increase in weight gain was reported by Kardivel *et al*. (1993 when beta-glucanase enzyme was used to supplement broiler diets with 10% and 15% cashew apple meal in replacement for maize. Feed intake was increased thereby lowering feed efficiency. Supplementing with enzyme had no significant effect on dressing percentage, weights of heart, gizzard and spleen but a significantly lower liver weight ($P \geq 0.05$) however there was reduced occurrence of pasted vents.

The fact that cashew apple is highly perishable limiting its fresh consumption without further preservation has led to devising means of preservation such as ensiling and drying for use as livestock feed (Kinh *et al*., 1999; Yisa *et al*., 2017). Drying seems the best method for use in broiler feed. This calls for assessing how long this product can last in storage.

2.6 Shelf life

2.6.1 Definition

Shelf life is the maximum time a material which is packaged can be stored under given conditions with the view of meeting the standard required when needed, the measure of which commences from the time it is produced and /or packed. It can also be defined as the space of time within which an item can be stored and it remains usable, edible or saleable (Food Safety Authority of Ireland ,2017; Bhilave, 2018).

2.6.2 Methods of preserving fruits and vegetables for use animal feed

By products of fruits and vegetable harvest are being considered as valuable alternatives to conventional feed ingredients, however their high moisture content is a barrier to their long term usage. Sun drying and ensiling are methods that have been used for their preservation (Ogunjobi and Ogunwolu, 2010; Dele *et al.,* 2013).

2.6.3 Methods of preserving cashew apple in animal feed

Cashew apple constitutes the larger portion by weight of every cashew produced but also forms the bulk of loss in cashew production. Sun-drying of the pulp after the mechanical expulsion of the liquid has been employed in processing the waste as animal feed (Adebowale *et al*. 2011, Okpanachi *et al*., 2016). However it has become necessary to study the durability of such product in storage in view of long-term usage.

Most crop residues and agro- industrial by-products in general require one form of processing or the other to make them acceptable as feed ingredient. Cashew apple as a residue or the bagasse as a by-product of alcoholic or non- alcoholic beverage cannot be used directly in broiler feed. Different methods have been used in preserving cashew apple for use in livestock feed, the best method for use in broiler diet is sun drying as it is a low- cost technology which ensures the reduction of water in fruit to a minimal quantity which prohibits the nurture of enzymes and bacteria (Ofor and Ibeawuchi, 2010)

Cashew apple has been known to deteriorate within 24 hours of harvest, several methods have been proposed for its preservation as animal feed. Ensiling has been experimented. Kihn *et al*. (1996) reported that ensiling cashew apple or cashew apple waste alone or with 10% poultry litter were best options in feeding animals than increasing the quantity of poultry litter and Dele *et al*. (2013) mixed 25% of each of guinea grass and cassava peel with 50% of wet cashew apple pulp produced a stable silage at 30-60 days concluded this could be stored in dry season as ruminant feed. Kinh *et al.* 1996 opined that sun drying cashew for animal feed was not economical; this is contrary to the view of other authors who declared sun drying as the easiest and cheapest method of preserving cashew pulp for use in animal feed (Swain and Barbuddhe, 2014; Yisa and Longe, 2017).

Though sun-drying may be a cheap method of preservation of waste fruits, there are challenges to this method which include labour, variation in season, contamination and time. Labour is required for collection, reduction in size by cutting/ slashing and this may not be readily available in view of the preferred picking of cashew nuts. Contamination may be by dust, chemicals and/ animal wastes while seasons may vary with rain or cloudy weather (Bhat *et al.* 2012). The use of cottage industrial setting and formation of cooperatives could be solutions to labour and achieving commercial status of such products. Splash drying, use of solar driers, convective drying or a combination of methods could be adopted provided cost is put into consideration (Bhat *et al.* 2012, Figiel and Michalska 2017)

There is need to confirm how long sun dried cashew apple pomace can be stored and used in animal feed. Shelf- life parameters could include physical, chemical, biological or microbiological parameters which are necessary for measuring the stability of a feed ingredient in storage (ICCF, 2018).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study One: Chemical composition and metabolisable energy of dry cashew apple pomace (DCAP)

3.1.1 Chemical analysis of dried cashew apple

Experimental Site

The experiment was carried out at the Agricultural Biochemistry and Nutrition Laboratory, Department of Animal Science, University of Ibadan, Ibadan, Nigeria.

Sample collection

Cashew apples were gathered from Aremu Farms Iwo, Osun State, Nigeria. The liquid was mechanically extracted and the pomace was dried on cement floor for three days. It was turned regularly to enhance quick drying. The semi-dry cashew apple pomace was bagged and transferred to Ibadan where further drying was done until constant moisture level was attained.

Proximate composition

Sample Preparation

Random samples of dry cashew apple pomace were taken and mixed and ground to mesh size 2mm.

Analysis

Proximate composition of DCAP was determined according to AOAC (1990). The following parameters were determined: moisture content (930.15), crude protein (976.06), crude fibre (978.10), ether extract (954.02), ash and nitrogen-free extracts (by difference). Each determination was carried out in two replicates.

Fibre Fractions

Sample preparation

The DCAP sample for fibre fractions was milled to a particle size <1mm, the samples are then pre-extracted with acetone to remove fat. The weighed sample covered with acetone is agitated for 30seconds. This is repeated in three different containers with solvent, drained and air –dried in fume hood.

Fibre fractions were determined according to Van Soest *et al*. (1991). The parameters determined were Acid Detergent Fibre (ADF), Neutral Detergent Fibre (NDF), Cellulose and Hemicellulose.

Determination of Vitamin C

Vitamin C was determined using UV/VIS Spectrophotometer at 550nm (Revanasiddappa and Veena, 2008).

Sample preparation

The DCAP sample was ground in a mortar to pass through 2mm sieve; 30g was measured and mixed with water and shaken thoroughly for 20 minutes, the water was made up to 100ml, mixed well and filtered using Whatman filter paper.

Procedure for analysis

From the filtrate, 1ml was taken with a pipette into 10ml flask, 0.8ml 10ppm $K_2Cr_2O_2$ solution and 1ml of 1MH_2SO_4 were added and allowed to stand for 10minutes. 1.0ml of DPC was added and the content was made up to the mark with distilled water. The absorbance of the coloured species was measured against the distilled water using Buck AAS Spectrophotometer.

Some phytochemicals of DCAP

Determination of tannin

Sample preparation

The dried sample was ground to pass through 2mm sieve. 20ml of cold methanol was added to the sample for extraction. This was shaken and centrifuged for 10 minutes and filtered. This was done in two replicates.

Procedure for analysis

5ml of the filtrate was measured into a 50ml flask, 0.3ml of Folin D reagent was added then 0.6ml Na_2CO_3 solution was added. It was allowed to stand for about 30 minutes then the absorbance of blue colour was read. This was carried out in duplicate.

Tannin was determined by reading the concentrations of tannin in the extract at an absorbance of 760nm in a spectrophotometer according to AOAC (1984). Calculation

$$Tannins\ (ppm) = \frac{absorbance \times extract\ ratio \times slope\ gradient}{weigh\ \ sample}$$

Determination of flavonoid

Sample preparation

The DCAP sample was ground finely; 5g was weighed and extracted with 50ml of HCl. It was boiled for 30minutes, cooled and filtered.

Flavonoid was determined gravimetrically according to the method of Harbone (1973). It is calculated by: $Flavonoids\ (\%) = \frac{W2-W1}{W0} \times 100$

Where

W0= the weight of sample

W1= the weight of empty filter paper

W2= the weight after oven-drying

Determination of oxalate

Sample preparation

The DCAP sample was ground to pass through 2mm sieve. 2g of the sample was weighed and digested with 10ml of 6M HCl for 1hour; it was filtered and made up to 50 ml in a conical flask.

Oxalate was determined using titrimetric method (Zarembski and Hodgkinson, 1962) using 6M HCl, conc. Ammonium hydroxide (NH_4OH), 5% Calcium hydroxide (CaOH), 20% H_2SO_4, 0.05$KMnO_4$

Calculation: $Oxalate\ (\%) = \frac{Molarity\ of\ KMnO_4 \times T \times 60}{Weig\quad of\ sample \times aliquot\ taken} \times 100$

Where T= Titre value (blank sample)

Determination of alkaloids

Alkaloids were determined using gravimetric method (Harborne, 1973).

Sample preparation

5g of sample was weighed into a 250ml flask, 100ml of 10% acetic acid in ethanol was added and allowed to stand for 4hours and filtered. This was concentrated to about ¼ of its original size by evaporation

Analysis

The concentrated filtrate was treated with a drop wise addition of NH_4OH to precipitate the alkaloid, this was then filtered in a weighted filter paper. The filter paper was dried in the oven and calculations done as shown below.

Calculation: $Alkaloids\ (\%) = \frac{W2-W1}{W0} \times 100$

Where

W0=the weight of sample

W1=the weight of empty filter paper

W2=the weight after oven-drying

Determination of Minerals-

Minerals were determined using AOAC methods. Sodium was determined by digesting the sample with perchloric and nitrc acid using the method of AOAC 2005 (975.11), Phosphorus by spectrophotometric method (965.16 2003) while Calcium, Iron and Zinc were dertermined by method 975.23 (2005).

Sample preparation

The samples were pounded using mortar and pestle, about 1g of each was dried in oven at 105^0C and put in furnace overnight at 550^0C to ash. 0.5g of each was taken into 100ml digestion tube, 5ml of concentrated nitric acid was added and samples were digested for 90minutes at 130^0C. The digested samples were filtered into a 25ml flask and made up to the mark with distilled water. The samples were read on Atomic Absorption Spectrophotometer. Each sample was replicated twice.

Determination of Amino Acids

Sample preparation

The DCAP sample was milled to particle size 2mm, packaged and sent to the laboratory.

Analysis

Amino acid profile of dried cashew apple pomace was determined by Total Amino Acid Analysis (ISO 17025:2005) at AltaBioscience (UK) after acid hydrolysis for 24 hours at 110^{o}C using High Performance Liquid Chromatography (HPLC).

The proteins and/or peptides in the sample are hydrolysed by acid into individual amino acids.The extract which is made up of free amino acids is then separated into its components using a sodium citrate buffer system prior to detection.

Determination of other chemical constituents

Preparation of sample

The DCAP sample was milled to particle size 2mm, packaged and sent to the laboratory

Analysis

Analysis was carried out by ALS Food and Pharmaceutical West Yorkshire, UK.

Total carbohydrate was and available carbohydrate was determined and total sugars expressed as glucose. Total dietary fibre was determined by enzymatic gravimetric method of AOAC 1985 (985.29), Saturated Fatty Acids, Monounsaturated Fatty Acids and Polyunsaturated Fatty Acids were also determined.

3.1.2 Determination of Metabolisable Energy (ME)

Experimental site was the Teaching and Research Farm of the University of Ibadan, Ibadan Nigeria. Thirty-two 16 weeks old cockerels were procured from a commercial farm in Ibadan, sixteen of these were randomly selected and trained to consume 100g of feed in 1 hour (Farrel, 1977) within 10 days. Sixteen birds which consumed more than 80g in 1 hour were used for this experiment.

Growers' mash was formulated with 17.80% CP and 2504.6 kcal/kg ME as reference diet. Fifty percent of the reference diet was substituted with DCAP for the test diet. Eight birds for reference diet and 8 birds for test diet were fed within one hour, record of feed intake and excreta outpu t within 24 hours were taken. Gross energy of feed, sample ingredient, test diet and excreta were determined using adiabatic bomb calorimeter (Parr Model 6200 Isoperibol Calorimeter). Nitrogen content of the feed and feacal sample was determined by Khjedahl method. (Table3.1) shows the gross composition of the basal diet fed to cockerels. Metabolisable energy was calculated using the formula of Matterson *et al.* (1965)

3.2 Study Two: Growth, haematology, intestinal measurements and carcass characteristics of broilers fed DCAP in replacement for maize

Experimental site

This study was carried out at the Teaching and Research Farm, University of Ibadan.

Experimental animals

A total of 400 one-day-old Arbor Acre Plus unsexed broiler chicks were obtained from CHI Farm in Ibadan. The one-day old chicks were randomly allotted to five treatment groups of eight replicates each and ten birds per replicate. The poultry house which was partitioned into 40 pens was cleaned, sanitized, fumigated and rested for one week before the arrival of the day-old-chicks. Each replicate was housed in a wood shavings littered pen and were brooded accordingly.

Experimental diets and layout

Five broiler starter and finisher diets were prepared containing 0, 5, 10, 15 and 20% DCAP in replacement for maize. The dietary compositions are shown in Tables 3.2 and 3.3 for both phases respectively. Feed and water were made available *ad libitum.*

Treatment 1 – 0% DCAP

Treatment 2 - 5 % DCAP

Treatment 3 – 10% DCAP

Treatment 4 - 15% DCAP

Treatment 5 – 20% DCAP

Table 3.1 Gross composition of basal diet fed cockerels

Ingredients	%
Maize	45.80
Soybeanmeal	17.00
Wheat bran	22.50
Palm Kernel cake	11.00
Di-calcium Phosphate	1.30
Limestone	1.70
Salt	0.25
Vitamin/mineral premix	0.25
Methionine	0.15
Total	100.00
Calculated analysis	2570.00
ME kcal/kg	2570.00
Crude Protein (%)	17.80
Crude Fibre (%)	0.93
Calcium (%)	0.93
Available Phosphorus	0.43
Lysine	0.94
Methionine	0.40

2.5kg of Premix contains:, Vitamin A -12,500,000.00 I.U., Vitamin D3- 2,500,000.00I.U., Vitamin 0.00, Iron 100,000.00mg, Zinc80,000.00, Copper8,500mg, Iodine 1,500.00mg, Cobalt 300.00mg, Selenium 120.00mg, Anti-oxidant120,000.00mgE- 40,0000.00mg, Vitamin K 2.000.00mg, Vitamin B1- 3,000.00mg, Vitamin B2 – 5,5000.00mg,, Niacin – 55,000.00, Calcium Pantothenate – 11,500.00mg , Vitamin B12 – 25.00, Choline Chloride500,000.00mg, Folic acid1,000.00, Biotin 80.00mg, Manganese 120,00Vitamins and Trace Minerals Vitamin 0.00, Iron 100,000.00mg, Zinc 80,000.00, Copper8,500mg, Iodine 1,500.00mg, Cobalt 300.00mg, Selenium 120.00mg, Anti-oxidant120,000.00mg

Calculation of metabolizable energy

$$\text{AME of diet} = \frac{(\text{Feed intake X GE diet}) - (\text{Excreta output X GE excreta})}{\text{Feed Intake}}$$

$$\text{AME}_n \text{ of diet} = \frac{(\text{Feed intake X GE diet}) - (\text{Excreta output X GE excreta}) \text{ N retained X 8.22kcal.}}{\text{Feed Intake}}$$

$$\text{AME}_n \text{of feedstuff} = \text{AME}_n \text{basal diet} + \frac{\text{AMEn test diet} - \text{AME}_n \text{basal diet}}{\text{\%test ingredient on basal diet g/kg/100}}$$

Where

AME – apparent metabolizable energy

AME_n – Nitrogen corrected AME

GE – gross energy

bd – basal diet

td – test diet

ti – test ingredient

Table 3.2 Gross composition of starter diets of broiler chickens fed dried cashew apple pomace in replacement for maize

Ingredients kg/100kg	Dried cashew apple pomace %				
	0	5	10	15	20
Maize	54.55	51.82	49.09	46.42	43.64
Dried cashew apple pomace	0	2.73	5.46	8.13	10.91
Soybean meal	36.00	36.00	36.00	36.00	36.00
Fish meal	3.00	3.00	3.00	3.00	3.00
Soya oil	3.00	3.00	3.00	3.00	3.00
Di-calcium Phosphate	2.00	2.00	2.00	2.00	2.00
Vitamin/Mineral premix	0.25	0.25	0.25	0.25	0.25
Methionine	0.15	0.15	0.15	0.15	0.15
Lysine	0	0	0	0	0
Limestone	0.80	0.80	0.80	0.80	0.80
Salt	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100
Calculated analysis					
Metabolisable energy kcal/kg	2984.83	2959.69	2934.56	2909.42	2884.29
Crude Protein%	22.91	23.01	23.11	23.20	23.30
Fat	3.58	3.61	3.64	3.67	3.70
Crude Fibre	3.74	3.93	4.21	4.31	4.50
Calcium	1.01	1.01	1.02	1.03	1.03
Non-Phytate Phosphorus (NPP)	0.81	0.81	0.80	0.80	0.79
Calcium:NPP	2.10	2.12	2.14	2.16	2.17

Micro-Mix Broilers and Chicks. Vitamins and Trace Minerals Declaration : 2.5kg of Premix contains:, Vitamin A -12,500,000.00 I.U., Vitamin D3- 2,500,000.00I.U., Vitamin E- 40,0000.00mg, Vitamin K3- 2.000.00mg, Vitamin B1- 3,000.00mg, Vitamin B2 – 5,5000.00mg,, Niacin – 55,000.00, Calcium Pantothenate – 11,500.00mg , Vitamin B12 – 25.00, Choline **Chloride500,000.00mg, Folic acid 1,000.00, Biotin 80.00mg, Manganese 120,000.00, Iron 100,000.00mg, Zinc 80,000.00, Copper 8,500mg, Iodine 1,500.00mg, Cobalt 300.00mg, Selenium** 120.00mg, Anti-oxidant120,000.00mg

Table 3.3 Gross composition of finisher diets of broiler chickens fed dried cashew apple pomace in replacement for maize

	Dried cashew apple pomace (%)				
Ingredients kg/100kg	0	5	10	15	20
Maize	58.00	55.15	52.25	49.35	46.48
Dried cashew apple pomace	0	2.90	5.80	8.70	11.60
Soybean meal	34.00	34.00	34.00	34.00	34.00
Fish meal	0.40	0.40	0.40	0.40	0.40
Soya oil	4.10	4.10	4.10	4.10	4.10
Di- calcium Phosphate	2.00	2.00	2.00	2.00	2.00
Limestone	0.80	0.80	0.80	0.80	0.80
Vitamin/Mineral Premix	0.25	0.25	0.25	0.25	0.25
Methionine	0.15	0.15	0.15	0.15	0.15
Lysine	0	0	0	0	0
Salt	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100
Calculated analysis					
Metabolisable Energy kcal/kg	3083.16	3056.71	3029.71	3002.89	2976.26
Crude Protein	20.47	20.58	20.68	20.79	20.89
Fat	3.53	3.56	3.60	3.63	3.66
Crude Fibre	3.66	3.86	4.06	4.27	4.68
Calcium	0.87	0.87	0.88	0.89	0.90
Non-Phytate Phosphorus (NPP)	0.73	0.73	0.72	0.72	0.71
Calcium:NPP	1.82	1.84	1.86	1.88	1.90

Micro-Mix Broilers and Chicks. Vitamins and Trace Minerals Declaration : 2.5kg of Premix contains:, Vitamin A -12,500,000.00 I.U., Vitamin D3- 2,500,000.00I.U., Vitamin E- 40,0000.00mg, Vitamin K3- 2.000.00mg, Vitamin B1- 3,000.00mg, Vitamin B2 – 5,5000.00mg,, Niacin – 55,000.00, Calcium Pantothenate – 11,500.00mg , Vitamin B12 – 25.00, Choline Chloride 500,000.00mg, Folic acid1,000.00, Biotin 80.00mg, Manganese 120,000.00, Iron 100,000.00mg, Zinc 80,000.00, Copper 8,500mg, Iodine 1,500.00mg, Cobalt 300.00mg, Selenium 120.00mg, Anti-oxidant120,000.00m

Experimental design

The experimental design was Completely randomized design.

Collection of data

Feed Intake

Feed served was weighed. Leftover feed was collected and weighed.

FI (Feed intake) = Feed served – Leftover feed

This was expressed as starter phase feed intake, finisher phase feed intake and overall feed intake.

Weight Gain

Birds were tagged and weighed individually at the beginning of the experiment. Subsequently, they were weighed on weekly basis. The weekly weights were subtracted from the previous to get the weekly weight gain, initial weight was subtracted from day 21 to get starter phase weight gain, day 21 weight subtracted from day 42 to get finisher phase weight gain and initial weight was subtracted from day 42 weight to get overall weight gain.

Sample collection for haematological and serum parameters

Blood samples were collected from the jugular veins of two birds per replicate which were randomly selected from each treatment at the end of the starter and finisher phases of the experiment. The birds were fasted overnight; 5mls of blood was collected from each bird using needle and syringe. This was shared into two bottles, an EthyleneDiamine Tetra Acetic Acid (EDTA) bottle and a sterile plain bottle. Each bottle was labeled according to the tag number of each bird. The samples in EDTA bottles were used for haematological analysis while the ones in sterile bottles were centrifuged and serum was decanted and stored in the freezer at -4°C for further analysis.

Carcass characteristics

On day 21, two birds per replicate that had been fasted overnight were randomly selected and their live weights were recorded. The birds were slaughtered and carcass measurements such as eviscerated weight, dressed weight, primal cuts and organs were recorded relative to the live weight of the bird. The same procedure was followed for the same number of birds on day 42.

Intestinal measurements

Measurements of intestinal parts such as jejunum, duodenum, ileum, ceaca, pancreas and total gastro-intestinal tract were taken and recorded using the meter tape. The measurements were taken on day 21 and day 42.

pH of organs

At the end of the starter phase (day 21), a pH meter was calibrated and pH of the digesta in the following parts was taken: ceaca, duodenum, proventriculus, jejunum, gizzard and ileum.

Proximate composition of feed

Proximate composition of the feed for starter and finisher phases were determined by AOAC (1990) method.

Cost Analysis

The cost of the feed formulated for the experiment was analysed.

Statistical analysis

Data collected were analyzed using one-way ANOVA and means were separated by Duncan Multiple Range Test using SPSS Version 17 at α0.05. Regression analysis was carried out for fees cinversion ratio.

3.3 Study three: Effect of exogenous enzyme on the utilisation of dried cashew apple pomace in broiler chicken diets

Experimental site

The study was carried out at the Teaching and Research Farm, University of Ibadan, Ibadan, Nigeria.

Experimental animals and management

A total of two hundred and eighty-eight unsexed Arbor Acre Plus broiler chicks were obtained from CHI Farm, Ibadan. The one-day-old chicks were randomly allotted to six treatments and replicated six times in a 2x3 factorial arrangement in a completely randomized design. There were eight birds per replicate.

Six diets each were formulated for starter and finisher phase, three levels of 0%, 15% and 30% DCAP replacement for maize without enzymes, another three levels of 0%, 15% and 30% DCAP replacement for maize with enzyme. The enzyme used was a multienzyme named NATUZYME and contained amylase α-amylase (400,000Ukg^{-1}) from *Bacillus subtillis,* β-glucanase (700,000 Bioproton bukg^{-1}) from *Trichoderma longibrachiatum*, phytase (1,300,000ukg^{-1}) *Aspergillus niger,* cellulase (6,000,000 Bioproton cukg^{-1}) from *Trichoderma longibrachiatum* , xylanase (10,000,000Bioproton xukg^{-1}) from *Trichoderma longibrachiatum* and protease (700,000Ukg^{-1}) .Gross composition of starter and finisher diets are as shown in Table 3.4 and 3.5 respectively.

Data collection

Feed Intake

Feed served was weighed. Leftover feed was collected and weighed.

FI (Feed intake) = Feed served – Leftover feed

This was expressed as starter phase feed intake, finisher phase feed intake and overall feed intake.

Weight Gain

Birds were tagged and weighed individually at the beginning of the experiment. Subsequently, they were weighed on weekly basis. The weekly weights were subtracted from the previous to get the weekly weight gain, initial weight was subtracted from day 21 to get starter phase weight gain, day 21 weight subtracted from day 42 to get finisher phase weight gain and initial weight was subtracted from day 42 weight to get overall weight gain.

Feed conversion ratio

Feed conversion ratio was calculated from the feed intake and weight gain.

Digestibility study

At three and six weeks, two birds per replicate for each treatment were selected and transferred to the metabolic cage. They were adjusted to the cage for three days and feacal samples were collected over a three-day period. The feacal samples collected were weighed and oven dried at 55^{o}C. Chemical analysis of droppings and feed was carried out according to AOAC (1990). Digestibility coefficients of dry matter, crude protein, crude fibre, ether extract, ash and nitrogen free extracts were determined.

Haematology and serum parameters

At the end of the starter phase, 5mls of blood sample was collected from the neck vein of a total of ten birds per treatment. About 2.5mls of the blood was put into labeled EDTA bottles while the remaining was poured into ordinary sample bottles and were kept for haematological and serum biochemical analysis respectively.

Carcass characteristics

At the end of the starter phase, the birds were fasted overnight; ten birds per treatment (two birds per replicate) were randomly selected, weighed and slaughtered by cutting transversely across the trachea, oesophagus, large carotid arteries and jugular veins to ensure maximum bleeding. The carcasses were defeathered, eviscerated and cut in pieces for yield and organ weight determination. Weights were recorded as follows: thigh, breast, intestine, heart, liver, gizzard and empty gizzard. At the end of the finisher phase, the same procedure as above was followed for slaughtering and records were taken for the following: dressed weight, thigh, drumstick, breast, liver, gizzard, empty gizzard and lining, empty gizzard without lining, intestine, empty intestine and heart.

Intestinal pH

pH of digesta of different parts (ceaca, duodenum, proventriculus, jejunum, gizzard and ileum) of the gastro- intestinal parts was taken using the pH meter.

Intestinal length

Measurements of intestinal parts such as jejunum, duodenum, ileum, ceaca, pancreas and total gastro-intestinal tract were taken and recorded using the metre tape. The measurements were taken on day 21 (starter phase) and day 42 (finisher phase).

Cost analysis

The cost of feed was calculated using the prevailing prices of ingredients at the time the experiment was performed. Dry cashew apple pulp was being requested for at a farm gate price of ₦30/kg.

Statistical analysis

Data was analysed using descriptive statistics and orthogonal contrasts.

Table 3.4 Gross compositions of starter diets of broiler chickens fed dry cashew apple pomace in replacement for maize with or without enzyme

	Dried cashew apple pomace (%)					
`	NE	WE	NE	WE	NE	WE
Ingredient (kg/100kg)	0		15		30	
Maize	54.55	54.51	46.38	46.34	38.19	38.15
Dried cashew apple pomace	0.00	0.00	8.17	8.17	16.36	16.36
Soyabean meal	36.00	36.00	36.00	36.00	36.00	36.00
Fishmeal	3.00	3.00	3.00	3.00	3.00	3.00
Soyaoil	3.00	3.00	3.00	3.00	3.00	3.00
Dicalcium Phosphate	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin/mineral premix	0.25	0.25	0.25	0.25	0.25	0.25
Limestone	0.80	0.80	0.80	0.80	0.80	0.80
Methionine	0.15	0.15	0.15	0.15	0.15	0.15
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Natuzyme multienzyme	0.00	0.04	0.00	0.04	0.00	0.04
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis						
Metabolisable Energy kcal/kg	2984.83	2984.83	2909.42	2909.42	2834.01	2834.01
Crude Protein %	22.91	22.91	23.20	23.20	23.50	23.50
Fat %	3.58	3.58	3.67	3.67	3.76	3.76
Crude Fibre %	3.74	3.74	4.22	4.22	4.88	4.88
Calcium	1.01	1.01	1.03	1.03	1.05	1.05
Total Phosphorus	0.81	0.81	0.80	0.80	0.78	0.78
Non-Phytate Phosphorus	4.79	4.79	4.76	4.76	4.72	4.72

Micro-Mix Broilers and Chicks. Vitamins and Trace Minerals Declaration : 2.5kg of Premix contains:, Vitamin A -12,500,000.00 I.U., Vitamin D3- 2,500,000.00I.U., Vitamin E- 40,0000.00mg, Vitamin K3- 2.000.00mg, Vitamin B1- 3,000.00mg, Vitamin B2 – 5,5000.00mg,, Niacin – 55,000.00, Calcium Pantothenate – 11,500.00mg , Vitamin B12 – 25.00, Choline Chloride500,000.00mg, Folic acid1,000.00, Biotin 80.00mg, Manganese 120,000.00, Iron 100,000.00mg, Zinc80,000.00, Copper8,500mg, Iodine 1,500.00mg, Cobalt 300.00mg, Selenum 120.00mg, Anti-oxidant120,000.Multienzyme Feed Supplement: Each gram contains not less than Alpha amylase/Baccillussubtilis (400U/g), Beta-Glucanase/Trichodermalongibranchiatum (700 Bioprotonbu/g),Phytase/Aspergillusniger (1300u/g),Cellulase/Trichodermalongibrachiatum(6000 Bioproton cu/g),Xylanase/longibrachiatum(10000 Bioprotonxu/g),Protease/Aspergillusniger (700U/g).

NE – No enzyme, WE – With enzyme,

Table 3.5 Gross compositions of finisher diets of broiler chickens fed dry cashew apple pomace in replacement for maize with or without enzyme

	%DCAP					
	NE	WE	NE	WE	NE	WE
Ingredient(kg/100kg)	0		15		30	
Maize	58.05	58.01	49.34	49.30	40.63	40.59
Dry cashew apple pomace	0.00	0.00	8.71	8.71	17.42	17.42
Soyabean meal	34.00	34.00	34.00	34.00	34.00	34.00
Fishmeal	0.40	0.40	0.40	0.40	0.40	0.40
Soya oil	4.10	4.10	4.10	4.10	4.10	4.10
Dicalcium Phosphate	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin/mineral premix	0.25	0.25	0.25	0.25	0.25	0.25
Limestone	0.80	0.80	0.80	0.80	0.80	0.80
Methionine	0.15	0.15	0.15	0.15	0.15	0.15
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Multienzyme	0.00	0.04	0.00	0.04	0.00	0.04
TOTAL	100.00	100.00	100	100	100	100
Energy kcal/kg	3083.16	3083.16	3002.89	3002.89	2976.26	2976.26
Crude Protein	20.47	20.47	20.79	20.79	21.10	21.10
Fat	3.53	3.53	3.63	3.63	3.73	3.73
Crude Fibre	3.66	3.66	4.27	4.27	4.87	4.87
Calcium	0.87	0.87	0.89	0.89	0.86	0.91
Total Phosphorus	0.73	0.73	0.71	0.71	0.70	0.70
Non-phytate P	0.48	0.48	0.47	0.47	0.47	0.47
Ca:NPP	1.82	1.82	1.83	1.83	1.84	1.84

Micro-Mix Broilers and Chicks. Vitamins and Trace Minerals Declaration : 2.5kg of Premix contains:, Vitamin A -12,500,000.00 I.U., Vitamin D3- 2,500,000.00I.U., Vitamin E- 40,0000.00mg, Vitamin K3- 2.000.00mg, Vitamin B1- 3,000.00mg, Vitamin B2 – 5,5000.00mg,, Niacin – 55,000.00, Calcium Pantothenate – 11,500.00mg , Vitamin B12 – 25.00, Choline Chloride500,000.00mg, Folic acid1,000.00, Biotin 80.00mg, Mangmdanese 120,000.00, Iron 100,000.00mg, Zinc80,000.00, Copper8,500mg, Iodine 1,500.00mg, Cobalt 300.00mg, Selenum 120.00mg, Anti-oxidant120,000.Multienzyme Feed Supplement: Each gram contains not less than Alpha amylase/Baccillussubtilis (400U/g), Beta-Glucanase/Trichodermalongibranchiatum (700 Bioprotonbu/g),Phytase/Aspergillusniger (1300u/g),Cellulase/Trichodermalongibrachiatum(6000 Bioproton cu/g),Xylanase/longibrachiatum(10000 Bioprotonxu/g),Protease/Aspergillusniger (700U/g)

DCAP – dried cashew apple pomace, Ca – Calcium, NPP – Non-phytate Phosphorus, NE – No enzyme, WE – With enzyme, ME – metabolsable energy

3.4 Study Four: Shelf life of dried cashew apple pomace

Experimental site

This study was done at the Department of Animal Science, University of Ibadan, Ibadan, Oyo State, Nigeria.

Collection and preparation of sample

Cashew apples were collected after the removal of the nuts at Aremu Farms, Iwo, Osun State, Nigeria. The cashew apples were mechanically pressed to extract juice and the residue was sun-dried first for three days and later until constant moisture content was attained. Dry cashew apple pomace (DCAP) was stored using polyethylene sacks and plastic containers. The dried sample was mixed thoroughly and randomly shared into five polyethylene sacks and containers for the experiment. The experiment lasted between May 2017 and May 2018. There were two treatments, storage with plastic container and in polyethylene bag. Each treatment was replicated five times. Plate 3.1 shows cashew apple collected in a basket, Plate 3.2 shows cashew loaded on the mechanical press, Plate 3.3 shows cashew pomace on the drying floor while Plate 3.4 shows DCAP stored in plastic container and Plate 3.5 shows DCAP stored in polyethylene sack.

Plate 3.1 Cashew apples in a basket

Plate 3.2 Bagged cashew apples on a mechanical press

Plate 3.3. Cashew pomace on the drying floor

Plate 3.4 Dry cashew apple pomace stored in plastic containers

Plate 3.5 Dry cashew apple pomace in polyethylene sacks

Experimental design and layout

The experimental design was a completely randomized design.

Treatment 1 – Storage of DCAP in woven polyethylene sack

Treatment 2 – Storage of DCAP in plastic container

The parameters considered were

1. Proximate composition, which was monitored on a quarterly basis
2. Physico- chemical properties of DCAP. Bulk density was determined
3. Storage pest. Identification of the insect was done at the Department of Crop Protection of the University of Ibadan.
4. Insect count was done at the end of six months by taking batches of the Dry cashew apple pomace on white muslin cloth and individual counts were recorded. The samples were placed in the fridge for 3-5 minutes to prevent them from flying. Number of insects was reported as number per kg sample.
5. Determination of aflatoxin content by ELISA method

Statistical analysis

Data collected were subjected to regression analysis and T- test

CHAPTER FOUR

4.0 RESULTS

4.1 Study One: Chemical composition and metabolisable energy of Dry Cashew Apple Pomace (DCAP)

4.1.1 Chemical composition of DCAP

4.1.1.1 Proximate composition of DCAP

The proximate composition of DCAP is as shown in Table 4.1, the moisture content was 11.60±2.16%, crude protein, 12.60±1.26%, ether extract 5.14±0.02%, crude fibre 9.17±0.23%, ash 5.20%±1.27 nitrogen free extract 62.31±3.90% and gross energy 4227.55±5.45kcal/kg.

4.1.1.2 Fibre fractions of dried cashew apple pomace

The fibre fraction is as shown in Table 4.2, neutral detergent fibre 35.46±0.11, acid detergent fibre (ADF) 23.32±0.16%, acid detergent lignin 18.8±0.15%, cellulose 7.3±0.49% and hemicellulose 12.3±0.78%.

4.1.1.3 Amino acid content of DCAP

Amino acid result of DCAP is shown on Table 4.3 with threonine 5.76, serine 6.46, glutamic acid 12.4, proline 3.87, glycine 4.42, alanine 4.59, cysteine 0.65, valine 4.96, methionine 1.99, isoleucine 4.45, leucine 7.21, tyrosine 3.35 and phenylalanine 4.33.

4.1.1.4 Other chemical constituents of DCAP

Total carbohydrate was 70.6g/100g, available carbohydrate 47.2g/100g, total sugars (expressed as glucose) 8.9g/100g, total dietary fibre 47.2g/100g, saturated fatty acids 1.15g/100g, monosaturated fatty acids 3.13g/100g , polyunsaturated fatty acids 0.31g/100g, fibre and fat is shown in Table 4.4.

Vitamin C and mineral composition of the DCAP is shown on Table 4.4, Vitamin C 3.26 ± 0.44mg/100g, Calcium 0.12%±0.02, Sodium 107 mg/kg, Iron 339.75mg/kg±4.75, Zinc 34.76±2.01mg/kg and Phosphorus 19.01±1.01mg/kg. The phytochemicals determined include tannin, which was below detectable quantity, flavanoid, 2.80mg/g, alkaloid, 2.85mg/g and saponin 1.80mg/g

Table 4.1 Proximate composition of dried cashew apple pomace

Parameters	%Dry Matter
Dry matter	88.40±2.05
Moisture content	11.60±2.05
Crude protein	12.60±1.26
Ether extract	5.14±0.23
Crude Fibre	9.17±0.23
Total ash	5.88±0.46
Nitrogen Free Extract	67.21±2.18
Gross energy (kcal/kg)	4227.55±5.45

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Table 4.2 Fibre fractions of dried cashew apple pomace

Parameter	Value (%)
Neutral detergent Fibre (NDF)	35.46±0.11
Acid Detergent Fibre (ADF)	23.32±0.16
Acid detergent lignin (ADL)	18.80±0.15
Cellulose	7 .32±0.49
Hemicellulose	12.34±0.78

Table 4.3 Amino acid constituents of dried cashew apple pomace

Amino Acid	µg/mg
Cysteic acid	-
Hydroxyproline	-
Aspartic acid	9.93
Threonine	5.76
Serine	6.46
Glutamic acid	12.4
Proline	3.87
Glycine	4.42
Alanine	4.49
Cysteine	0.65
Valine	4.96
Methionine	1.99
Isoleucine	4.45
Leucine	7.21
Tryosine	3.35
Phenylalanine	4.33
Histidine	3.20
Tryptophan	-
Lysine	4.96
Arginine	4.61

Table 4.4 Other Chemical constituents of dried cashew apple pomace

Parameters	Value
Total Carbohydrate (g/100g)	70.60
Total dietary fibre (g/100g)	47.20
Available Carbohydrate (g/100g)	23.40
Total Sugars (expressed as glucose) (g/100g)	8.90
Sodium	10.70
Calcium	2.74
Phosphorus (mg/kg)	0.42
Iron (mg/kg)	339.75
Zinc (mg/kg)	36.21
Saturated Fatty acids (g/100g)	1.15
Monounsaturated Fatty Acids (g/100g)	3.13
Polyunsaturated Fatty Acids(g/100g)	0.31
Vitamin C (mg/100g)	3.26
Tannin	Not Detectable
Flavonoid (mg/g)	2.80
Alkaloid (mg/g)	2.85
Saponin (mg/g)	1.80
Phytate(mg/100g)	0.10
Oxalate (%)	0.05

4.1.2Metabolisable energy of DCAP

The metabolisable energy derived from *in-vivo* assay with cockerel was 2428.51 Kcal/kg is as shown in Table 4.5

4.2 Growth, haematology, intestinal measurement and carcass characteristics of broiler chickens fed dried cashew apple pomace in replacement for maize.

4.2.1 Proximate composition of diets

Proximate composition of starter diets of broiler chickens fed DCAP in replacement for maize at 0, 5, 10, 15 and 20% inclusion level is shown in Table 4.6 while proximate composition of finisher diets of broiler chickens fed DCAP in replacement for maize at the same level as the starter phase is shown in Table 4.7

Table 4.5 Apparent metabolisable energy of dried cashew apple pomace in poultry

Parameter	kcal/kg
AMEn	2428.51±273

kg – kilogram, kcal - kilocalorie

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Table 4.6 Proximate composition of starter diets of broiler chickens fed dry cashew apple pomace in replacement for maize

Parameter	Dry Cashew Apple Pomace (%)				
	0	5	10	15	20
Dry Matter	91.07	92.89	93.01	93.77	94.20
Crude Protein	22.58	23.60	23.71	23.73	23.77
Ash	3.00	3.33	4.45	4.43	4.47
Ether Extract	4.20	3.23	3.52	3.50	5.00
Crude Fibre	3.70	6.03	4.94	3.22	4.32
Nitrogen Free Extract	57.59	56.70	56.39	58.89	56.64

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Table 4.7 Proximate composition of finisher diets of broiler chickens fed dry cashew apple pomace in replacement for maize

Parameters	Dry Cashew Apple Pomace (%)				
	0	5	10	15	20
Dry Matter	91.24	91.03	91.44	92.01	94.51
Crude Protein	20.08	20.11	21.07	21.27	21.52
Ash	5.10	5.60	5.53	5.46	6.70
Ether extract	3.54	4.56	3.94	4.00	3.50
Crude Fibre	5.80	4.68	4.20	2.78	2.00
Nitrogen Free Extract	56.72	56.08	56.70	58.50	60.79

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4.2.2 Performance characteristics of broiler chickens fed DCAP in replacement for maize

There was no significant difference in feed intake at the starter or finisher phase and entire rearing period. The same is true for weight gain. Feed conversion ratio (FCR) showed no significant difference at the starter phase. However, there was significant difference at the finisher phase and overall performance. Feed conversion ratio increased with increasing DCAP except at 10% inclusion for the finisher phase. The observation was that 20% inclusion had a significantly higher ($P \leq 0.05$) FCR than 0% inclusion though similar to 5%, 10% and 15% inclusion. However FCR obtained at 0% inclusion was similar to that obtained at 5%, 10% and 15% DCAP inclusion at the finisher phase and for the entire feeding period. This is as shown on Table 4.8

Figure 4.1 shows the linear regression for feed conversion ratio when DCAP was replaced with maize at 0, 5, 10, 15 and 20%. As the DCAP content increased, FCR also increased with an equation $y= 0.026x + 2.264$ and $R^2= 0.961$

4.2.3 Cost analysis of broiler chicken fed DCAP in replacement for maize

Feed cost per bird and cost of feed per kilogramme gain is shown in Table 4.9. Dry cashew apple cost/kg was ₦30 which was lower than maize (₦80/kg). The inclusion of DCAP in the diets of broiler chickens at the starter phase had no significant effect on the cost of feed. The DCAP replacement of maize significantly increased the cost of feed consumed per bird except at 5% replacement which did not differ from the control and 10% replacement which was lower than the cost of feed for the control. There was increased cost of feed for the whole rearing period although no particular trend was followed, 5% and 10% replacement of DCAP for maize was not significantly different from the control contrary to 15% and 20% replacement.

The cost of producing 1kg of chicken ranged between ₦315.18 - ₦360.61, ₦321.60 - ₦377.98 and ₦647.92 - ₦725.24 respectively for 1 – 3 weeks, 4 – 6 weeks and 1- 6 weeks but DCAP did not have any significant effect.

Table 4.8 Performance characteristics of broilers fed dry cashew apple pomace in replacement for maize

Parameters	Dry Cashew Apple Pomace (%)						
	0	5	10	15	20	SEM	P value
Feed intake (g)							
1-3 weeks	723.35	761.89	765.56	766.61	748.77	6.40	0.16
4-6 weeks	1843.48	1995.80	1882.71	2107.41	2149.09	46.59	0.15
1-6 weeks	2566.83	2757.69	2648.64	2874.02	2897.84	46.22	0.09
Weight gain (g)							
1-3 weeks	362.91	375.89	325.08	350.21	329.36	8.30	0.26
4-6 weeks	764.40	692.69	745.53	748.40	684.61	15.92	0.40
1-6 weeks	1136.82	1125.90	1080.60	1084.85	1038.17	11.33	0.07
Feed Conversion Ratio							
1-3 weeks	2.02	2.08	2.36	2.32	2.32	0.05	0.18
4-6 weeks	2.42^{b}	2.90^{ab}	2.56^{b}	2.89^{ab}	3.24^{a}	0.09	0.05
1-6 weeks	2.24^{b}	2.46^{b}	2.48^{ab}	2.67^{ab}	2.80^{a}	0.05	0.02

Means with different superscripts are significantly different along the same row (P<0.05)

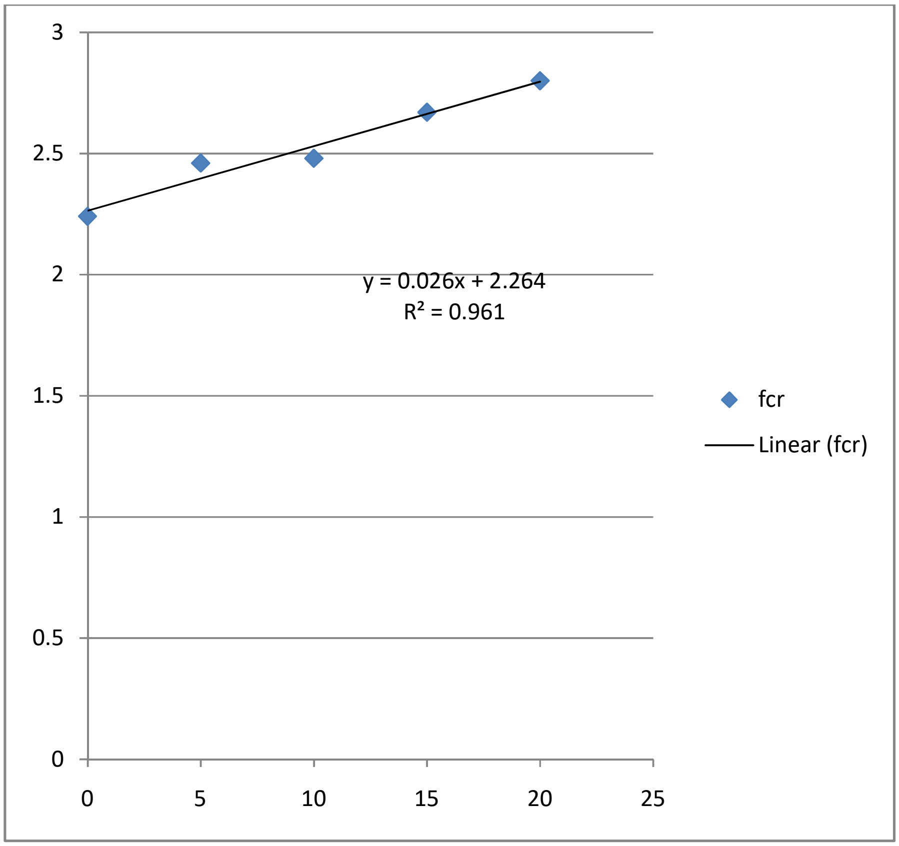

Figure 4.1 Linear regression of dry cashew apple pomace (DCAP) replacement for maize (%) over Feed Conversion Ratio (FCR)

x- axis - % replacement of DCAP for maize

y- axis – Feed Conversion Ratio

Table 4.9 Cost analysis of birds fed dry cashew apple pomace in replacement for maize

Parameter	Dry Cashew Apple Pomace (%)					SEM	P value
	0	5	10	15	20		
Feed cost(₦)/bird							
1-3weeks	112.45	117.23	116.59	115.56	111.66	0.963	0.254
4-6weeks	265.46[a]	284.02[ab]	264.77[a]	317.67[b]	320.49[b]	7.303	0.017
1-6weeks	377.91[a]	401.26[ab]	381.35[a]	433.23[b]	432.16[b]	7.137	0.016
Cost/gain (₦/kg)							
1-3 weeks	315.18	319.96	360.61	334.47	347.26	7.710	0.318
4-6 weeks	332.74	351.42	321.60	368.30	377.98	8.868	0.228
1-6 weeks	647.92	671.38	682.21.	702.77	725.24	12.382	0.345

DCAP – Dry cashew apple, ₦ - Naira, [ab]Means with different superscript along the same row are significantly different P≤0.05).

4.2.4 Haematological parameters of broiler chickens fed DCAP in replacement for maize

The haematological parameters of broiler chickens fed DCAP in replacement for maize at the starter phase (Table 4.10) showed no significant difference in Packed Cell Volume, Haemoglobin, Red Blood Cell, White Blood Cell, Platelet, lymphocyte, heterocyte and eosinophil for all the levels of inclusion while 15% and 20% inclusion of DCAP were significantly higher than 0% inclusion though similar to 5% and 10% inclusion of DCAP at $P \leq 0.05$.

The result for finisher phase (Table 4.11) revealed significantly higher values in packed cell volume ($P \leq 0.05$) at 0%, 5% and 20% inclusion of DCAP than 10%, though similar to 15% DCAP replacement for maize. Haemoglobin at 0%, 5% and 20% DCAP replacement for maize was observed to be significantly higher ($P \leq 0.05$) than 10% and15% DCAP in replacement for maize.

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Table 4.10 Haematological parameters of broiler chickens fed dry cashew apple pomace in replacement for maize (starter phase)

Parameter	Dry cashew apple pomace (%)					
	0	5	10	15	20	SEM
PCV	29.71	29.88	28.13	27.00	28.33	0.41
Haemoglobin	9.60	9.78	9.19	8.64	9.25	0.14
RBC	3.33	3.46	3.33	2.86	3.23	0.08
WBC	1.68	1.56	1.59	1.71	1.70	0.40
Platelet	26.53	20.7	19.74	20.24	24.21	1.44
Lymphocyte	68.57	64.38	63.63	66.71	66.67	0.91
Heterocyte	27.71	62.50	29.50	25.29	26.44	7.15
Monocyte	2.57^{b}	3.00^{ab}	3.50^{ab}	3.86^{a}	4.00^{a}	1.09
Eosinophil	3.86	4.25	3.38	4.14	2.89	0.93

Means with different superscripts along the same row are significantly different ($P<0.05$)

Table 4.11 Haematological parameters of broiler chickens fed dry cashew apple pomace in replacement for maize (finisher phase)

Parameters	Dry Cashew Apple Pomace (%)					
	0	5	10	15	20	SEM
PCV	29.67^{a}	29.17^{a}	24.50^{b}	26.40^{ab}	29.13^{a}	0.55
Haemoglobin	9.50^{a}	9.33^{a}	7.67^{b}	8.20^{b}	9.37^{a}	0.20
RBC	3.55	3.28	2.10	2.89	3.36	0.66
WBCtx10^4	17.15	17.92	17.17	17.54	15.90	3.30
Plateletx10^4	18.93	16.85	17.17	17.43	14.36	3.80
Lymphocyte	59.67	58.00	54.33	57.50	57.25	7.35
Monocyte	3.00	3.17	3.67	3.50	3.00	1.08
Eosinophil	3.67	4.33	4.33	3.50	3.00	1.16

Means with different superscripts along the same row are significantly different ($P<0.05$)

4.2.5 Selected serum lipid profile of broiler chickens fed DCAP in replacement for maize

Cholesterol, triglyceride, HDL-C and LDL-C for starter and finisher phase showed no significant difference as shown on Table 4.12 and Table 4.13 respectively

Table 4.12 Selected serum lipid profile of broiler chickens fed dry cashew apple pomace in replacement for maize (starter phase)

Parameter	Dry Cashew Apple Pomace (%)					SEM	P value
(mg/dL)	0	5	10	15	20		
Cholesterol	181.89	132.16	170.58	126.79	119.69	9.763	0.129
Triglyceride	27.05	24.79	25.63	25.49	22.81	0.903	0.605
HDL-C	60.31	57.23	57.95	64.05	71.86	2.262	0.206
LDL-C	115.06	58.16	107.49	55.40	62.06	10.298	0.147

HDL-C – High density lipid cholesterol, LDL-C - Low density lipid cholesterol

Means are not significantly different at $P<0.05$

Table 4.13 Selected serum lipid profile of broiler chickens fed dry cashew apple pomace in replacement for maize (finisher phase)

Parameter (mg/dL)	Dry Cashew Apple Pomace (%)					SEM	P value
	0	5	10	15	20		
Cholesterol	108.55	89.37	134.63	112.52	98.81	5.404	0.102
Triglyceride	32.08	21.07	31.83	32.25	23.52	2.761	0.591
HDL-C	31.25	33.92	39.82	34.69	36.96	1.033	0.126
LDL-C	45.82	45.04	44.53	53.13	34.15	3.404	0.555

HDL-C - High density lipid cholesterol, LDL-C - Low density lipid cholesterol,
Means are not significantly different at P<0.05

4.2.6 Relative weights of some carcass parts and organs of birds fed dry cashew apple pomace

Starter phase relative weight (Table 4.14) of the breast showed no significant difference among the treatments while thigh revealed higher weight ($P \leq 0.05$) at 10% and 20% DCAP inclusion than 15% but similar to 0% and 5%.DCAP in replacement for maize. 15% DCAP was also similar to 0% and 5% DCAP.

Relative weights of gastro-intestinal tract, heart, liver and gizzard were similar for all the treatments while empty gizzard had significantly higher weight ($P \leq 0.05$) at 20% than at 0, 10 and 15% DCAP but not at 5% DCAP inclusion. 0, 10 and 15% inclusion were also similar to 5%DCAP inclusion.

At the finisher phase (Table 4.15), all the parameters (dressed weight, thigh, drumstick, breast, gliver, gizzard, empty gizzard with lining, empty gizzard without lining, gastro-intestinal tract, heart and empty gasto-intestinal tract) were not different.

Table 4.14 Relative weights of some primal cuts and internal organs of birds fed dry cashew apple pomace in replacement for maize (starter phase)

Parameters	Dry Cashew Apple Pomace (%)						
	0	5	10	15	20	SEM	P value
Primal cuts							
Thigh	15.63[ab]	14.52[ab]	15.85[a]	13.79[b]	16.18[a]	0.30	0.05
Breast	14.66	14.48	15.53	15.73	15.32	0.27	0.53
Internal organs							
Gastro-intestinal tract	15.66	16.04	15.77	16.48	17.36	0.21	0.63
Heart	0.92	0.68	0.82	0.79	0.72	0.04	0.24
Liver	2.80	2.83	2.66	2.76	2.81	0.09	0.98
Gizzard	4.51	4.81	4.48	4.57	5.17	0.12	0.34
Empty gizzard	2.66[b]	2.86[ab]	2.77[b]	2.76[b]	3.26[a]	0.07	0.04

[ab]Means with different superscript along the same row are significantly different ($P<0.05$)

Table 4.15 Relative weights of some primal cuts and internal organs of birds fed dry cashew apple pomace in replacement for maize (finisher phase)

Parameter	Dry Cashew Apple Pomace (%)						
	0	5	10	15	20	SEM	P value
Dressed weight	62.40	56.20	61.30	60.70	58.80	0.91	0.26
Primal cuts							
Thigh	10.20	11.10	10.80	10.60	9.68	0.23	0.47
Drumstick	10.70	10.40	11.70	10.30	10.20	0.30	0.53
Breast	19.30	17.80	18.10	17.60	18.40	0.36	0.64
Internal organs							
Liver	2.73	2.72	2.66	2.47	2.70	0.06	0.63
Gizzard	8.09	8.64	8.37	8.72	9.50	0.23	0.40
Empty gizzard with lining	2.37	2.12	2.03	2.32	2.51	0.05	0.16
Empty gizzard without lining	1.96	1.76	1.62	1.77	1.95	0.19	0.15
Gastro-intestinal tract	14.10	14.30	14.00	14.70	16.10	0.40	0.47
Heart	0.47	0.44	0.49	0.43	0.44	0.02	0.85
Empty gastro-intestinal tract	7.38	8.12	6.84	7.81	8.93	0.29	0.19

Means are not significantly different at $P<0.05$

4.2.7 pH of some segments of the gastro-intestinal tract of broilers chickens fed dry cashew apple pomace (DCAP) as a replacement for maize

The pH of ceaca, duodenum, proventriculus, jejunum, gizzard and ileum of broiler chickens fed DCAP as replacement for maize at the starter phase (Tables 4.16) are not significantly different among treatments (0, 5, 10, 15 and 20% DCAP replacement for maize). At the finisher phase (Table 4.17),ceaca, duodenum, proventriculus and ileum followed the same trend as with starter phase while significant difference was observed in jejunum and gizzard at $P \leq 0.05$. The pH of jejunum and gizzard of birds fed DCAP replacement for maize at 0,5,15 and 20% were higher than 10% DCAP replacement.

Table 4.16 pH of some segments of GIT of broilers fed dry cashew apple pomace as a replacement for maize (starter phase)

Parameter	Dry Cashew Apple Pomace (%)						
	0	5	10	15	20	SEM	P value
Caeca	5.74	5.73	5.38	5.41	5.59	0.14	0.88
Duodenum	5.56	5.41	5.14	5.51	5.60	0.14	0.86
Proventriculus	5.51	6.17	4.72	5.44	5.50	0.19	0.28
Jejunum	5.40	5.68	4.77	5.40	5.52	0.12	0.56
Gizzard	5.41	6.29	4.41	5.63	5.51	0.25	0.24
Ileum	5.15	4.81	4.87	5.40	5.44	0.17	0.82

Means are not significantly different ao P<0.05

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Table 4.17 pH of some segments of gastro-intestinal part of broilers fed dry cashew apple as replacement for maize (finisher phase)

Gastro-intestinal part			Dry Cashew Apple Pomace (%)				
	0	5	10	15	20	SEM	P value
Ceaca	5.75	5.33	5.34	5.41	5.59	0.13	0.85
Duodenum	5.37	5.41	4.94	5.51	5.60	0.13	0.59
Proventriculus	5.56	5.89	4.47	5.44	5.50	0.21	0.29
Jejunum	5.35^{a}	5.68^{a}	4.69^{b}	5.40^{a}	5.52^{a}	0.11	0.02
Gizzard	5.40^{a}	6.06^{a}	3.56^{b}	5.13^{a}	5.51^{a}	0.28	0.01
Ileum	4.92	4.81	4.55	5.40	5.44	0.19	0.57

^{ab}Means with different superscript are significantly different along the same row ($P<0.05$)

4.2.8 Intestinal length of broiler chickens fed dry cashew apple pomace (DCAP) in replacement for maize

There was no significant difference in the lengths of jejunum, duodenum, ileum, ceaca, pancreas and total gastro-intestinal length of broilers fed DCAP in replacement for maize at 0, 5, 10, 15 and 20% at the starter phase (Table 4.18).

At the finisher phase (Table 4.19), jejunum ($P \leq 0.05$) were longer at 5% and 20 than 10% but similar to 0 and 15% DCAP replacement for maize. 0, 10 and 15% were also similar. No significant difference was observed in the lengths for duodenum, ileum, ceaca and total gastro-intestinal tract

4.3 Study 3.Effect of exogenous enzyme on the utilisation of dried cashew apple pomace in broiler diets

4.3.1 Proximate composition of starter and finisher diets of broiler chickens fed dried cashew apple pomace with or without enzyme

The analysed dry matter, crude protein, ash, ether extract, crude fibre and calculated nitrogen free extract for the starter diets of broiler chickens fed DCAP with or without enzyme are as shown on Table 4.20.

At the finisher phase, Table 4:21 shows analysed composition (dry matter, cruude protein, ash, ether extract, crude fibre) and calculated nitrogen free extract.

Table 4.18 Intestinal length of broilers fed dry cashew apple pomace in replacement for maize (starter phase)

Intestinal part (cm)	Dry Cashew Apple Pomace (%)						
	0	5	10	15	20	SEM	P value
Jejunum	53.07	58.31	55.56	56.55	58.75	0.97	0.39
Duodenum	18.06	20.00	19.63	20.25	19.25	0.39	0.82
Ileum	50.36	56.50	55.69	57.31	57.44	1.06	0.23
Caeca	11.00	13.00	12.00	13.00	16.00	5.92	0.50
Pancreas	7.86	8.00	8.38	8.43	8.38	0.18	0.82
Total Length	151.36	166.31	162.31	168.11	167.94	2.82	0.34

Means are not significantly different at $P<0.05$

Table 4.19 Intestinal length of broilers fed dry cashew apple pomace (DCAP) in replacement for maize (finisher)

Intestinal part (cm)	Dry Cashew Apple Pulp (%)						
	0	5	10	15	20	SEM	P value
Jejunum	89.42^{ab}	97.63^{a}	83.63^{b}	94.06^{ab}	99.38^{a}	0.23	0.08
Duodenum	29.13	27.75	28.38	31.75	31.25	0.63	0.18
Ileum	89.00	94.50	88.81	82.81	97.06	2.99	0.59
Ceaca	21.00	24.00	21.00	23.00	25.00	1.18	0.04
Total length	266.12`	279.50	262.75	284.62	292.75	0.20	0.20

^{ab}Means with different superscript along the same row are significantly different ($P<0.05$)

Table 4.20 Proximate composition of starter diets of broiler chickens fed dry cashew apple pomace in replacement for maize with or without enzyme

Parameter	Dry Cashew Apple Pomace (%)					
	0		15		30	
	No enzyme	With enzyme	No enzyme	With enzyme	No enzyme	With enzyme
Dry Matter	91.10±0.10	91.10±0.10	92.55±0.78	92.55±0.78	93.92±1.04	93.92±1.04
Crude Protein	21.55±0.22	21.55±0.22	21.68±4.27	21.68±4.27	22.09±0.71	22.09±0.71
Ash	4.33±1.10	4.33±1.10	4.90±0.71	4.90±0.71	4.90±0.54	4.90±0.54
Ether Extract	4.25±0.47	4.25±0.47	3.55±0.49	3.55±0.49	4.18±0.06	4.18±0.06
Crude Fibre	5.55±0.02	5.55±0.02	5.57±0.71	5.57±0.71	5.46±0.35	5.46±0.35
Nitrogen Free Extract	64.32±0.40	64.32±0.40	64.30±1.61	64.30±1.61	63.37±0.37	63.37±0.37

Table 4.21 Proximate composition of finisher diets of broiler chickens fed dry cashew apple pomace in replacement for maize with or without enzyme

Parameter	Dry Cashew Apple Pomace (%)					
	0		15		30	
	No Enzyme	With Enzyme	No Enzyme	With Enzyme	No Enzyme	With Enzyme
Dry Matter	91.26±0.07	91.26±0.07	91.74±2.26	91.74±2.26	93.66±0.47	93.66±0.47
Crude Protein	20.25±0.54	20.25±0.54	20.11±2.11	20.11±2.11	20.32±1.94	20.32±1.94
Ash	4.80±2.05	4.80±2.05	5.30±1.41	5.30±1.41	4.03±0.27	4.03±0.27
Ether Extract	3.30±1.55	3.30±1.55	3.06±0.04	3.06±0.04	3.18±0.79	3.18±0.79
Crude Fibre	5.44±0.16	5.44±0.16	5.57±0.71	5.57±0.71	5.67±0.64	5.67±0.64
Nitrogen Free Extract	66.21±0.75	66.21±0.75	65.85±0.89	65.85±0.89	66.80±0.72	66.80±0.72

4.3.2 Performance characteristics of broiler chickens fed DCAP in replacement for maize with or without enzyme

Feed intake (Table 4.22) at the starter phase was not significantly impacted by enzyme at 0% and 30% DCAP replacement for maize; however at 15% DCAP replacement enzyme, significantly ($P \leq 0.05$) reduced feed intake. The same pattern obtained during the 21-42 day period (finisher phase). Total feed intake revealed no significant difference with the addition of enzyme.

Weight gain was higher ($P \leq 0.05$) in 30% DCAP with enzyme but not in 0% DCAP with enzyme and 15% DCAP with enzyme at the starter phase. Enzyme did not have any effect on weight gain at the finisher phase neither on total rearing period.

No significant difference was observed in feed conversion ratio at the starter, finisher and total rearing phases.

4.3.3 Nutrient digestibility of broiler chickens fed dry cashew apple pomace in replacement for maize with or without enzyme

Nutrient digestibility of broiler chickens fed DCAP in replacement for maize at the starter phase is as shown on Table 4.23. Enzyme supplementation significantly affected all parameters considered. At 30% replacement for maize apparent digestibility of all nutriens were increased while enzyme exhibited a lowering effect on the apparent digestibility of chickens fed 15% DCAP replacement for maize

Nutrient digestibilities of broiler chickens fed DCAP are as shown on Table 4.24 for the finisher phase. All parameters considered except dry matter were significantly impacted apparent, at 15% DCAP replacement; crude protein crude fibre and ether extract digestibility was improved by enzyme supplementation with 75.11%, 77.83%, 43.33% against 73.74%, 71.82% and 38.66% respectinely. At 30% DCAP replacement for maize; crude protein, ash, crude fibre, ether extract and nitrogen free extract digestibilities were improved but not dry matterdigestibility.

Table 4.22 Performance characteristics of broiler chickens fed dry cashew apple pomace with or without enzyme

Treatment	Feed Intake			Weight Gain			Feed Conversion		
	Weeks								
	1-3	4-6	1-6	1-3	4-6	1-6	1-3	4-6	1-6
DCAP (%)									
0-E	934.59	23585.11	3319.69	361.66	1031.27	1415.21	2.62	2.31	2.35
0+ E	910.63	2215.81	3136.43	370.21	988.33	1357.02	2.46	2.27	2.32
15-E	1014.10	2089.42	3026.34	443.50	896.01	1311.10	2.29	2.38	2.36
15+E	903.79	2559.39	3463.18	406.87	976.55	1373.49	2.29	2.66	2.57
30-E	998.13	2597.48	3595.61	410.53	694.50	1162.08	2.46	3.43	2.99
30+E	1053.93	2837.48	3891.40	464.65	797.39	1271.88	2.28	3.54	3.04
SEM	14.24	66.04	71.70	8.91	27.76	26.69	0.06	0.11	0.08
Contrast P value									
0-E vs 0+E	#	#	#	#	#	#	#	#	#
15-E vs 15+E	0.009	0.019	#	#	#	#	#	#	#
30-E vs 30+E	#	#	#	0.031	#	#	#	#	#

DCAP – Dry cashew apple pomace, 0-E – 0% DCAP without enzyme, 0+E – DCAP with enzyme, 15-E –15% DCAP without, 15+E – 15% DCAP with enzyme, 30-E – DCAP without enzyme, 30+E – 30% DCAP with enzyme , vs – versus, # – not signifcant

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Table 4.23 Apparent nutrient digestibility of broiler chickens fed dry cashew apple pomace in replacement for maize with or without enzyme at the starter phase

Treatment/ Parameters	Dry Matter	Crude Protein	Ash	Crude Fibre	Ether Extract	Nitrogen Free Extract
0% DCAP without enzyme (-E)	84.12	79.50	64.52	78.30	82.57	79.36
0% DCAP with enzyme (+E)	89.39	85.50	57.25	85.50	87.64	86.31
15% DCAP without enzyme	89.20	85.01	65.18	85.01	83.12	85.81
15% DCAP with enzyme	87.25	82.30	66.42	82.30	81.69	82.77
30% DCAP without enzyme	88.54	83.85	68.08	83.85	86.83	84.27
30% DCAP with enzyme	91.88	88.56	77.06	87.70	90.92	89.07
SEM	0.693	0.924	1.818	0.934	0.900	0.915
Contrast P value						
0%-E vs 0%+E	0.001	0.001	0.001	0.001	0.001	0.001
15%-E vs 15%+E	0.001	0.001	0.001	0.001	0.001	0.001
30%-E vs 30%+E	0.001	0.001	0.001	0.001	0.001	0.001

vs – versus, # - not significant

Table 4.24 Apparent nutrient digestibility of broiler chickens fed dry cashew apple pomace in replacement for maize with or without enzyme at finisher phase

Treatment/parameter	Dry matter	Crude Protein	Ash	Crude Fibre	Ether extract	Nitrogen Free Extract
0% DCAP without enzyme (-E)	87.88	70.28	92.78	76.85	43.47	82.68
0% DCAP with enzyme (+E)	87.68	74.24	93.73	76.48	49.37	84.19
15% DCAP without enzyme	87.91	73.74	94.62	71.82	38.86	82.74
15% DCAP with enzyme	87.91	75.11	94.34	77.83	43.33	84.27
30% DCAP without enzyme	88.23	67.91	90.41	72.80	29.29	79.51
30% DCAP with enzyme	85.59	72.23	92.99	77.44	41.02	82.31
SEM	0.290	1.133	0.279	1.005	2.586	0.709
Contrast P value						
0-E vs 0%+E	0.001	0.001	0.001	0.001	0.001	0.001
15%-E vs 15%+E	0.001	0.001	0.001	0.001	0.001	0.001
30%-E vs 30%+E	0.001	0.001	0.001	0.001	0.001	0.001

Vs – versus, # - not significant

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4.3.4 The haematological parameters of broiler chickens fed DCAP in replacement for maize with or without enzyme

Enzyme inclusion durig 1-21day feeding period - starter phase (Table 4.25) did not have any effect on all the haematological parameters (packed cell volume, haemoglobin, red blood cell, white blood cell, platelet, lymphocyte, heterocyte, monocyte, eosinophil and basophil) at 0% DCAP replacement for maize. At 15% DCAP replacement for maize, enzyme significantly ($P \leq 0.05$) increased only heterocytecount while no effect was observed on other parameters. Packed cell volume, haemoglobin and platelet were significantly ($P \leq 0.05$) lowered by enzyme inclusion at 30% replacement level of DCAP with maize while no effect was recorded on other parameters.

At the finisher phase (Table 4.26), enzyme had no effect on all the parameters mentioned above at 0 and 30% DCAP replacement for maize but packed cell volume and haemoglobin counts were lower ($P \leq 0.05$) at 15% DCAP replacement for maize

Table 4.25 Haematological parameters of broiler chickens fed dry cashew apple pomace with or without enzyme (starter phase)

Parameters	PCV	HB	RBC	WBCx10^4	PLAx10^4	LYM	HET	MO	EO	BA
0-E	34.82	11.60	3.48	1.51	8.92	65.55	26.73	3.45	4.00	0.27
0+E	32.27	10.60	3.37	1.53	8.44	65.27	27.27	2.82	4.27	0.36
15-E	32.83	10.85	3.47	1.51	9.93	66.92	25.33	3.67	3.75	0.25
15+E	32.91	10.85	3.45	1.53	10.68	62.27	31.00	3.18	3.55	0.36
30-E	33.31	11.03	3.38	1.44	14.61	62.69	30.15	3.08	3.62	0.46
30+E	30.00	9.70	3.35	1.54	9.71	62.00	30.36	3.18	4.45	0.18
SEM	0.48	0.17	0.03	0.02	0.56	0.76	0.79	0.12	0.14	0.06
Contrast P Value										
0-E vs 0+E	#	#	#	#	#	#	#	#	#	#
15-E vs 15+E	#	#	#	#	#	#	0.048	#	#	#
30-E vs 30+E	0.041	0.18	#	#	0.008	#	#	#	#	#

0-E – 0% DCAP inclusion without enzyme, 0+E – 0% DCAP inclusion with enzyme, 15-E – 15% DCAP inclusion without enzyme, 15+E – 15% DCAP inclusion with maize, 30-E – 30% DCAP inclusion without enzyme, 30+E – 30% inclusion with enzyme, # =Not significant, DCAP – Dry cashew apple pomace

Table 4.26 Haematological parameters of broiler chickens fed dry cashew apple with or without enzyme (finisher phase)

Parameters	PCV	HB	RBC	WBCx10^4	PLATx10^4	LYM	HET	MO	EO	BA
0-E	36.70	12.11	3.58	2.75	1.56	59.00	33.10	3.70	4.00	0.10
0+E	32.23	11.09	3.41	1.46	1.67	61.85	31.08	2.69	3.77	0.31
15-E	35.55	11.91	3.56	1.63	1.86	62.73	29.73	3.82	3.36	0.27
15+E	32.57	10.94	3.43	1.44	1.85	66.14	26.79	3.07	3.93	0.14
30-E	33.42	11.26	3.52	1.54	1.75	58.92	28.17	2.75	3.83	0.42
30+E	32.33	10..84	3.38	1.56	1.85	63.89	28.29	2.78	4.11	0.22
SEM	0.514	0.170	0.43	1886.68	5208.99	1.811	0.753	0.151	0.203	0.052
Contrast P value										
0-E vs 0+E	#	#	#	#	#	#	#	#	#	#
15-E vs 15+E	0.35	0.31	#	#	#	#	#	#	#	#
30-E vs 30+E	#	#	#	#	#	#	#	#	#	#

0-E – 0% DCAP inclusion without enzyme, 0+E – 0% DCAP inclusion with enzyme, 15-E – 15% DCAP inclusion without enzyme, 15+E – 15% DCAP inclusion with maize, 30-E – 30% DCAP inclusion without enzyme, 30+E – 30% inclusion with enzyme, vs – versus, # – not significant, DCAP – Dry cashew apple pomace

4.3.5 The relative weight of some carcass parts of birds fed DCAP with or without enzyme

Enzyme inclusion increased ($P \leq 0.05$) dressed weight and breast yield at 0% DCAP replacement for maize and live weight at 30% DCAP replacement for maize during 1-21day feeding period - starter phase (Table 4.27a). Bled weight, defeathered weight, eviscerated weight, thigh, drumstick were not significantly impacted by the supplementation of enzyme at all levels of DCAP in the broiler diets. The same holds for abdominal weight, wings, back, head, neck, shank, heart, full gizzard, empty gizzard and gizzard without lining (Table 4.27b).

The carcass analysis (Table 4.28a) of live weight, bled weight, defeathered weight, eviscerated weight, dressed weight, thigh, drumstick, breast and back revealed no significant difference in enzyme supplementation at 0 and 15% DCAP replacement for maize. However enzyme supplementation reduced relative weights of thigh, drumstick, breast and back at $P \leq 0.05$ for the finisher phase of broiler chickens fed DCAP in replacement for maize at 30% with or without enzyme. In Table 4.28b, enzyme did not impact any difference on relative weight of head, shank, neck, full gizzard, empty gizzard with lining, empty gizzard without lining, heart, liver and abdominal fat in the different treatments administered. Significant difference was obtained only in wings, where enzyme impacted lowered weight at 30% DCP replacement for maize at $P \leq 0.05$.

Table 4.27a Relative weight of some carcass parts and organs of broiler chickens fed dry cashew apple pomace in replacement for maize with or without enzyme (starter phase)

Parameters	Live wt.	Bled wt.	Def. wt.	Evisc. wt.	Drsd. wt.	Thigh	Drum-stick	Brst.
0-E	414.17	88.97	86.42	71.02	54.54	9.81	10.49	15.16
0+E	437.08	90.59	87.29	71.53	56.83	10.26	10.36	16.23
15-E	473.43	90.36	86.09	72.41	57.74	10.47	10.92	16.38
15+E	452.27	92.72	89.70	74.97	56.33	10.67	10.79	17.14
30-E	436.82	97.75	93.52	74.12	59.42	10.33	10.01	17.55
30+E	486.92	92.61	87.51	71.51	57.31	10.31	10.40	17.28
SEM	7.251	1.104	1.028	0.896	0.611	0.131	0.138	0.243
Contrast P value								
0-E vs 0+E	#	#	#	#	0.029	#	#	0.048
15-E vs15+E	#	#	#	#	#	#	#	#
30-E vs 30+E	0.038	#	#	#	#	#	#	#

0-E – 0% DCAP inclusion without enzyme, 0+E – 0% DCAP inclusion with enzyme, 15-E – 15% DCAP inclusion without enzyme, 15+E – 15% DCAP inclusion with maize, 30-E – 30% DCAP inclusion without enzyme, 30+E – 30% inclusion with enzyme, # - not significant, DCAP – Dry cashew apple pomace

Table 4.27b Relative weight of some carcass parts and organs of broiler chickens fed dried cashew apple pomace in replacement for maize with or without enzyme (starter phase)

Parameters	Abd. Fat	Wings	Back	Head	Neck	Shank	Heart	Full gizzard	Empty gizzard	Empty gizzrd-lining
0-E	0.31	7.26	12.79	3.60	5.99	4.59	0.65	1.49	1.15	0.88
0+E	0.32	7.34	12.85	3.27	5.47	4.30	0.51	2.47	1.86	1.48
15-E	0.21	7.55	13.17	3.31	5.65	4.65	0.57	1.05	0.85	0.69
15+E	0.25	7.51	13.17	3.46	5.93	4.73	0.65	1.28	0.95	0.76
30-E	0.17	7.99	13.06	3.43	5.86	4.93	0.66	2.46	1.89	1.27
30+E	0.12	7.33	12.29	5.27	5.60	4.42	0.72	1.12	0.83	0.68
SEM	0.03	0.093	0.203	0.407	0.124	0.112	0.028	0.270	0.203	0.151
Contrasts P value										
0-E vs 0+E	#	#	#	#	#	#	#	#	#	#
15-E vs 15+E	#	#	#	#	#	#	#	#	#	#
30-E vs 30+E	#	#	#	#	#	#	#	#	#	#

0-E – 0% DCAP inclusion without enzyme, 0+E – 0% DCAP inclusion with enzyme, 15-E – 15% DCAP inclusion without enzyme, 15+E – 15% DCAP inclusion with maize, 30-E – 30% DCAP inclusion without enzyme, 30+E – 30% inclusion with enzyme, # - not significant, DCAP – Dry cashew apple pomace

Table 4.28a Relative weight of some carcass cuts and internal organs of broiler chickens fed dried cashew apple pomace in replacement for maize with or without enzyme (finisher phase)

Parameter	Live wt	Bled wt	Def. wt	Evisc. Wt	Dressed wt	Thigh	Drum-stick	Breast	Back
0-E	1582.44	93.92	90.00	75.60	61.98	10.78	9.99	20.64	13.12
0+E	1521.09	95.40	91.92	76.16	62.46	10.72	10.22	19.58	13.50
15-E	1393.09	94.84	90.34	75.72	61.87	10.68	9.93	20.18	13.29
15+E	1731.91	96.92	92.38	75.62	62.15	10.24	9.79	20.41	13.43
30-E	1327.45	93.47	89.15	73.91	61.1	9.95	10.00	19.89	12.56
30+E	1481.71	91.79	88.00	73.07	60.98	7.71	7.44	15.56	10.11
SEM	35.045	0.593	0.562	0.457	0.429	0.260	0.245	0.538	0.326
Contrasts P value									
0-E vs 0+E	#	#	#	#	#	#	#	#	#
15-E vs 15+E	0.04	#	#	#	#	#	#	#	#
30-E vs 30+E	#	#	#	#	#	0.008	0.002	0.020	0.025

0-E – 0% DCAP without enzyme, 0+E – 0% DCAP with enzyme, 15-E – 15% DCAP without enzyme, 15+E – 15% DCAP with enzyme, 30-E – 30% DCAP without enzyme, 30+E – 30% with enzyme, # - Not significant, DCAP – Dry cashew apple pomace

Table 4.28b Relative weight of some carcass cuts and internal organs of broiler chickens fed dried cashew apple pomace in replacement for maize with or without enzyme (finisher phase)

Parameter	Wings	Head	Shank	Neck	Full Giz.	Empty giz. + lining	Empty giz. - lining	Heart	Liver	Abdominal fat
0-E	7..85	2.75	4.23	5.21	2.03	1.49	1.25	0.20	1.12	0.75
0+E	7.87	2.73	4.63	5.64	2.21	1.68	1.39	0.30	0.73	0.40
15-E	8.16	2.78	4.44	5.23	2.14	1.47	1.35	0.31	1.64	0.45
15+E	7.66	2.58	4.34	5.44	1.74	1.40	1.12	0.30	1.14	0.49
30-E	8.17	2.69	4.35	5.29	2.53	1.92	1.64	0.14	1.20	0.40
30+E	6.15	2.58	4.32	4.92	2.04	1.50	1.29	0.14	1.03	0.15
SEM	0.195	0.035	0.066	0.082	0.215	0.156	0.132	0.043	0.159	0.056
Contrast P value										
0-E vs 0+E	#	#	#	#	#	#	#	#	#	#
15-E vs 15+E	#	#	#	#	#	#	#	#	#	#
30-E vs 30+E	0.003	#	#	#	#	#	#	#	#	#

0-E – 0% DCAP inclusion without enzyme, 0+E – 0% DCAP inclusion with enzyme, 15-E – 15% DCAP inclusion without enzyme, 15+E – 15% DCAP inclusion with maize, 30-E – 30% DCAP inclusion without enzyme, 30+E – 30% inclusion with enzyme, # – Not significant, DCAP – Dry cashew apple pomace

4.3.6 The pH of internal organs of broiler chickens fed DCAP in replacement for maize with or without enzyme

Enzyme only lowered pH ($P \leq 0.05$) in ileum and crop at 15% and 30% DCAP respectively. No significant difference was obtained in other parameters at the starter level (Table 4.29). On Table 4.30 is report for finisher phase.

Table 4.29 pH of internal organs of birds fed dried cashew apple pomace in replacement for maize with or without enzyme at starter phase

Parameters	Jejunum	Proventriculus	Duodenum	Gizzard	Ileum	Caecum	Crop
0-E	6.40	6.15	6.50	5.60	6.55	5.75	6.15
0+E	6.43	6.10	6.18	5.77	6.43	6.44	6.37
15-E	6.75	6.20	6.45	5.85	6.80	6.75	6.55
15+E	6.45	6.15	6.10	5.65	6.38	5.77	6.13
30-E	6.43	6.30	6.53	5.83	6.53	6.73	6.63
30+E	6.33	6.17	6.17	6.15	6.27	6.53	6.30
SEM	0.605	0.072	0.091	0.111	0.049	0.121	0.076
Contrast P value							
0-E vs 0+E	#	#	#	#	#	#	#
15-E vs 15+E	#	#	#	#	0.023	#	#
30-E vs 30+E	#	#	#	#	#	#	0.012

0-E – 0% DCAP inclusion without enzyme, 0+E – 0% DCAP inclusion with enzyme, 15-E – 15% DCAP inclusion without enzyme, 15+E – 15% DCAP inclusion with maize, 30-E – 30% DCAP inclusion without enzyme, 30+E – 30% inclusion with enzyme, # – Not significant, DCAP – Dry cashew apple pomace

Table 4.30 pH of internal organs of birds fed dry cashew apple pomace in replacement for maize with or without enzyme at finisher phase

Parameter	Jejunum	Proventriculus	Duodenum	Gizzard	Ileum	Caecum	Crop
0-E	6.20	5.95	6.35	6.45	6.00	6.50	6.80
0+E	6.55	6.05	6.45	5.40	5.70	6.25	6.70
15-E	6.00	6.55	6.30	6.30	6.35	5.85	6.10
15+E	6.00	6.33	6.00	5.72	5.90	5.70	6.45
30-E	6.40	6.50	6.45	6.47	6.35	6.50	6.50
30+E	6.45	6.70	6.80	6.75	6.37	6.80	6.70
SEM	0.132	0.112	0.108	0.126	0.122	0.156	0.092
Contrast P Value							
0-E vs 0+E	#	#	#	0.027	#	#	#
15-E vs 15+E	#	#	#	0.036	#	#	#
30-E vs 30+E	#	#	#	#	#	#	#

0-E – 0% DCAP inclusion without enzyme, 0+E – 0% DCAP inclusion with enzyme, 15-E – 15% DCAP inclusion without enzyme, 15+E – 15% DCAP inclusion with maize, 30-E – 30% DCAP inclusion without enzyme, 30+E – 30% inclusion with enzyme, # – not significant, DCAP – Dry cashew apple pomace

4.3.7 The length of intestinal parts of broiler chickens fed DCAP with or without enzyme
Supplementation of enzyme in diets did not have any effect on the length of jejunum, duodenum, ileum, ceaca and total intestinal length at $P \leq 0.05$ at the starter phase (Table 4.31) for all the levels of inclusion (0-E versus 0+E, 15-E versus15+E and 30-E versus 30+E. Finisher phase (Table 4.32) followed pattern as observed at the 1-21 days (starter phase).

Table 4.31 Intestinal length of broilers fed dry cashew apple pomace in replacement for maize with or without enzyme (starter phase)

Parameter(cm)	Jejunum	Ileum	Duodenum	Caecum	Total
0-E	49.00	60.50	25.00	12.11	146.61
0+E	51.67	51.83	20.83	12.33	134.60
15-E	55.00	58.00	20.00	13.03	136.03
15+E	55.00	55.00	21.50	12.63	105.88
30-E	59.00	63.33	20.67	12.11	155.11
30+E	55.33	57.00	20.67	13.46	109.84
SEM	1.176	2.143	0.882	0.364	8.697
0-E vs 0+E	#	#	#	#	#
15-E vs 15+E	#	#	#	#	#
30-E vs 30+E	#	#	#	#	#

0-E – 0% DCAP inclusion without enzyme, 0+E – 0% DCAP inclusion with enzyme, 15-E – 15% DCAP inclusion without enzyme, 15+E – 15% DCAP inclusion with maize, 30-E – 30% DCAP inclusion without enzyme, 30+E – 30% inclusion with enzyme, # – Not significant, DCAP – Dry cashew apple pomace

Table 4.32 Intestinal length of broilers fed dried cashew apple pomace in replacement for maize with or without enzyme (finisher phase)

Parameter (cm)	Jejunum	Ileum	Duodenum	Caecum	Total
0-E	86.83	86.73	30.67	18.59	226.41
0+E	91.08	91.36	32.45	19.13	235.86
15-E	92.92	88.67	31.17	19.36	230.79
15+E	95.58	95.00	32.33	20.88	243.79
30-E	93.55	83.55	30.36	19.36	223.84
30+E	91.26	89.82	31.67	19.96	240.15
SEM	1.303	1.245	0.413	0.294	2.712
Contrast P value					
0-E vs 0+E	#	#	#	#	#
15-E vs 15+E	#	#	#	#	#
30-E vs 30+E	#	#	#	#	#

0-E – 0% DCAP inclusion without enzyme, 0+E – 0% DCAP inclusion with enzyme, 15-E – 15% DCAP inclusion without enzyme, 15+E – 15% DCAP inclusion with maize, 30-E – 30% DCAP inclusion without enzyme, 30+E – 30% inclusion with enzyme, # - not significant, DCAP – Dry cashew apple pomace

4.3.8 Cost analysis of replacing maize with DCAP with or without enzyme

The cost of dry cashew apple pomace was factored inntthe cost of feed of each diet.

The cost analysis for feed at starter phase revealed that enzyme increased the cost /kg feed (Table 4.33) for 0, 15 and 30% DCAP replacement for maize at the starter phase and 0 and 15% at the finisher phase. However, enzyme reduced the cost of feed /kg at 30% DCAP replacement during the finisher phase.

Enzyme supplementation significantly lowered the cost of average feed consumed per bird at 15% DCAP replacement for maize ($P \leq 0.05$) for starter phase while no effect was observed at 0 and 30% DCAP treatments. Contrariwise, enzyme supplementation significantly increased the cost of feed consumed per bird at the finisher phase for 15% DCAP while no 10impact was observed on birds fed 0 and 30% DCAP treatments. Enzyme supplementation did not have effect on overall average cost of feed consumed per bird on any of the treatments.

At the starter phase, feed cost/kg weight gain was significantly ($P \leq 0.05$) lower in 15%DCAP with enzyme than 15% DCAP without enzyme; this did not hold for0 and 30% DCAP ntreatments. However, at finisher phase, enzyme significantly increase the cost of feed to kilogram weight gain at 15% DCAP replacement for maize but not at 0 and 30%DCAP treatments.

There was no significant difference in the overall cost of feed consumed/weight gain in the three levels of DCAP replacement for maize.

Table 4.33 Cost Analysis of replacing maize with dry cashew apple pomace with or without enzyme

Parameter	Feed cost/kg (starter)₦	Feed cost/kg (finisher)₦	Starter cost/ bird₦	Finisher cost/bird₦	Total cost/bird	Sta. feed cost/ kg gain₦	Fin. feed cost/ kg gain₦	Total feed cost/ kg gain₦
0-E	211.19	196.91	197.38	467.48	664.48	250.94	444.92	695.86
0+E	211.96	197.88	193.02	438.46	631.48	245.27	415.20	660.47
15-E	205.63	190.99	207.89	399.06	606.95	266.65	377.39	644.04
15+E	206.40	191.76	186.54	490.79	677.33	238.41	464.43	702.84
30-E	200.45	185.88	200.50	482.82	683.32	256.89	453.75	710.64
30+E	200.88	185.33	211.71	525.87	737.58	272.15	498.09	770.24
SEM/ SD	±4.89	±5.29	2.596	11.841	12.475	3.397	11.182	12.49
0-E vs 0+E	NA	NA	#	#	#	#	#	#
15-E vs 15+E	NA	NA	0.013	0.017	#	0.010	0.016	#
30-E vs 30+E	NA	NA	#	#	#	#	#	#

0-E – 0% DCAP inclusion without enzyme, 0+E – 0% DCAP inclusion with enzyme, 15-E – 15% DCAP inclusion without enzyme, 15+E – 15% DCAP inclusion with maize, 30-E – 30% DCAP inclusion without enzyme, 30+E – 30% inclusion with enzyme, NA – Not available, # – Not significant, DCAP – Dry cashew apple pomace

4.4 Study: Shelf –life and physico- chemical properties of dried cashew apple pomace

4.4.1 Monitoring of the proximate composition of DCAP

The proximate composition of DCAP was monitored quarterly as shown on Table 4.34 for plastic container and on Table 4.35 for polyethylene sack.

4.4.2 Identification of the major storage pest and insect count

The major storage pest of DCAP in this study was identified as *Lasioderma serricone* by an entomologist at the Department of Crop Protection, University of Ibadan. The insect was first seen during the second quarter of the experiment and the counting was done in December. Plate 3 shows the picture of Lasioderma serricone found in DCAP during storage. Figure 4.1 shows the stacked column for *Lasiderma serricorne* count in polyethylene sack and in plastic container.

4.4.3 Physico- chemical properties of DCAP

The results obtained for physico- chemical studies which include: bulk density, compact bulk density, water holding capacity and pH are as shown on Table 4.36

4.4.4 Aflatoxin level of DCAP

The total aflatoxin level for DCAP stored plastic container (0ppb) and woven polyethylene sack (0ppb) are shown on Table 4.37

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Table 4.34 Quarterly mean proximate composition and R^2 of dry cashew apple pomace stored in plastic container and woven polyethylene sack for one year-period

Month/parameters	Dry Matter		Crude Protein		Crude Fat		Crude Fibre		Ash		NFE	
(%)	PC	WPS	PC	WPS	PC	WPS	PC	WPS	PC	WPS	PC	WPS
June 2017	85.35	85.26	14.91	14.90	4.55	4.55	8.26	8.23	4.45	4.45	53.18	53.13
September 2017	85.49	85.93	14.45	15.01	5.76	3.97	10.54	11.18	5.29	4.67	49.45	51.10
December 2017	85.81	86.32	15.04	14.30	3.33	2.3	10.06	9.82	5.67	5.89	51.71	54.01
March 2018	85.73	85.80	14.77	14.74	4.78	3.59	13.36	10.16	8.89	7.16	43.93	50.15
June 2018	85.77	85.85	14.80	14.71	4.65	3.49	12.59	10.20	8.18	7.93	45.55	49.52
R^2	0.480	0.779	0.083	0.122	0.263	0.836	0.720	0.867	0.433	0.525	0.122	0.001
P- value	0.004	0.015	0.593	0.457	0.160	≤0.01	≤0.001	≤0.001	0.033	0.012	0.203	0.905

PC – Plastic container, WPS – Woven polyethylene sack, R^2 – Coefficient of determination

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Plate 4.1 Dorsal view of *Lasioderma serricorne* 10x

A - Elytra

Plate 4.2 Ventral view of *Lasioderma serricorne* 10x

A – Hind leg

Plate 4.3 Dorso-lateral view of *Lasioderma serricorne* 10x

A- Head

Table 4.35 Physico- chemical properties of dry cashew apple pomace

Parameter	BD (g/l)	CBD (g/l)	SG	Ph	WHC
Milled DCAP	0.64±0.01	0.77±0.01	0.64	4.25±0.02	0.261±0.01
Unmilled DCAP	0.30±0.01	0.35±0.02	0.30	NA	NA

BD – Bulk Density, CBD – Compact Bulk Density, SG – Specific Gravity, WHC – Water Holding Capacity, NA – Not Assessed

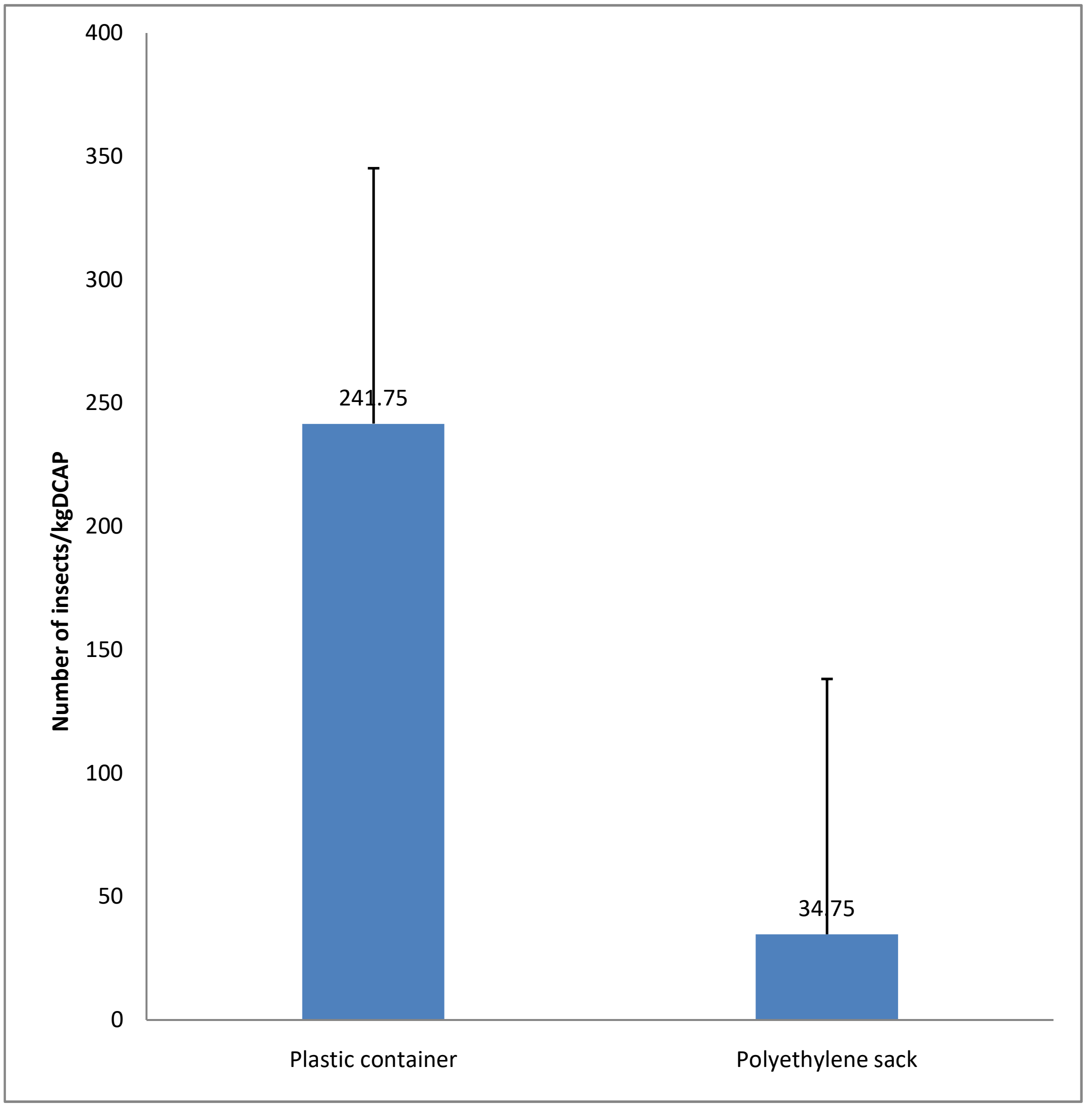

Figure 4.2 Number of insects in plastic container and polyethylene sacks

Table 4.36 Total aflatoxin level in Dry Cashew Apple Pomace stored in plastic containers and woven polyethylene sacks

Storage type	OD(1/10th)	Aflatoxin level	Standard
Plastic container	1.552	0ppb	20ppb
Woven polyethylene sack	1.568	0ppb	20ppb

OD – Optical density

CHAPTER FIVE

DISCUSSION

5.1 Chemical composition and metabolisable energy of Dry Cashew Apple Pomace (DCAP)

5.1.1 Chemical composition of DCAP

The proximate composition of DCAP obtained in this study falls in the range obtained by Heuzê *et al*. (2016). The observed 11.60% moisture in this study is between 9.2% and 12.5% reported by Nghi *et al*. (1995) and Gomes *et al*. (2018) respectively as moisture content for dry cashew apple pomace by sun drying. The differences obtained could be due to drying techniques and prevailing climatic conditions for drying cashew apples. The crude protein (12.60%) of DCAP is between the values by Rodrigues *et al.* (2010) who reported varying CP (7.8-14.9%) and Adebowale *et al.* (2011) who observed 14.42% crude protein. The variations observed in these results could be due to differing soil and environmental conditions as cashew is known to thrive in many climatic conditions which could reflect in the chemical compositions of fruits produced.

The crude protein content of DCAP is higher than 8.75% (Ape *et al.* 2016) and 9.8% (Abiose and Ikujenlola, 2014) reported for maize. Crude protein is very important in broiler chicken feed for the rapid production of meat; however, the profile of the amino acids in a feed ingredient is most vital to the efficiency of utilization. Methionine and lysine are among the limiting amino acids and are usually substituted with commercial forms. The values obtained in this study were close to 0.19% and 0.48% observed by Nghi *et al.* (1995) in dry cashew residues for methionine and lysine respectively. On the contrary, methionine in DCAP in this study was about 10% higher and methionine about 50% higher than methionine and lysine respectively observed in yellow maize by Nghi *et al*. (1995) and (Panda *et al*., 2012) for normal maize.

The crude fibre (9.17%) obtained in this study, is higher than the average of 1.9% obtained Iken *et al.* (2002)for some newly developed varieties of maize in Nigeria. Following the same trend, the fibre fractions of DCAP in this study were higher than NDF (13.8%), ADF (3%), hemicellulose (12.34%), cellulose (2.3%) and lignin (7%) for yellow maize by Ngongoni *et al.* (2007). Energy contribution and the physiological effect of the fibre content of a feed ingredient, depends on the fibre fractions. NDF observed in this study was lower than reported by Nghi *et al.* (1995) howbeit, the contrary was observed in lignin.

Tannin level was not detectable in this study, while Nghi *et al.* (1995) reported 4.8% tannin content in DCAP. Difference observed in both studies might be due to difference in location, breed and the years of harvest. Vitamins and phytochemicals have been known to play natural roles as growth promoters in poultry by their antioxidant properties and prevention of the growth of harmful microbes (NRC, 1994; Achilonu *et al.,* 2018). Vitamin C is known for its antistress, anti-oxidant and disease prevention activities (Ahmadu *et al*., 2015). This may be responsible for the no record of disease and stress influence by the replacement of DCAP for maize in the brioiler chickens used in the studies. The reasonable content of Vitamin C and phytochemicals (flavonoid, alkaloid and saponin) in DCAP could be responsible for similar performance of broiler chickens fed DCAP in their diets and the control in spite of the lower metabolisable energy of DCAP than that of maize in broiler chickens.

5.1.2 Apparent metabolisable energy (AME) of DCAP

Low apparent metabolisable energy (AME) has been reported for non-conventional feedstuffs particularly fruit wastes. There is paucity of information about the AME of DCAP in literature but Farias *et al.* (2008) reported an ME of 1015kcal/kg for growing pigs however AME (2428.51 kcal/kg) derived from the assay with cockerels in this study is within the range(2172 -2456 kcal/kg), in tomato pomace meal (Lira *et al.,* 2011) and (1331-2226 kcal/kg) obtained in feeding guava residues to broilers (El-Deek *et al.,* 2009; Lira *et al*., 2011). The variation in AME for each feed ingredient could be due to difference in age of birds used and the environmental conditions of crops and location of the experiments. AME of different hybrids of maize in broiler chickens was significantly lower at the first week (3563 kcal/kg) than for older birds (3778 kcal/kg) according to Kato *et al*. (2011) and Poultry Hub (2019). The AME observed in this study for DCAP is however 37.6% lower than reported by Zhai (2002) in normal maize for poultry and 43.1% lower than found by Kato *et al.* (2011) in hybrid maize for broilers.

The low ME recorded in this study can be due to higher NDF in DCAP as compared with the value obtained in maize. A value of 1607 kcal/kg was obtained for sunflower meal in broiler chickens. There was decrease in ME of diets formulated as DCAP replacement for maize increased from 0-20% and 0-30% with exogenous enzyme supplementation in Study 2 and Study 3 respectively. This is in agreement with the findings of Longe and Ogedegbe (1989) who reported a decrease in the ME of pullet diets, from 2823.16kcal/kg to 2338.30kcal/kg, as dietary neutral detergent fibre increased from 182 to 330g/kg, with the inclusion of graded levels of corn cobs in the diet. This resulted in a general increase in feed intake in study two at the starter, finisher and throughout the entire experiment. The same trend was followed in study three though feed intake was lower at the finisher and overall feeding phase for birds on 15% DCAP replacement for maize without enzyme. This is because broiler chickens usually feed to meet their energy requirements (NRC, 1994). The feed conversion ratio also slightly DCAP increased in the diets, this follows pattern with the observations of Nghi *et al.* (1995) but Swain and Barbudhe (2014) reported significant reduction in feed efficiency at 10 and 15% replacement of DCAP for maize

5.2. Growth performance, haematology, intestinal measurement and carcass characteristics of broiler chickens fed DCAP in replacement for maize

The need to reduce pressure on maize as an energy source in view of stiff competition between man and animals has led to the use of alternative sources such as DCAP. In this study, feed intake, weight gain and FCR at the starter phase using 0-20% DCAP replacement for maize in broiler chicken diets did not show any deleterious effect. This is in agreement with Sontakke *et al.* (2014) who opined that non-conventional feeds could partially substitute conventional ingredients thereby reducing erstwhile competition between humans and animals. Contrary to the finding in this work Ayhan *et al.* (2009) recorded increase in feed intake when more than 5% dried apple pomace replaced maize in the starter diets though weight gain was not affected.

Teguia (1995) also observed negative effect on weight gain and feed consumption when 20% ground mango kernel was used to replace maize in broiler starter feed. Feed conversion ratio also increased with increasing dried apple pomace. This result however corroborates the work of Swain *et al.* who recorded no difference in performance characteristics between control and up to 20% replacement of maize with cashew apple waste in Vanaraja chicks. Nghi *et al* (1995) had reported no effect of cashew on growth performances of broiler starter birds fed up to10% cashew residues in their diet. The adverse effect in the trial with mango kernel was attributed to tannin, an anti-nutritional factor. Tannin is known to bind protein in the digestive system, but since tannin in DCAP in the current study is below detectable, it could not have hindered the utilisation of protein in the diets. At the finisher phase, feed intake and weight gain were similar to the control; this is contrary to the findings of El-Deek *et al.* (2009). However this present study is in agreement with Emshaw *et al.* (2012) who reported no difference in feed intake when mango waste was used to replace maize in broiler chicken diets. Nghi *et al*. (1995) and Yisa *et al.* (2018) by their studies using up to 10% and 20% cashew apple pomace respectively corroborates this study with reports of no adverse effects in growth performance characteristics at the finisher phase. Feed intake and weight gain were also not affected on overall basis (1-8 weeks) contrary to the observations of Swain *et al.* (2007) and Bhamare *et al*.

(2016) where feed intake reduced significantly in broiler chickens fed beyond 10% replacement of cashew apple waste. It however corroborates the reports of Gomes *et al*. (2018) who observed no significant difference in feed intake when broilers were fed up to 20% mango peels in replacement for maize. Feed conversion rate was influenced by DCAP replacement of maize in finisher broiler diets. The FCR of control diet was superior to others howbeit, no trend was followed. Similar results obtained for 1-6 weeks although FCR was depressed with increasing DCAP replacement in broiler diets. The linear regression for FCR of this study revealed every increase of DCAP in the broiler chicken diet will continue to depress feed conversion ratio. FCR of broiler chickens with inclusion of nonconventional feed ingredients have been diverse. Diarra *et al*. (2005) reported improved FCR using up to 60% of boiled mango kernel in broiler finisher. Dry cashew apple inclusion (up to 15%) also improved FCR in ducks (Song and Seng, 2008). However Botsami *et al*. (2015) reported no significant effect when 0-2% pomegranate was used in broiler while Emshaw *et al*. (2015) observed depressed FCR (2.49-5.23) in a trial with up to 30% mango flour inclusion in broiler chicken diets. This implies that DCAP could adequately replace maize up to 20% in broiler diets without negative effect in consumption.

The haematological parameters examined in this study which include packed cell volume, haemoglobin, red blood cell, white blood cell, platelet, lymphocyte, heterocyte, monocyte and eosinophil were not significant at the starter phase except for monocyte count which showed significantly higher values for birds fed 15 and 20% replacement of DCAP for maize in their diets. However, there was a trend of increasing monocyte cells as DCAP increased in the experimental diets. Treatments that had 5and 10% were comparable to control and higher values obtained in 15 and 20%. All the values are in accordance with those reported by Nanbol *et al.,* 2016. Increase in monocyte count could be due to enhancement of immune system as postulated by Shittu *et al*., (2016) who reported increased monocyte (4%) in broilers fed 15% inclusion of biscuit dough in replacement for maize at the finisher phase. Monocytes are said to be second to white blood cell in defense against infection.

At the finisher phase, the above named parameters were also examined and significant difference was observed only in packed cell volume and haemoglobin. Although significant difference was obtained in these parameters, values were within the expected range for healthy birds (Mitruka and Rawnsley, *et al.* 1977; Ikhimioya *et al.,* 2000) except for birds on10% replacement of maize with DCAP which showed slightly lower values. These values are however not significantly different from 15% DCAP replacement of maize which fall within reference range. The determined PCV is lower than observed by Nanbol *et al*., (2016) who are working at establishing reference range for broilers in Nigeria. The haemoglobin is at par with the results of the said authors safe for a slightly lower value for 10% DCAP replacement as earlier discussed. The results obtained for this study therefore shows no adverse effect to health status and no stress to the broiler chickens in the course of utilization of DCAP in replacement for maize.

DCAP had no adverse effect on the carcass parameters examined at both (1-21 days) starter and (22-42 days) finisher phases as most of the results obtained were not significantly different from the control. These include dressed weight, drumstick, breast, liver, gizzard, empty gizzard and heart. Only thigh and empty gizzard relative weights showed significant difference. Inclusion of DCAP at 5, 10, 15 and 20% all compared favourably with control. The difference was within treatment and 20% DCAP inclusion had a higher relative thigh weight than 15% DCAP inclusion which could be due to the fact that birds in 20% inclusion utilized the energy available to them which was lower than the other to lay protein rather than fat. The relative weight of empty gizzard at 20% replacement of maize with DCAP was higher than control diet which could be attributed to the fibre content of DCAP which could have increased grinding activities thereby enhancing muscle formation in gizzards. This is in agreement with Mateos *et al.,* (2012) who proposed that the feeding of coarse or fibrous materials helps gizzard functioning and development.

The DCAP replacement of maize in broiler diets did not have any adverse effect on the pH of proventriculus, gizzard, duodenum, jejunum, gizzard and ileum as no significant difference was recorded at the starter phase.

The lengths of jejunum, duodenum, ileum and total gastro-intestinal length were not significantly affected at both starter and finisher phase though there was numerical increase except for a significantly higher increase observed in jejunum at the finisher phase. These observations could be due to higher fibre content of the diets with DCAP. Imaseun *et al.,* (2014) *reported* increased small intestine length as *Telferia occidentalis* (pumpkin leaves) was added to commercial diet (0, 5, 10, 15% inclusion rate).

The intestinal pH of the broiler chickens were not significantly affected by DCAP replacement of maize in broiler diets, this implies that DCAP can adequately replace maize at the given levels without reducing nutrient absorption rate and immunity particularly against bacterial infection. This result is corroborated by Rahmani *et al.,* (2005) who reported a ph range of 5.6-5.9 in duodenum and jejunum of broiler chickens fed corn- soya meal diet +2.5% citric acid. They suggested that the lowered pH than the control could increase *Lactobacillus* and *Escherichia coli* ratio and make nutrients more available.

5.3. Effect of exogeneous enzyme on the utilisation of DCP in broiler chicken diets

Natuzyme, a multienzyme was used in this study and it contained amylase (400U/g), betaglucanase (700 Bioproton bu/g), phytase (1300u/g), cellulase (6000 Bioproton cu/g), xylanase (10,000 Bioproton xu/g) and protease (700U/g). At the starter phase, enzyme supplementation in this study reduced feed intake at 15% DCAP replacement for maize while there was improved weight gain with enzyme supplementation at 30% DCAP replacement for maize. FCR was not adversely affected by enzyme supplementation. The finding in this present study is however supported by Onu *et al*., 2011 who recorded lower feed intake in enzyme supplemented heat treated sheep manure based broiler chicken starter diets than the unsupplemented heat treated sheep manure based diets. The observation in this study could be due to the amelioration of AME of the feed by the depolymerisation effect of enzyme on some of the NSP in the diet. Birds generally consume more of low energy feed to meet their energy requirement. The reduction in feed intake observed resulted in 12.6% improvement of FCR over the control which confirmed that the energy needs was met by the feed consumed. Increased weight gain in this study could be attributed to improved digestion of protein (2.8% higher than control) enhanced by enzyme supplementation and the higher protein content in DCAP with its superior threonine and lysine constituents. Higher quantity of cashew than in 0 and 15% replacement could also imply sufficient substrate for enzyme action. As young birds lack sufficient endogenous enzymes for digestion, there is positive reaction to exogenous enzyme in higher weight gain against the control diet (Olukosi *et al*., 2007). At the starter level, enzyme supplementation generally improved the digestion coefficient of dry matter, crude protein, ash crude fibre, ether extract and organic matter. Khan *et al.* (2006) reported higher values of digestibility parameters for broiler chicks fed with enzyme supplemented diets. At the finisher phase, enzyme supplementation increased feed intake at 15% DCAP, there was no adverse effect to weight gain and FCR. Salinas-Chavira *et al.* (2018) reported improved feed intake at the finisher phase when protease+zylanase enzyme complex was used to supplement broiler chicken diets. This corroborates the work of Kardivel *et al*. (1993) who observed increased feed intake when broiler diets were supplemented with beta-glucanase in broiler chicken diets however feed efficiency was not compromised in the present study. Digestibility of crude protein, crude fibre, ether extract and organic matter was improved within the range of 1.4 – 11.4% at the finisher phase by enzyme supplementation on broiler diets with15 and 30% DCAP replacement for maize. Increase in nutrient digestibility though significant for all levels of treatment is notably higher in 30% DCAP replacement for maize which could be due to larger substrate for the action of the enzyme complex. It could be reason for recording lowest FCR in this treatment at the starter phase. The enzyme complex must have hydrolysed some cell wall and reduced intestinal viscosity thus reducing the anti-nutritional effect of the DCAP. This could be attributed to the combined effect of amylase, beta-glucanase, phytase, cellulase, xylanase and protease constitution of the enzyme complex. This submission is in agreement with Khan *et al.* (2006) and who reported increased digestibility of fibre and other nutrients in broiler chicks. Considering the overall rearing period, enzyme supplementation did not affect any of the performance parameters negatively but digestibility was enhanced. Weight gain at the starter level was enhanced by enzyme supplementation but not at the finisher phase and total weight gain though numerically higher than birds fed DCAP without enzyme. Iyayi and Davies (2005) and Ravindran (2013) support the observation of increased weight gain at starter phase. This could be due to the presence of protease in the enzyme cocktail as young birds respond quickly to protein input than older birds. Feed conversion ratio was not significantly affected, however, enzyme supplemented 30% DCAP replacement for maize showed highest impact of the enzyme, it could therefore be proffered as the best level for enzyme supplementation in this kind of study. Non significant effect of enzyme on FCR observed in the present study corroborates the findings of Dalólio *et al*. (2016) using Allzyme (with phytase, protease, zylanase, glucanase, cellulase, α amylase and pectinase) in broiler chicken diets respectively. Though significant results were not obtained, in this study and that of Dalólio (2016), a lowering of feed conversion ratio resulted from enzyme supplementation of diets with lowered ME. However, in the previous study, beyond the starter phase, feed conversion was significantly increased with increasing DCAP replacement for maize in the diets of broiler chickens. This could be attributed to the lowered ME in diets other than the control.

In this study, the limitation of the enzyme to enhance performance could be attributed to the lack of quantitative information on the type of sugars making up the NSP of DCAP. This is not so for cereal grains and by-products whose levels of soluble and insoluble NSP have been well defined through various studies over time (Khairy 2012). The challenge therefore remains for the characterization of the NSP of dry cashew apple pomace.

Haematological parameters are used to determine the health status of animals, hence the set range for boundaries of safety. Decrease in values below range for parameters such as PCV, haemoglobin and RBC could be signs of anaemia which may be an indication of inadequate nutrients Esonu *et al*.,

(2001). In certain trials conducted by Ahmed *et al*. (2007) reported that enzyme supplementation in broiler diets significantly increased haemoglobin count and packed cell volume. In this present study, at the starter phase, PCV and HB were significantly lowered by enzyme supplementation in birds fed 30% DCAP replacement for maize. At the same time, heterophil was increased which contradicts the result of Tehrani *et al*. (2012) whose observation was lowered heterophil in broiler chickens fed *Artemia urmiana* in their diets than the control. At the finisher phase, PCV and Hb were significantly low for broiler chickens fed enzyme supplemented 15% DCAP replacement for maize while all other parameters were not affected. However, at both the starter and finisher phases, values obtained were within the expected range for healthy chickens (Nanbol *et al.,* 2016).
Enzyme supplementation had increased carcass weight, liveweight and dressed weight in trials conducted by Iyayi and Davies (2005) and Akintunde *et al*. (2012). In this present study, at the starter phase, enzyme supplementation increased the liveweight of birds on 30% DCAP replacement for maize. This could be due to better utilsation of the high fibre diets by the cleavage of complex polysaccharride bonds and their release as simpler forms of pentoses, disaccharides, monosaccharrides and oligosaccharides which can be easily digested. Other parameters such as thigh, drumstick, abdominal fat, wings, back, neck, shank and gizzard were not affected. However, enzyme increased dressed weight and breast yield of control diet but not treatment diets; this could be accrued to the energy density in corn diet which is lowered with the replacement by DCAP or increased proportion of protein deposition (Abudabos, 2012). At the finisher phase, there was no significant effect of enzyme on all the parameters considered for birds on 15% DCAP replacement for maize, this is in agreement with the observation of Kardivel *et al.* (1993) when glucanase was used to supplement diets with 10% and 15% cashew meal in replacement for maize. However, relative weights of thigh, drumstick, breast, back and wing were lower in birds fed enzyme supplemented 30% DCAP replacement for maize.

Enzyme supplementation did not affect lengths of jejunum, ileum, duodenum and caecum at the starter phase for both 15% DCAP and 30% DCAP replacement in this experiment. The same trend as in starter phase obtained for finisher phase. The finding is in accord with Nageswara *et al.* (2003) while it contradicts the observation of Thavasiappan *et al*. (2016) where enzyme supplementation influenced mean length of small intestine at both starter and finisher phase in a 42-day broiler feeding experiment.

The cost of production of feed with enzyme supplementation generally increased and this is expected due to the technology of production of feed enzymes. However, supplementation of enzyme caused a significant reduction in feed cost per kg weight gain in 15% DCAP replacement for maize, numerical decrease was attained for control diet while numerical increase was observed in 30% DCAP replacement for maize. The difference obtained for 15% DCAP replacement follows reports that younger birds respond favourably to the influence of enzyme due to their yet to be developed endogenous enzyme, thus resulting in better utilization of the feed by increased metabolisable energy (Alagawany *et al*., 2017)

5.4 Shelf life of DCAP

In this study, the observed dry matter in dry cashew apple pomace adequately supported the storage of the feed ingredient without significant deterioration to the other proximate components. The observed DM is within the range of 10-12% moisture content recommended for storage of feed stuff to prevent fungal growth. Aflatoxin level in the ingredient revealed a value within the permissible level of any standard feed ingredient. This could be attributed to the effectiveness of sun drying in the preservation of DCAP as a feed ingredient when adequate standards are adhered to.

5.4.1 Physical properties of DCAP observed were bulk density, compact bulk density, pH and water holding capacity. There is currently no literature on these physical properties for DCAP in animal feed. The bulk density obtained for milled DCAP was 0.63±0.01 while for unmilled was 0.30±0.01 while related sources in food nutrition observed 0.49-0.59g/cc in maltodextrin treated cashew apple powder (Khanvilkar, 2012). The difference obtained could be attributed to different methods of drying (sun drying versus spray drying), the maltodextrin treatment for food purposes and particle size. The result obtained in this study is within the range of 0.60-0.64 for maize (FAO, 1987) but lower than 0.71±0.01 and 0.7'70±0.01 for common maize and Quality protein maize as reported by Abiose and Ikujenlola (2014) although higher than 0.02-0.03gm^{-3} reported by Omede *et al*. (2012) for *Microdesmis puberula* leaf meal, rumen digesta and poultry dung as feedstuffs. Compact bulk density was 0.71±0.01 and 0.35±0.02 for milled and unmilled DCAP respectively, no literature was sighted.

The specific gravity (SG) of 0.64 and 0.30 were observed for milled and unmilled DCAP respectively. Omede *et al.* (2011) observed a range of 0.24-0.45 for protein sources and industrial by-products ingredients. A relatively high SG could signify reasonable retention time desirable for livestock feed ingredients.

In this present study, a pH of 4.25 was obtained, this falls within the range recorded by different authors such as Akinwale (2000) recorded a pH range of 4.15-5.09 in dry cashew apple powder and cashew apple juice respectively. The differences in pH obtained in different studies could be attributed to the locations in which the cashew apples were obtained, the different products and treatments the cashew apple was subjected to such as juicing, washing, spray drying, sun drying and chemical treatment. In their study, Lowor and Agyente-Badu (2009) reported a different pH due to location in Ghana, lower pH was reported for cashew apple juice from cashew apples collected from the Coastal Savannah than from the Forest Savannah of the country. pH of feed is a determinant of digestibility and gives indication of availability of nutrients. This is also true for pH of feed ingredients (Lević *et al*., 2005). It is required for the determination of buffer capacity used in obtaining B-value range require in feed and feed stuff. The pH in this study falls in the range of 4 - 6.95 reported by Lević *et al*. (2005) for cereal feedstuffs wherein the value for maize (5.8) lies. Although the buffer capacity and B-value for DCAP were not determined, the utilsation in this trial does not show any detelerious effect to the broiler chickens. Low initial pH could also be responsible for DCAP conservation.

Water holding capacity (WHC) value 0.26±0.01 obtained in this study is lower 0.61, 0.67 and 0.35 for Leaf meal, rumen digesta and poultry dung respectively which were reported by Omede *et al.* (2012). It could be inferred from the suggestion of the earlier mentioned authors that non- soluble Non- starch Polysaccharide (NSP) is responsible for the lower values of WHC. Insoluble NSP are known to reduce viscosity, enhance motility in gut and gizzard bringing to bear positively on the digestive tract, promoting the proliferation of useful microflora (improved health status) and improving growth performance (Iyayi and Davies 2005; Mateos *et al*., 2012)

The major insect pest in storage of DCAP identified in this study was *Lasioderma serricorne* F. though there are no previous literature reports of DCAP insect pest in storage. The identification follows pattern described by Hagstrum and Subramanyam (2009). *Lasioderma serricorne* is commonly known as cigarette beetle or tobacco beetle. It belongs to the family Ptinidae and order Coleoptera. Apart from its impact on stored tobacco, chewing tobaccos, cigars and cigarettes, it is known to be found on stored products such as grains, spices, raisins, ginger, drugs, seeds and even dried flowers. After six months in storage, polyethylene sacks had only about 14% of the insects found in the plastic container. Although there is no reference literature on DCAP storage, this result corroborates that of Mali and Satyavir (2005) where insect damage on wheat stored in polyethylene bag was less than in jute bags and tin containers. This could be due to air movement possible in the sacks than the bin thereby lowering temperature which could encourage insect proliferation.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

Four studies were conducted to assess the potentials of dried cashew apple pomace in broiler feed as an energy source in replacement for maize. The first study was an assay on chemical composition of DCAP and its metabolisable energy in cockerels. The second study was on the effect of different level of inclusions of DCAP in broiler diets in replacement for maize. The third study was based on the result of the second study, seeking the influence of exogenous enzymes on broiler chickens fed dried cashew apple pomace with or without enzyme. The fourth study was conducted to determine the shelf life and physico-chemical properties of dried cashew apple pomace.

In study one, chemical composition of DCAP and its metabolisable energy in chickens, results show that

1. The protein content of DCAP is higher than that of maize at 12.60%
2. The amino acid profile of DCAP compares favourably with that of maize
3. Tannin, the constraining anti-nutritional factor was below detectable level in the sample analysed.
4. Metabolisable energy of dried cashew apple in chickens was 2428.51 kcal/kg.

In study two, results showed that

1. Feed intake and weight gain were not significantly different from control for all the levels of DCAP at 0-21, 21-42 and 0-42 days of feeding
2. Feed conversion was significantly lower in control diet than 20% replacement but not with 5, 10 and 15% level of replacement for maize
3. Ceaca length was significantly higher at 21-42 days at 20% replacement of DCAP with maize than other levels.
4. DCAP partially replaced maize successfully in broiler diet without adverse effect

In study three, the effect of exogenous enzymes on the utilisation of DCAP on broiler diets, results showed that

1. Enzyme inclusion only had significant effect at 15% inclusion level with a decrease in intake at the starter phase and an increase at the finisher phase. This shows the benefit of enzyme inclusion for younger birds at this level of DCAP replacement of maize.

2. Enzyme significantly increased weight gain at starter phase at 30% DCAP replacement for maize

3. The multienzyme used conferred benefit to the partial replacement of maize with dry cashew apple pomace (DCAP) only at starter phase

4. Dried cashew apple pomace could be used up to 15% as a replacement for maize in broiler diet with or without enzyme without any deleterious effect and with the benefit of lowered cost at the starter phase

In study four, shelf life and physico-chemical properties of DCAP

1. The major insect pest of stored DCAP was identified as *Lasioderma serricone*

2. It has been established that properly dried cashew apple pomace could be stored in polyethylene bags and is durable for at least a year

3. The bulk density of milled DCAP was similar to that of ground maize

4. Crude Protein and Nitrogen Free Extract of DCAP did not alter significantly after one year in storage.

RECOMMENDATION

There is need for further research into types of sugars and their fibre fractions in dry cashew apple pomace along with the appropriate enzyme complex best for economical results in broiler chickens and other poultry species.

Having established metabolisable energy for poultry using cockerels in this research, it is hereby recommended that studies be carried out to establish metabolisable energy for different categories and ages of poultry such as layers and breeders for effective integration of dry cashew apple pomace into poultry feed.

Further studies are also recommended into the collection, processing, storage and preservation of dry cashew apple pomace.

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