EVALUATION OF COTTON PRODUCTS ON PERFORMANCE, HEMATOLOGICAL PARAMETERS AND CARCASS CHARACTERISTICS OF GROWING RED SOKOTO BUCKS

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DEPARTMENT OF ANIMAL SCIENCE,

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NIGERIA.

NOVEMBER, 2015

DECLARATION

I declare that this dissertation titled "**Evaluation of Cotton Products on Performance, Hematological Parameters and Carcass Characteristics of Growing Red Sokoto Bucks"** has been written by me in the Department of Animal Science, Ahmadu Bello University, Zaria, under the supervision of Dr. S.B. Abdu and Prof. O.S. Lamidi. The information derived from the literature has been duly acknowledged in the text and the list of references provided. No part of this thesis was previously presented for another degree or diploma at any University.

Laraba Ruth YAKUBU _____ _____

Signature **Date**

CERTIFICATION

This dissertation entitled "**Evaluation of Cotton Products on Performance, Hematological Parameters and Carcass Characteristics of Growing Red SokotoBucks"** by **Ruth Laraba YAKUBU** meets the regulations governing the award of the degree of Master of Science in Animal Science of Ahmadu Bello University, Zaria, Nigeria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to the Sovereign Lord-who is my always present help and also to my dear Family.

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ABSTRACT

A comparative study was conducted to evaluate the effect of cotton products (WCS and CSC) on performance, carcass characteristics and organs function of Red Sokoto bucks. A total of 24 bucks weighing averagely 8.625kg were randomly assigned to six diets formulated to contain 14% Crude Protein in a complete diet. The diets contained 10, 20 and 30% inclusion levels of Whole Cotton Seed (WCS) and Cotton Seed Cake (CSC) each and bucks were fed 4% of their body weights throughout the trial period of 90 days in a 2 x 3 factorial arrangement in a completely randomized design. Growth performance, digestibility and nitrogen balance, haematology and carcass characteristics, as well as organ functions were all studied. Results obtained showed that all the evaluations differed significantly at either the main effect of cotton products, inclusion levels and the interaction. Total weight gain (TWG) differed significantly ($p<0.05$) in bucks fed WCS (1.125kg) and CSC (1.833kg) with CSC performing better. Also, 20% (2.00kg) inclusion of cotton products (WCS and CSC) performed better than 10% (1.125kg) and 30% (1.313kg). Similar results were obtained for the interaction effect of cotton products and inclusion levels. Bucks fed WCS and CSC did not differ significantly ($p>0.05$) in digestibility study although, a significant difference ($p<0.05$) was obtained for inclusion levels of WCS and CSC with 20% (67.346%) inclusion level performing better than 30% (59.989) and 10% (49.843%) being the least for dry matter (DM), organic matter (66.484, 58.511 and 48.044), crude protein (78.077,76.046 and 63.725%), Neutral detergent fibre (68.587, 65.264 and 57.511%) and Acid detergent fibre (76.860, 72.046 and 63.725%) respectively. Nitrogen retained as percent intake was higher in bucks fed CSC (53.026%) comparedto WCS (48.435%)treated group while 30% inclusion level of cotton products retained more nitrogen (62.47 compared to 53.24 and 36.480%) of 20 and 10% respectively which differed ($p<0.05$) significantly. There

was a significant difference ($p<0.05$) of cotton products on total protein (6.563 and 7.431 g/day), Packed Cell Volume, PCV (26.8 and 34.333%), heamoglobin, Hg (8.840 and 11.417 g/dl), Red Blood Cell, RBC (4.473 and 5.833 *10^6/l) and neutrophil (59.6 and 77.167%) for WCS and CSC respectively with CSC having the highest values all through the measured parameters. There was significant ($p<0.05$) difference in the inclusion levels of cotton products in the Blood Urea Nitrogen BUN, (69.330, 42.530 and 58.440µmol/dl) for 10, 20 and 30% respectively with 10% inclusion being the highest value followed by 30 and 20%. Neutrophil followed the same order while albumin (12.733, 23.333 and 23.333 µmol/l), PCV (29.889, 26.444 and 34.111%), Hg (10.033, 8.789 and 11.133g/l) and RBC (4.978, 4.589 and 5.867*10^6/l) differed significantly ($p<0.05$) on bucks fed 10, 20 and 30% inclusion levels with 30% being the highest value obtained. The interaction of cotton products and inclusion levels for most parameters measured differed significantly ($p<0.05$) except for BUN and monocytes counts. Using WCS or CSC had no significant effect ($p>0.05$) on hot carcass weight, dressing percentage and organ weights although, inclusion level of these products affected hot carcass weight, dressing percentage, empty small intestine and lungs weights significantly with 30% inclusion having the highest value and 20% the lowest value for the parameters observed. Similarly, prime cuts of leg, chump and main rib differed significantly for the effect of cotton products with WCS having better muscle development compared to CSC treated group. It can be concluded that, the use of either WCS and CSC, and their inclusion at various levels will give a similar result although, for better digestibility and nutrient absorption, CSC is more preferable at 20% inclusion.

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CHAPTER 1

1.0 INTRODUCTION

With the increasing per capital income, the livestock sector has become one of the fastest developing agricultural sub-sectors, exerting substantial pressure on the fragile natural resources. The competitive demand for conventional plant protein sources particularly soybean meal and groundnut cake has led to high cost of animal feed in Nigeria. This has necessitated the search for alternative replacement that has competitive nutritive value also and preferably cheaper than the conventional protein source (Atteh*et al*., 1995).

Whole cotton seed (WCS) and Cotton Seed cake (CSC) are by-products of the cotton industry. Whole cotton seed is unprocessed and contains a high level of crude protein (20-24%) with high digestible energy content, making it a very useful by-product (Pooreand Rogers, 1995). Due to its high content of fat and protein, it can be defined as a concentrate. Furthermore, regarding effectiveness in the rumen, it has properties similar to forage fibre sources (Arieli, 1998). Increasing demands for energy and protein sources by ruminants have increased the importance of whole cotton seed (WCS) as an energy and protein supplying ingredient. Due to the high energy, oil and protein contents, WCS is a popular feedstuff for ruminants and it has been accepted as an alternative to cereal grain in many rations (Kandylis *et al*., 1998). In addition WCS is a good source of phosphorus and vitamin E.

Cotton Seed Cake (CSC) is also high in protein (26-48%), a good source of fiber and phosphorus. Cotton Seed Cake supplies protein of satisfactory quality for cattle, sheep or horses, but less for poultry if fed as sole protein source because of its low lysine contents (Ibrahim, 1998). It is also deficient in calcium and a poor source of carotene. Chesworth,

(1992) categorized CSC as a type of concentrate supplying both rumen degradable (RDP) and undegradable (UDP) protein and gave the RDP and UDP levels of CSC to be 27.4% and 18.3% respectively for a 45.7% CP, CSC. One potential problem in the feeding of cottonseed or cottonseed products is gossypol toxicity; gossypol is a yellow polyphenotic compound indigenous to the cotton plant. The concentration of free gossypol in feed stuffs such as WCS and CSC varies considerably. The level of gossypol in the seed is about 0.7 – 0.8 %, (Pereira *et al.,* 2002) its concentration can be affected by the variety of cotton, soil conditions, levels of fertilizer applied, water supply and any factor that may affect plant growth. In cotton seed cake however, the method of processing, the duration of heat treatment or processing, and the extent of oil extraction affects its gossypol content.

Ruminants have the ability to detoxify large amounts of gossypol within the rumen (Reiser and Fu, 1962). Diets containing up to 25% (DM basis) WCS have been reported to be safe for consumption by cattle (Calhoun and Holmberg, 1991). Solaiman (2007) reported safe level of 30% inclusion of WCS in diets fed to goats with no adverse effect on dry matter intake and growth performance, but had an adverse effect on some blood metabolites, liver related enzymes and semen quality. While 16% inclusion level of WCS was reported to have negative effect on lamb performance (Absalan*et al*., 2011).

Justification of the Study

Although WCS and CSC have been used extensively in cattle feeding systems (Poore and Rogers, 1995; Arieli, 1998), they have not been fully investigated as a sole dietary ingredient for small ruminants especially for meat and dairy purposes in Nigeria. The Agricultural Transformation Agenda in 2012 proposed the use of 3000 metric tonnes of cotton seed for

planting which has being reported to have commenced in Bauchi state in 2014. This increase in availability of planting materials will encourage and boost the production of cottonseed and its by-products and also bridge the gap of proximity in the region, which will serve as alternative feedstuff for ruminant animalsthereby reducing competition with other conventional feedstuffs.

Objectives of the study

Broad objective:

The present study was aimed at evaluating cotton products on performance, haematological parameters and carcass characteristics of growing Red Sokotobucks.

Thespecific objectives of the study are to determine:

1. The effect of feeding various levels of cotton products (WCS and CSC) on the voluntary intake and response when fed to Red Sokotobucks
2. Theeffect of feeding various levels of WCS and CSC on nutrient digestibility and nitrogen balance of Red Sokoto bucks.
3. The effect of feeding various levels of WCS and CSC on carcass characteristics and histopathology of organs of Red Sokoto bucks.
4. The effect of cotton products (WCS and CSC) on blood metabolites of Red Sokoto bucks.

Hypotheses of the study

H_{O1}= Feeding diet containing different levels of WCS and CSC have effect on the performance and carcass characteristics of Red Sokoto bucks.

H_{A1}= feeding diets with inclusion levels of WCS and CSC have no effect on the performance and carcass characteristics of Red Sokoto bucks.

H_{O2}= Diet containing varied levels of WCS and CSC have effect on blood metabolites of growing bucks.

H_{A2}= Diet containing varied levels of WCS and CSC have no effect on blood metabolites of growing bucks.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 History of cotton plant

2.1.1. Origin of cotton plant

Cotton is a natural fibre used by modern humans. Cultivated cotton is also a major oilseed crop and a protein source for animal feed. Cotton plants thus have an enormous weight in the world economy and are of great importance for the agriculture, industry and trade of many tropical and subtropical countries of Africa, South America and Asia. The origin of Gossypium is dated to around 5-10 million years ago (USDA, 2007).

2.1.2 Description of cotton plant

Gossypium comprises around 50 species making it the largest in specie number in the tribe *Gossypieae*. It is derived from the Arabic word goz, which refers to a soft substance. Cultivated cottons are perennial shrubs most often grown as annuals. Plants are 1-2m high in modern cropping systems, sometimes higher in traditional, multi-annual cropping systems, now largely disappearing. The leaves are broad and lobed, with 3-5 (or rarely 7) lobes. The seeds are contained in capsule called a "boll", each seed surrounded by fibres of two types. These fibres are the most commercially interesting part of the plant and they are separated from the seed by a process called ginning. At first ginning the longer fibres, called staples, are removed, and these are twisted together to form yarn for making thread and weaving into high quality textiles. At the second ginning, the shorter fibres, called "linters" are removed and these are woven into lower quality textile (which includes the eponymous lint) USDA, (2007).

Commercial species of cotton plants are *G. hirsutum* (> 90% of world population*), G. barbadense* (3-4%), *G. arboretum and G. herbaceum* (2%). Many varieties of cotton have been developed by selective breeding and hybridization of these species. Experiments are ongoing to crossbreed various desirable traits of wild cotton species into principal commercial specie, such as resistance to insects and diseases, and drought tolerance. Cotton fibres occur naturally in colors of white, brown, green and some mixing of these. Most wild cottons are diploid, apparently due to a single hybridization event around 1.5- 2 million years ago. The tetraploid species are *G. hirsutum, G. mustelinum, G. tomentosum, G. barbadense and G. darwinii,* (USDA, 2007*).*

2.1.3 Economic importance of cotton plant

The seed oil extracted from the kernels, after being refined serves as a good edible and nutritious source. It can be used as cooking oil, salad dressings. It is also highly beneficial for the production of shortening and margarine. Cotton grown for the extraction of cottonseed oil is one of major crops grown around the world for the production of oil, after soy, corn and canola.

The cottonseed meal after being dried up can be used as a dry organic fertilizer. As it contains 41 percent protein and comprises other natural nutrients such as omega-9 fatty acids. It does not contain any added products or chemicals and is free of animal residue. It can also be mixed with other natural fertilizers to improve its quality and use. Due to its natural nutrients, cottonseed meal improves soil's texture and helps retain moisture. It serves as a good source of natural fertilizers in dry areas due to its tendency of keeping the soil moist. Cottonseed meal fertilizers can be used for roses, camellias or in vegetable

gardens.The fine quality oil extracted from cottonseeds during the extraction process is also used in cosmetic (moisturizing lotions and bath soaps) production USDA, (2007).

2. 2 Description of cotton products

Cotton products are by- products or materials obtained from cotton industry and processing. These products include whole cotton seeds, cottonseed cakes, cotton hulls and ginnery waste. Their uses differ based on the products type and purpose of use. Cotton products also have varying nutritional values and benefits although major use of cotton products includes Whole Cotton Seed, Cotton Seed cake and Cotton hulls.

2.2.1 Whole Cotton Seed

Whole cottonseed also known as fuzzy cottonseed is the remains of cotton seed covered with linters after the separation of the lint from the seed. Amount of linters left on the seeds varies from 4 to 8%, except for seeds of *Gossypiumbarbadense* varieties (such as American Pima cotton), which are naturally without linters (NCPA, 2012). Linters are a valuable fibre used for paper, cellulose acetate, viscose, explosives, plastic or photographic film. Fuzzy cotton seeds are subject to a mechanical delinting process that yields linters and naked seeds called delintedcottonseedor blackorslickcottonseed (Hoffman, 1998). Cotton seeds intended for sowing generally undergo chemical (sulphuric acid) treatment in order to remove linters but these delinted seeds (sometimes called acidcottonseed) should not be used as feed as they may contain chemicals residues and may have an unpalatable flavour (Smith *et al.*, 1999).

Fuzzy or delinted cotton seeds may be either fed to livestock or submitted to oil extraction, yielding oil, cottonseed meal and hulls. Cotton seeds contain about 20% of

valuable cooking oil. A typical cottonseed crushing operation separates the seed into oil (16%), hulls (26%), meal (45.5%) and linters (8.5%) (O'Brien *et al.,* 2005)

Whole cotton seeds are rich in protein (about 22% DM) and oil (about 20% DM), resulting in a high gross energy content, (Heuze*et al.,*2013). Combined with their high fibre content (about 28% DM crude fibre), these qualities make them a good feed for ruminant animals. However, the high fibre content and the presence of gossypol are limiting factors for monogastric animal and since cotton seeds contain more fibre and free gossypol than cottonseed meal, whole cotton seeds are much less used in pigs and poultry diets than cottonseed meal. Cottonseeds can serve as both a protein and energy source.

As a protein source, delinting tends to decrease the fibre content and increase the protein and oil concentration (Göhl, 1982). Cottonseed protein is highly degradable: soluble proteins (albumin and globulin) make up 75% of total proteins and protein degradability values are usually over 70% (Arieli, 1998). Because the energy of cotton seeds is mainly provided by their fat content, methane production in the rumen is lower than that obtained with fermentable carbohydrates (Arieli, 1998). Cotton seeds provide by-pass energy in the form of long chain fatty acids that are released in the rumen after oil hydrolysis, the addition of cotton seeds was found to greatly reduce the numbers of protozoa, as excessive fat in the rumen may have a detrimental effect on cellulolytic bacteria (Bird *et al.,* 1987). Umpapol*et al.,* (2011) recommended limiting cotton seeds level in order not to exceed about 6% of the total fat content in the diet because of its high fat content. It can be an interesting source of energy when incorporated up to 15% for steers under hot and humid climate. Those animals show less thermal stress (lower

respiration and sweating rates) maintaining their body temperature with a lower water consumption and better performance.

2.2.2 Cotton Seed Cake

Cottonseed cake is the by-product of oil extraction from cotton seeds, also known as Cottonseed meal; naming and categorizing cottonseed cakes is particularly difficult. Cake (high residual oil, not ground) and meal (low residual oil, ground) should correspond to different products, they are often indistinguishable in the literature as authors tend to use both terms as synonyms. The level of decortications is often unknown or not well described. Worse, *hulled* may mean either *without hulls* or *with hulls*, depending on the author. Also, the term *expeller* is not always clear, as it may apply both to meals that have undergone only mechanical extraction and to meals that have undergone both mechanical (screw press) and solvent-extraction. Likewise, solvent-extracted may apply to meals that have been extracted only with a solvent or to meal extracted using a preliminary mechanical step (Heuze, *et al.*, 2013).

Cottonseed cake is a common source of protein (protein-rich feed) for ruminants, notably in cotton-producing areas in developed countries such as India, China and the USA, where it is used as a partial substitute for soybean meal. Several methods are used to extract cottonseed oil, resulting in different types of cottonseed cake. This situation is slightly different from that of other major oilseeds such as soybean and sunflower, where one process is usually dominant. As a result, there is a wide range of cottonseed cakes differing on their protein, fibre and oil content (Heuze, *et al.*, 2013).

While some industrial processes include a dehulling step (notably those used in the US), hulls are not always removed or are sometimes only partially removed, resulting in undecorticated or partially dehulled, fibre-rich cottonseed meals containing in some cases more than 20 % crude fibre. Such cottonseed meals were formerly called Egyptian cotton cake (from black cotton seeds) or Bombay cotton cake (from white cotton seeds)(Göhl, 1982). Likewise, oil-rich, mechanically-extracted cottonseed cakes and meals are also available. There is a great variability in the chemical composition and nutritional value of cottonseed cake due to those various processes in addition to the original variability of the seeds themselves.

Cottonseed cake is mostly used to feed adult ruminants, which are relatively tolerant to gossypol. It can be a good source of protein for monogastrics provided that its limitations are taken into account, notably the fibre content and the presence of gossypol (Tanksley, 1990; Chiba, 2001). Cottonseed meal is also used as fertilizer (NCPA, 2002).

Cottonseed cake is valued as a protein feed, but the protein content is highly variable as it depends on the amount of dehulling and on the efficiency of oil extraction. The range of protein content goes from 30 % DM for non-dehulled cottonseed cake to up to 50 % DM for fully dehulled cakes. Lower and higher values than these extremes have also been recorded. The fibre content varies accordingly, from 25 % (non-dehulled) to 5 % (fully dehulled) crude fibre. The various methods used for oil extraction also explain the large range of residual oil present in cottonseed cake. Some solvent-extracted meals contain less than 2 % oil, like the other major oilseed meals, but many cottonseed meals contain higher oil values, often in the 5-10 % range but sometimes over 20 %. The cottonseed meal protein is less rich in lysine than soybean meal (4 % *vs* 6 % of the protein) and since

the protein content is generally lower, the total content in lysine and essential amino acids is lower for cottonseed meal (Heuze, *et al*., 2013).

Cottonseed cake is a good protein source for ruminants (Göhl, 1982). It is palatable with a nutritive value (for dehulled meals) slightly lower (85-90 %) than that of soybean meal. It is among the least expensive sources of protein in some regions. It is for instance the main source of protein for livestock in the cotton growing belt of India (NDDB, 2012). However, while gossypol is much less toxic to ruminants than to pigs and poultry, it is still recommended to limit its use to animals with a mature rumen, and to non-reproductive females or males, for short periods and at relatively low inclusion rates unless free gossypol content is known to be below risk level. Generally, cottonseed meal can be safely included up to 15 % in cattle diets (NDDB, 2012).

Cottonseed cake is a good protein supplement for low nutritive value forages and fibrous by-products because of its high protein digestibility, association with a source of degradable energy increases the efficiency of cottonseed meal supplementation (Brown and Pate, 1997; Bonsi and Osuji, 1997) since it decreases the urinary nitrogen, as most of the cottonseed meal energy comes from its fat content (for cottonseed meals with a high amount of residual oil) which is not adapted for the rumen microbe development at high levels (Bonsi and Osuji, 1997). Both decorticated and undecorticated cottonseed meal/ cake have a constipating effect on cattle, which is beneficial in feeds with high molasses content (Göhl, 1982).

2.2.3 Cotton Hulls

Cottonseed hulls are the outer coverings of cotton seeds, and the by-product of the dehulling step of cottonseed oil extraction. After delinting, the hulls are separated from the kernel by screening. Cottonseed hulls are a fibrous product, primarily used to feed ruminants (Hall and Akinyede, 2000).Cottonseed hulls are a low-protein 3-9% DM, (nearly 100% cellulose), highly fibrous by-product (ADF 57-73% DM) mostly used for ruminant feeding, NCPA, 2002.

Cottonseed hulls are used for feed in bulk or pellet form. They are sometimes mixed with cottonseed meal to create a higher density product that is easier to transport and handle (Blasi and Drouillard, 2002). Cottonseed hulls are one of the best roughages used to add bulk to diets rich in protein and energy, in order to reduce digestive upsets in ruminants (Lane, 2006). Cottonseed hulls are a valuable substrate for mushroom cultivation and the spent substrate can be fed to livestock (Bae*et al.*, 2006; Miles and Shu- Ting, 2004). Cottonseed hulls have also numerous industrial uses such as plastic manufacture, oil drilling (mud additive) and furfural production (a solvent used in plastic and synthetic rubber production and in petroleum refining) (NCPA, 2011).

Cottonseed hulls are available at the mill where cottonseed oil and cottonseed meal are obtained. Due to their low density, they may be difficult to transport and are thus confined to a fairly restricted market radius (Blasi and Drouillard, 2002). They can be prepared in mixture with cottonseed meal. In the USA, the use of cottonseed hulls in pellets increased in the late 1990s (Coombs and Pontif, 1996). The demand for hulls and the prices vary considerably with changes in the availability of other roughage feeds (NCPA, 2011).

2.3 Potential Constraint of Cotton Product

Some of the constraints or antinutritional factors/compounds found in cotton generally are; gossypol, cyclopropenoid fatty acid,phytate, tannins and aflatoxinsamongs others. Antinutritional factors are substances which under practical circumstances can impair some aspect of animal metabolism and produce adverse biological or economic effect on animal production.

2.3.1Gossypol

Gossypol is a toxic polyphenolic compound found mostly in glands localized in the cotton seeds. It exists in a free toxic form and in a bound, non-toxic form (Morgan, 1989). Free gossypol is the more important form in unprocessed cotton seeds. In *Gossypiumhirsutum* seeds, total gossypol concentrations ranging from 0.6 to 1.15 % DM and free gossypol concentrations from 0.05 to 0.7% DM have been reported (OGTR, 2008). Gossypol content depends on species, cultivars, fertilization, growing conditions, and insect pressure (Carter *et al.,* 1966,Randel*et al.,* 1992, Blasi and Drouillard, 2002). "Glandless" cotton varieties without gossypol have been developed but these varieties are more sensitive to pests and less productive, and have thus been found less economically viable, though investigations are still on-going (Rodman, 2006; Bourzac, 2006). The free gossypol content of cotton products may depend on processing: heating, for instance, increases gossypol binding and reduces toxicity, whereas fine grinding breaks the gossypol glands, releasing gossypol in the product (EFSA, 2008). Extrusion was shown to reduce free gossypol by 71 to 78% in cotton seeds (Buser and Abbas, 2001).

Free gossypol causes moderate to acute toxicity in animals. Signs of acute gossypol toxicity include constipation, dyspnoea, anorexia and loss of weight while repeated

exposure to lower doses of gossypol (in rats) mainly affects the testis in males (reduced sperm motility, inhibited spermatogenesis and depressed sperm counts) and reproductive organs and embryo development in females (EFSA, 2008). The bound form of gossypol is produced via covalent bonds between gossypol and the free epsilon-amino groups from lysine and arginine (Bressani et al., 1964, Fernandez *et al.,* 1995) through the browning or maillard reaction (Soto-Blance, 2008). This reaction reduces the availability of amino acids for absorption by the animal with lysine being the most affected (Fernandez *et al.,* 1995).

2.3.2 Tannins

Tannins are distributed in species throughout the plant kingdom. They are commonly found in both gymnosperms as well as angiosperms.). Most families of dicot contain tannin-free species (tested by their ability to precipitate proteins).The most abundant polyphenols are the condensed tannins, found in virtually all families of plants, and comprising up to 50% of the dry weight of leaves. Tannins of tropical woods tend to be of a cathetic nature rather than of the gallic type present in temperate woods. There may be a loss in the bio-availability of still other tannins in plants due to birds, pests, and other pathogens.

Tannins are found in leaf, bud, seed, root, and stem tissues. An example of the location of the tannins in stem tissue is that they are often found in the growth areas of trees, such as the secondary phloem and xylem and the layer between the cortex and epidermis. Tannins may help regulate the growth of these tissues. Tannins are classified as ergastic substances, i.e., non-protoplasm materials found in cells. Tannins, by definition,

precipitate proteins. In this condition, they must be stored in organelles able to withstand the protein precipitation process.

Tannins may be classified chemically into two main groups, hydrolyzable and condensed Encyclopedia (Tannin, 2014). Hydrolyzable tannins (decomposable in water, with which they react to form other substances), yield various water-soluble products, such as gallic acid and protocatechuic acid and sugars. Gallotannin, or common tannic acid, is the best known of the hydrolyzable tannins. It is produced by extraction with water or organic solvents from Turkish or Chinese nutgall. Tara, the pod from *Caesalpiniaspinosa,* a plant indigenous to Peru, contains a gallotannin similar to that from galls and has become an important source for refined tannin and gallic acid. The European chestnut tree (principally *Castanea sativa*) and the American chestnut oak (*Quercusprinus*) yield hydrolyzable tannins important in leather manufacture. Condensed tannins, the larger group, form insoluble precipitates called tanner's reds, or phlobaphenes. Among the important condensed tannins are the extracts from the wood or bark of quebracho, mangrove, and wattle.

2.3.3 Aflatoxin

Aflatoxins are produced by toxigenic strains of *Aspergillusflavus* and A.parasiticus on peanuts, soybeans, corn (maize), and other cereals either in the field or during storage when moisture content and temperatures are sufficiently high for mold growth. Usually, this means consistent day and night temperatures (>70°F), (Bakırdere*et al.*,2007). The toxic response and disease in mammals and poultry varies in relation to species, sex, age, nutritional status, and the duration of intake and level of aflatoxins in the ration. Earlier recognized disease outbreaks called "moldy corn toxicosis," "poultry hemorrhagic

syndrome," and "Aspergillustoxicosis" may have been caused by aflatoxins,(Akande*et al.*,2006).Aflatoxicosis occurs in many parts of the world and affects growing poultry (especially ducklings and turkey poults), young pigs, pregnant sows, calves, and dogs. Adult cattle, sheep, and goats are relatively resistant to the acute form of the disease but are susceptible if toxic diets are fed over long periods. Experimentally, all species of animals tested have shown some degree of susceptibility. Dietary levels of aflatoxin (in ppb) generally tolerated are ≤50 in young poultry, ≤100 in adult poultry, ≤50 in weaner pigs, ≤200 in finishing pigs, <100 in calves, and <300 in cattle. Dietary levels as low as 10–20 ppb may result in measurable metabolites of aflatoxin (aflatoxin M_1 and M_2) being excreted in milk; feedstuffs that contain aflatoxins should not be fed to dairy cows. Acceptable regulatory values in milk may range from 0.05 ppb to 0.5 ppb; individual regulatory agencies should be consulted when contamination occurs.

Aflatoxins are metabolized in the liver to an epoxide that binds to macromolecules, especially nucleic acids and nucleoproteins. Their toxic effects include mutagenesis due to alkylation of nuclear DNA, carcinogenesis, teratogenesis, reduced protein synthesis, and immune-suppression. Reduced protein synthesis results in reduced production of essential metabolic enzymes and structural proteins for growth. The liver is the principal organ affected. High doses of aflatoxins result in severe hepatocellular necrosis; prolonged low dosages result in reduced growth rate and liver enlargement (Akande, *et al.*, 2006, Pitt *et al.*, 2012).

In acute outbreaks, deaths occur after a short period of inappetence. Subacute outbreaks are more usual, and unthriftiness, weakness, anorexia, and sudden deaths can occur. Generally, aflatoxin concentrations in feed >1,000 ppb are associated with acute

aflatoxicosis. Frequently, there is a high incidence of concurrent infectious disease, often respiratory, that responds poorly to the usual chemotherapy. Dairy cattle experience inappetence, and ruminants may have decreased ruminal contractions at high concentrations (>1 ppm) of aflatoxins. Liver damage can lead to reduced clotting factor synthesis with acute to chronic hemorrhage.

2.3.4 Cyclopropenoid fatty acids

They occur in plant lipids mainly as glycerides as sterculic (I: n=7) and malvalic (I: n=6) acids which are the most abundant naturally occurring acid. Its quantitative estimation can be achieved conveniently by titration to a level of 0.01% (Durbetatti, 1956) although analysis for primary individual cyclopropene acids is rather complicated. Qualitative detection has also been possible for some time by the Halphen test (Halphen, 1897; Deutschmanand Klaus, 1960) which appears to be specific for cyclopropenoid material with unsubstituted ring methyl energy (Nordby, 1963) and involves the use of 1% sulphur carbon disulphide. Cotton seed oil contains 1-2% cyclopropenoid material, the distribution of which is reported being 0.7-1.5% malvalic acid and 0.3-0.5% sterculic acid (Shenstone and Vickery, 1961). Cyclopropenoid fatty acid has been shown to reduce fertility in hens, change the composition of the fat of animals and milk and cause death of rats. It is also reported that cyclopropenoid fatty acid have no adverse effect on growth aside depression, no effect on body organs except in pullets were notable differences were observed in the gall bladder, ovaries and oviducts after 5 weeks of supplementation and the retardation of comb growth.

2.3.5Phytate

Phytate are found stored in plant tissues, leaves and seeds. They form insoluble salts with the minrerals (phosphorus, calcium, iron, etc) in the plant that they become unavailable for absorption and utilization (Onwuka, 2005). It is the principal storage form of phosphorus and is common in legume seeds (Bisby and Harborne, 1994). Enneking and Winks, (2000) observed that phosphorus stored as phosphate and other important minerals cannot be available to animals especially non-ruminant due to the lack of digestive enzymes such as phytase to separate the minerals in the digestive system. Addition of phytase enzyme when processing feed helps in hydrolyzing and reducing the phytic acid composition of the feed (Bardocz and Pustzai, 1990).

2.3.6 Saponin

Saponins are naturally occurring surface- active glycosides produced by plants but also by lower marine animals and some bacteria. They derive their name from their ability to form stable, soap-like forms in aqueous solutions. Saponins consist of a sugar moiety usually containing glucose, galactose, glucuronic acid, xyllose, rhamnose or methylpentose, gylcosidically linked to a hydrophobic aglycone (sapogenin) which may be tripenoid or steroid in nature.

Tripenoidsaponin have been detected in many legumes such as soyabeans , beans, peas, Lucerne, alliums, tea, spinach, sugar beet, quinia, liquorice, sunflower, horse chestnut and ginseng. Steroid saponins are found in oats, capsicum peppers, aubergine, tomato seed, allium, asparagus, yam, fenugreek, yucca and ginseng (Francis*et al.*, 2002). Johnson *et al.*, (1986) found that some saponins increase permeability of intestinal mucosa cells in vitro, inhibit active mucosal transport and facilitate uptake of substances

that normally are not absorbed. It has also been found (MaderandBrumm, 1987) that Quillajasaponins improve growth, feed efficiency and health in ruminants, and increase efficiency of in vitro rumen-microbial protein synthesis and decrease degradability of feed protein (Makkarand Becker, 1996). Saponins reduce protein digestibility probably by the formation of sparingly digestible saponin- protein complexes (Potter *et al.,* 1993). Quillaja and other saponins either as crude mixtures or as purified compounds have been reported to increase immune- cell proliferation in vitro, boosted antibodies and immune-stimulating complexes formulated with Quillajasaponins preparation which induced specific cytotoxin T- lymphocyte responses (So *et al.,* 1997; Coulter *et al.,* 1998; Laceille- Dubois *et al.,* 1999). Saponins have high toxicity against fungi, are capable of deactivating viruses (Sindambiwe*et al.,* 1998), they are detrimental to protozoa and have been classified as possible defaunating agents in the rumen (Newbold*et al.,* 1997).

2.4 Methods of processing cotton products

2.4.1 Cotton Seed Cake

There are basically two methods of processing cotton products which is the heat and the mechanical treatment. Depending on the products type, some products are more tolerant to one method than the other as will be seen below;

Heat treatment: this is the application of heat at high temperatures such as roasting, moist cooking, boiling, extrusion, steam rolling, steam flaking, pressure flaking, autoclaving, popping, exploding, ashing, micromizing, solar heating or drying.

Mechanical treatment or process involves the use of machines to reduce particle size either by grinding, cracking or crushing. In cotton seed cakes, the mostly used methods are the mechanical extraction, direct solvent extraction and pre-press solvent extraction.

i. Mechanical extraction:this is a traditional method of cottonseed oil extraction that uses a circular mortar or more advanced technology such as a hydraulic press or a screw press (expeller). The cotton seeds may be dehulled, cracked, dried, and heated before being fed to the press. The resulting cake is dried, ground and then processed into large pellets (Ash, 1992). Mechanical extraction is not very efficient and up to 20 % of the seed oil may remain in the press cake, depending on the technology used (O'Brien *et al.,* 2005).

ii. Direct solvent extraction:as in the mechanical extraction, the seeds may be dehulled, cooked, cracked and flaked, but the oil is extracted by solvent (usually hexane) alone. The extracted cake is heated to eliminate the solvent and then generally ground into meal (Ash, 1992). This method was widely used in the 1980s in the USA (Morgan, 1989).

iii. Pre-press solvent extraction: this method combines a mechanical extraction (screw press or expander) step that reduces the oil by one-half to two-thirds of its original level, and solvent extraction, resulting in a 97 % oil extraction rate. The dehulled, cracked, dried, heated, flaked cotton seeds are first screw-pressed or expanded and the pressed flakes or pellets are then solvent-extracted.

In processing cotton seed cake, heat processing binds the free gossypol, thus reducing the opportunity for toxicity. The nutritional and chemical composition of cottonseed seed cake varies extensively by methods of processing and its variety.

2.4.2 Whole Cotton Seed

Whole cotton seed is said to contain high quantities of gossypol than the cake. Although several methods have been worked upon in reducing the effect/ content of gossypol in the whole seed(such as addition of iron salts), there has been contradiction in the findings and no specific conclusions have been made. Certain types of heat processing as reported by Bernard and Calhoun, (1999) suggested that there was notable alteration in gossypol binding so that gossypol bypasses the rumen detoxification process. In their research on roasted cottonseed, gossypol was found to be higher than in the unprocessed cottonseed implying that cottonseed that has gone through heat process is likely more toxic. In cotton seed, gossypol is contained in discrete structures called pigment glands, heating seed does not rupture pigment glands meaning that the enhanced availability of gossypol in heated seed is due to a chemical reaction between gossypol and other constituents in the pigment gland which produces a gossypol complex that by passes the normal detoxification process occurring in the rumen. Likewise, grinding or cracking as advocated by Arieli' (1998) is a means of increasing its feeding value however, breaking the seed coat also increases the gossypol (Prieto*et al.*, 2003).

Free gossypol generally present in whole cotton seed is extensively bound in the rumen and is much less available to ruminants than the free gossypol present in the cotton seed cake regardless of the process used in oil extraction, although, the free gossypol in cotton seed was much more available than that in the cotton seed cake when mixed with milk replacers and fed to lambs fed milk (Calhoun and Wan, 1995).

2.5 Effect of feeding cotton products on ruminant animals.

Despite the positive nutrient composition of cotton products, there are also some negative properties which may be detrimental to the animal which cannot be ignored.

2.5.1 Effect on performance:

Cunha *et al.*, 2012 reported that sheep with average weight of 30±2.6kg fed with varied levels of whole cotton seed with inclusion levels of 20, 30 and 40% had a mean intake of 0.249, 0.32 and 0.399 kg/day of inclusion levels respectively of the cottonseed with estimated gossypol intake corresponding to 6.8, 9.2 or 11.5 mg/kg/lwinclusion level respectively and the daily weight gain expressed in g/day had no influence from the levels of cotton seed with a mean value of 164 g/day indicating that the animals presented good development of weight throughout the study period and that gossypol intake was ata maximum range of 10 to 20 mg/kg. In a study using 20 Zandi male lambs with 29.8±1.6 kg body weight fed 0 to 16% varied levels of diets containing whole cotton seed (although with little quantity of cotton seed cake) no significant difference was observed on final weight, live weight gain but significant difference was observed in the average daily gain, dry matter intake and feed conversion ratio with no specific pattern but decreased values with increased inclusion level. Similarly, 12 Nubian buck kids fed with 50% Bermuda grass hay and 50% concentrate diet using Easiflo cotton seed at varied levels of 0, 15 and 30% inclusion in Texas with a duration of 24 weeks, showed that goats in diet consuming 15% whole cotton seed had high dry matter intake and average daily gain although gain efficiency was not affected. Also, as the percent of dry matter percentage increased with rise of whole cotton seed in the diets, total gossypol and both forms (+ or -) increased in plasma (Solaiman, 2007). Nunes*et al.*(2010) using 30 male

adult crossbreed goats fed 0.5kg/animal/day cotton seed as treated group and the second group with 0.5kg/animal/day corn meal as control diet for 120 consecutive days, reported differences in weight between the two groups to be 7.8kg and 8.6kg respectively. Also in a study using four rumen fistulated crossbred Thai native × Brahman steers aged about 2.5 years in a latin square design in Thailand comparing between whole cotton seed and sun flower seed at 3and 6% inclusion level respectively for both study materials, where 3% represented 15% WCS, 6% represented 30% WCS in the diets while 3% gave 8% of sunflower seed, 6% gave 15% of sunflower seed in the sunflower seed treatment diet (Polviset*et al*., 2010) observed no significant difference in dry matter (79.6,79.9, 80.0, 78.9), organic matter (82.5, 82.3, 82.7 and 81.8), neutral detergent fibre (79.4, 79.0, 79.0 and 77.8), acid detergent fibre (76.6, 75.9, 76.1 and 75.3) digestibility but showed significant difference in crude fat digestibility (80.8, 89.5, 76.6 and 86.4) respectively in the various treatment and inclusion levels.

Turki*et al.*(2011), in a study evaluating the effect of six dietary protein sources(oil seeds) on the performance of western Baggara cattle in diets formulated to be isocaloric and isonitrogenous with 25% inclusion level respectively in urea-molasses treated diets in Sudan reported cottonseed cake to be superior to other protein sources (guar germ, guar hulls meal, sesame meal, sunflower meal and groundnut meal) to have the highest live weight gain (1181g), feed conversion ratio efficiency (6.97kg/DM/kg live weight gain), and intermediate daily weight gain (8.23kg) compared with the other oilseed meals with ranges of 934-1113.0 of live weight gain, 7.08 to 8.06kg DM/kg/live weight and 6.92 to 8.45 kg/head/day dry matter intake respectively. In comparative study of cotton seed meal to sunflower meal in a total mixed ration with 20% inclusion levels, Kandylis*et al.,*

(1999) observed no difference in average daily gain with 200 to 220 g/day gain using 15kg Karagouniko sheep. Similarly, Khan *et al.* (1997) using 34 kg Afghani sheep with 20% inclusion level in the diet obtained slightly lower value (213g/day) of cottonseed meal compared to soybean and rapeseed meal (233 to 244g/day) in a total mixed ration respectively. On the other hand, a comparative study on untreated and formaldehyde treated cottonseed meal to lambs (fat tail salt range) with 40% inclusion level showed positive effect of treatment and higher average daily gain (185 vs 165g/day) and dry matter intake (1.6 vs 1.5kg) for treated against untreated respectively, showing that treatment of cottonseed meal tends to improve utilization even at higher inclusion levels (Khan*et al.,* 2000). Also, using 28kg Desert rams, a comparative study of cottonseed meal, sesame seed meal and groundnut meal with 8% inclusion level respectively showed no difference in ADG ranging from 73 to 88g/day, (Ahmed and Abdallah, 2005). Substitution of CSM for soybean meal in high concentrate diet with 30% inclusion level fed to 25kg Barki males showed lower ADG (170 vs 200g/day) and diet digestibility (65 vs 75%) which was attributed to gossypol effect (Ward *et al.*, 2008).

Solomon *et al.*(2008) observed that increasing level of CSM (200 to 400) decreases forage Dry Matter Intake (59 to 33 g/kg live weight), increases Organic matter (OM), (65 to 75%) and protein digestibility (41 to 73%), ADG (10 to 60 g/day) and carcass characteristics when increasing level of CSM with low quality/ nutritive value forage were fed to male Sidama goats weighing 17kg. similar result was obtained with 250 g/day inclusion level of CSM supplemented with local hay although there was no decrease in diet intake (Alemu*et al.,* 2010).

2.5.2 Effect on Blood/ Hematological Parameters

Solaiman, (2007) reported that with increase in the level of WCS in diet, fragility of RBC was observed, especially at 30% level of inclusion. Red blood cell, white blood cell, differencial counts and hematocrit was found to decrease in the treatment with 30% whole cotton seed. In the determination of serum levels of total proteins, glucose, cholesterol, urea, creatinine and triglycerides.Nunes*et al.* (2010) showed no significant differences between groups fed with0.5kg/animal/day cotton seed and 0.5kg/animal/day cornmeal respectively. Similarly, high concentration of plasma vitamin E in whole cotton seed treatments (113.9±3.5, 133.3±5.3 and 125.6±5.8) at 20, 30 and 40% varied levels than the control (107.9±1.7). The concentration of blood urea and ammonia were not influenced by WCS supplementation however, plasma urea- nitrogen (PUN) was decreased by WCS supplementation (Oguz*et al.,* 2006) and concluded that damaged liver cells as a result of gossypol intoxification was responsible for decrease of PUN, thus, the diminished capacity of the liver to synthesize urea.

2.5.3 Effect on rumen fluid;

Oguz*et al.*(2006) in an experiment using four lactating Holstein cows with average body weight of in Turkey fed four different diets containing 0, 12.5, 25,37.5% WCS formulated to be isocaloric and isonitrogenous observed no significant ($p>0.05$) effect on rumen parameters across treatment. However, the control had higher values in rumen TVFAs (125.8±8.9) and rumen ammonia (9.07±2.82) compared to 115.9±8.5, 121.3±6.4, 117.6±6.0 and 8.2±1.02, 8.4±1.13, 8.66± 1.96 for varied levels respectively but lower pH level (5.98±0.29) compared to (6.21±0.19,6.13±0.21 and 6.22±0.17) for the varied WCS levels. In a study of rumen fluid collected at 0, 3 and 6 hours post feeding (Polviset*et al.,*

2010) observed no significant difference in diet with cotton seed (7.05, 7.16) at 3 and 6% inclusion level, sunflower seed diet (7.00, 7.14) at 3 and 6% inclusion levels and 6 hours sampling time (7.08, 7.074) cotton seed, (7.07, 7.33) sunflower seed at 3 and 6% respectively. Ammonia nitrogen had no significant difference, rumen VFAs had no significant difference (59.1 to 62.9 acetate, 27.3- 31.7 propanionate and 9.6- 10.8 butyrate. There was also no significant difference in the rumen bacteria concentration. They stated in their result that high and low oil seed intake would induce less cellulolytic bacteria, less fermentation, less acetate production, higher ruminal pH values and higher rumen ammonia concentration where the pH increased with the increased levels of oil seeds in the ration. This indicates that high intake of oil seed only has mild impact on rumen function.

2.5.4 Effect on Carcass Characteristics;

Absalan*et al.*, 2011, reported significant difference in dressing percentage, hot carcass weight, liver, fat tail, intestinal fat and spleen with an increasing effect but no specific pattern for dressing percentage and hot carcass weight but a linear pattern was obtained for the organs weight respectively.

2.5.5 Effect on Organ Functions;

Absorped gossypol accumulates in the liver and kidney (Kim*et al.,* 1996). Gossypol is excreted primarily through the bile through feaces, urine (Chen *et al.,* 1987) and a little amount in expired air. Acute signs of gossypol toxicity generally includes; respiratory distress, impaired body weight gain, anorexia, weakness, apathy, heart failure in

ruminants and death after several days (Morgan *et al.,* 1988Kerr, 1989 andAlexander *et al.,* 2008).

In ruminants, toxicity includes pulmonary edema, yellowish liquid in the chest and peritoneal cavities, gastroenteritis, centrilobular liver necrosis and hypertrophic cardiac fiber degeneration. In calves, major signs are ascites, visceral edema, acute centrilobular hepatocyte necrosis, kidney damage and cardiovascular lesions. Increased pneumonia has been observed, likely due to increased sensitivity of secondary infections (Morgan *et al.,* 1988, Holmberg *et al.,* 1988, Risco *et al.,* 1992 and Zelski *et al.,* 1995).

Liver damage caused by gossypol toxicity showed signs like ascites and hepatocyte degeneration (strong cytoplasmic eosinophilia and nuclear pyknosis) and morphological changes such as enlarged endoplasmatic reticulum, mitochondrial vacuolation, an expanded perinuclear space and collagen fiber proliferation in the perisinusoidal space (Wang and Lei, 1987).

2.6 Population and Distribution of Goats:

Goats Population in Nigeria is about 22 to 26 million with rough estimates of 6.6million of them in southern region and 20million in the northern region of the country. The breeds of goats in Nigeria are largely indigenous; and the common ones include the West African Dwarf (WAD) goat, Sahel/desert goat- known as West African Long-Legged goat; and Sokoto Red/Maradi. The Kalahari goat breed, which is of South Africa origin is gradually being adapted to the Nigeria's ecological zones on experimental efforts. Distribution of the goat breeds in the country showed that the West African Dwarf (WAD) goat is common to southern Nigeria while the Sahel or desert goat and Sokoto Red are common to the northern region of the country, (Blench, 1999). It is said to have

originated from Sokoto province but spread throughout the northern parts of the country. Red sokoto have been found to be predominant in both the southern (Wamagi*et al.,* 2013) and northern (Ajala*et al*., 2008) part of Kaduna state although crosses with the WAD are also found.

2.6.2 Characteristics of RedSokoto Goat

- It has a distinctive red color which is basically used for its identification
- It is more resilient to pest and diseases compared to the West Africa Dwarf which results from its body configuration
- It is kept primarily for its skin which is of high quality in the tannery trade known as morocco leather
- Females grow up to 25kg while males 27kg
- It is short- haired but produces high quality skin
- Both sexes have scimitar- shaped horns
- Males have beards
- They have shorter legs than the typical desert goats
- Twinning is very common
- They have an average litter size of 1.8
- Milk yield ranges from 0.5- 1.5 litre/day
- Carcass yield is up to 45- 50% of live weight.Campell, (2003)

2.6.3 Economic importance of goats in Nigeria

Goats farming as reported by Foraminifera Market Research, (2013) require low initial investment, less housing requirements and managerial problems due to their small body

size and docile nature. They are prolific breeders and achieve sexual maturity at the age of 10- 12 months. It has short gestation period and females could produce milk from 16-17 months of age, both sexes have equal value, they are browsers and are capable of utilizing wide variety of feed which helps to save/ reduce the cost of production thereby increasing the farmers income. There is no religious taboo against goat slaughter and its meat consumption which encourages it production, wide distribution and available market. Goat meat (chevron) is more lean (i.e. contains low cholesterol) and relatively good for people who prefer low energy diet and has good chewing ability. Goat milk is easier to digest than cow milk because of the small fat globules and is naturally homogenized. It is also said to play a role in improving appetite and digestive efficiency. Goat milk is non allergic as compared to cow milk, it has anti- fungal and anti- bacterial properties and can be used for treating diseases of fungal origin. Goats are termed walking refrigerators for the storage of milk and can be milked number of times in a day. Goat production creates employment to the rural poor besides effectively utilizing unpaid family labor. There is ample scope for establishing cottage industries based on goat meat and milk products and value addition to skin and fiber. Their fecal outputs are use as organic manure to improve soil fertility.

2.6.4 Constrain to small ruminant production

1. The Control of Internal Parasites

The control of infestations of small ruminants by internal parasites (especially nematodes) is the most serious problem that challenges the small ruminant industry today. Infestations of these parasites can cause major economic losses to producers

because of the cost of treatment, production loss, and death of heavily infested animals (Fidelis and Tyrel, 2007).

Proper and effective management of internal parasites is extremely important for the survivability of the small ruminant industry. The ability to detect the clinical signs of a major worm infestation, to properly treat the infected animals, and to effectively reduce the herd's exposure to these parasites are all very important for effective internal parasite management. Worms that infect small ruminants have developed resistance against most of the available and widely used anthelmintics (dewormers). This is mainly attributed to the fact that many of these drugs are not approved for use in goats, are frequently used, and the animals are commonly under-dosed. Since there are few anthelmintics approved for use in goats, the dosage used for goats are normally "extra-label" or the producer uses the same dosages that are recommended for cattle or sheep. Goats are known to metabolize anthelmintics faster than cattle and sheep, which points to the fact that they require a higher dosage. Even though there is a need for drugs that have approved dosage rates for goats, it is unlikely there will be any new types or classes of anthelmintics for goats in the near future because the limited markets for these drugs do not validate the high discovery and developmental cost needed to create the drugs. Although preventive measures such as low stocking rate, pasture rotation, and proper nutrition could reduce the level and the effects of infestation by these parasites, prevention strategies that effectively reduce the need for anthelmintics and decrease parasitic infestations are needed. Effective prevention of parasitic infestations would bring a huge boost to the development of the small ruminant industry, (Geary *et al.*,1999).

2. Marketing Goat Meat

Despite the increasing demand, marketing goat meat is still a major challenge to the development of the meat goat industry. The current market situation is erratic and not organized. There are no established standards for marketing goat meat. Also, there are not enough government-approved processing plants for goats, and these plants are mostly located in large cities and are far from farmsteads. Consequently, the producer's ability to market his products is limited because of the difficulty and expense required to transport the animals to these slaughter facilities. Additionally, the link between the farmers and the ethnic consumers' needs to be strengthened because these ethnic groups prefer fresh meat slaughtered on the farm, and buying directly from the producers increases the producers' profit margin as compared to marketing through stock yard auctions.

Other serious marketing challenges facing the goat production industry are how to convince the mainstream sector of the population to consume goat meat, and how to establish a viable marketing outlet for this group. Large and established grocery companies are skeptical about the inclusion of goat meat in their stock because of the uncertainty of reliable and constant supplies, the uniformity of cuts, and the lack of a wide range of products from goat meat that will appeal to these emerging, mainstream groups. Predictable and consistent products like pre-cooked and pre-packaged products from goat meat should enhance the consumption by the mainstream. Also, a boost in the consumption of goat meat may come when the mainstream population becomes better informed about the health benefits they can receive from the consumption of goat meat. These are vital issues in the development and long-term sustainability of the meat goat industry as reported by Coffey, (2006).

3 Limited Expertise and Information

Available expertise and information for meat goat production are very limited when compared to what are available for the production of traditional meat animals such as cattle and swine. For example, there are no accurate statistics on the number of goats produced or sold, appropriate feeding regimes for goats are not yet determined, and standard goat herd health programs are not very developed. However, researchers are working in these areas and hope to develop a standard of production and a marketing strategy for goat meat in the near future (Fidelis and Tyrel, 2007).

4 Limited Access to Financial Support

Meat goat production is a relatively under-utilized industry. Lenders are skeptical of this enterprise because there is little or no available information for them to determine its profitability. This makes it difficult for owners of small farms to secure loans for meat goat enterprises compared to the monogastric (poultry) farming, Fidelis and Tyrel, (2007).

2.6.5 Small Ruminant Production Systems

Within the meat and dual production systems the following four management systems can be identified:

1. Extensive (migratory, free range, pasture or range grazing). Although this system of management is cheap and less labor intensive, it is characterized by low productivity and high losses due to accidents, diseases and theft.

2. Semi-intensive (pastures or range grazing, use of supplementary feeding mainly on crop residues and conserved roughage).

3. Intensive (grazing on improved pastures, zero grazing, conserved forage, crop residues and increased use of concentrates).

4. Tethering (small size flocks of 2–10 animals). This is a subsistence family system and the animals live on kitchen remnants crop residues, grazing near inhabited areas and other supplementary feed, (Lawal- Adebowale, 2012).

2.7 Nutrient requirements of growing goats.

Nutrient requirement of growing goats vary with other animals at different production stages such as lactating, pregnant, work bulls, kids, dry and animals kept for maintenance alone. Nutrients are basically classified into macro nutrients which consist of water, carbohydrate, protein and fats; and the micro nutrients which are the minerals and vitamins. Factors that can affect requirement are the environment, age of animal, purpose of production, environmental factors, physiological factors and the feed type.

2.7.1 Water

Goats should be provided unlimited access to fresh, clean, nonstagnant sources of freely accessible water. Goats are among the most efficient of domestic animals in their use of water; however, only ~10% of body water loss may prove fatal. They appear to be less subject to high temperature stress than other species of domestic livestock. In addition to a lesser need for body water evaporation to maintain comfort in hot climates, goats can conserve body losses of water by decreasing losses in urine and feces. Factors affecting water intake in goats include lactation, environmental temperature, water content of

forage consumed, amount of exercise, stage of production (growth, maintenance, lactation, etc), and salt and mineral content of the diet. Goats grazing lush pastures may consume much lower quantities of water than those feeding on dry hay. Still, it is imperative to allow free access to water for all goats regardless of age, breed, purpose, stage of life cycle, or environment.

2.7.2 Energy and Fat

Energy limitations may result from inadequate feed intake or from poor diet quality; excessive water content of the feedstuffs also may become a limiting factor. Energy requirements are affected by age, body size, body condition, stage of production (growth, maintenance, pregnancy, and lactation), and concurrent health conditions (e.g, parasitism, dental disease, arthritis). Energy requirements also may be affected by the environment, hair growth, activity, and relationship with other nutrients in the diet. Increased temperature, humidity, sunshine, and wind velocity may decrease energy requirements (David, 2014).

2.7.3 Protein

Protein is required for most normal functions of the body, including maintenance, growth, and reproduction, lactation, and hair production. Protein deficiencies in the diet deplete stores in the blood, liver, and muscles and predispose animals to a variety of serious and even fatal ailments. Feed intake and dietary digestibility are reduced if dietary crude protein is <6%, further compounding an energy-protein deficiency; thus, for maintenance of mature, healthy animals, the diet should have a minimum of 7% crude protein. Dietary crude protein requirements are higher for growth, gestation, and

lactation. Feeding adequate to slightly greater amounts of protein than required appears to aid in the control (both resistance and resilience) of internal nematode parasites. Protein is usually the most expensive component of the goat diet and is required both as a source of nitrogen for the ruminal bacteria and to supply amino acids for protein synthesis in the animal's body. When the levels of protein are low in the diet, digestion of carbohydrates in the rumen will slow down and intake will decrease. Inadequate levels of protein in the diet can affect growth rate, milk production, reproduction and disease resistance negatively, because insufficient amino acids are getting to the intestines to be absorbed by the body. Unlike energy, excess of protein is not stored in the body of the goat. Therefore, it is important to feed enough protein to cover the nutritional requirements of the animal(David, 2014).

2.7.4 Minerals

Goats require many minerals for basic body function and optimum production. Providing free choice a complete goat mineral or a 50:50 mix of trace mineralized salt and dicalcium phosphate is advisable under most situations. Major minerals likely to be deficient in the diet are salt (sodium chloride), calcium, phosphorous and magnesium. Most forage are high in calcium, so calcium is low only if high grain diets are fed, which would be unusual for goats. Low quality, weathered forages will be deficient in phosphorous, especially for high and average lactating does. The ratio of calcium to phosphorous in the diet is important and should be kept about 2:1.Trace minerals likely to be low in diets are copper, zinc and selenium with selenium being the most deficient and as such trace mineralized salts that include selenium should be provided to the goat herd

at all times. Producers should make sure that the trace mineralized salts they buy contain selenium.Lunginbuhl, (2015).

2.7.5 Vitamins

Vitamins are needed by the body in very small quantities. The vitamins most likely to be deficient in the diet are vitamin A and D. All B and K vitamins are formed by bacteria found in the rumen of the goat and are not considered dietetically essential. Vitamin C is synthesized in the body tissues in adequate quantities to meet needs. Vitamin A is not contained in forages, but carotene found in green, leafy forages is converted into vitamin A in the body. In addition, vitamin A is stored in the liver and fat of goats during times when intake exceeds requirements. Goats consuming weathered forages or forages that have undergone long-term storage should be fed a mineral mix containing vitamin A, or should receive vitamin A injections. Vitamin D may become deficient in animals raised in confinement barns. Animals should have frequent access to sunlight because it causes vitamin D to be synthesized under their skin, or they should receive supplemental vitamin D. Good quality sun-cured hays are excellent sources of vitamin D. A deficiency in vitamin D results in poor calcium absorption leading to rickets, a condition where the bones of young animals and joints grow abnormally, (NRC, 1985).

2.8 Digestive Systems

Adult ruminants have a distinctive digestive system from the monogastric animals where the oesophagus delivers food directly into the reticulo- rumen. Digestion in ruminants starts from the mouth, oesophagus, stomach, intestine and then excretion of waste products. Unlike the monogastrics, the stomach of a ruminant is divided into four parts; the rumen, reticulum, omasum and abomasums. This modification gives them the edge to

feed on wide range of feed material and adequately convert them to products such as meat or milk. Digestion process is divided into two because of their stomach compartment; the pre- gastric (occurs in the rumen by microbes) and post gastric (occurs in the abomasums which is same as true or glandular stomach).

The Rumen

Located on the left side of the body, the rumen makes up over 65% of an adult cow's total stomach volume with interior surface that forms numerous papillae that varies in shape and size from short and pointed to long and foliate. It is, in effect, a huge fermentation vat containing a soup of around 130 litres of chewed-up feed with large amounts of saliva and micro-organisms - primarily bacteria and protozoa. Floating on top of this soup is a fibrous mat of coarser solid material which acts as a filter. Feed particles are regurgitated and re-chewed until they are small enough to fall through the fibre mat into the rumen liquor below. The rumen liquor commonly contains between 109 and 1011 bacterial per ml, together with 105 -106 protozoa. These break down degradable feed materials to produce Volatile Fatty Acids (VFAs), ammonia and a variety of long chain fatty acids. Ammonia is used as a nitrogen source for microbial growth and VFAs absorbed from the rumen are a key energy source for the cow. Increasing the rumen-available energy content of the diet in the form of sugar and starch stimulates papillae growth, improving VFA absorption. While rumen fermentation allows good use to be made of fibrous feeds that could not otherwise be digested, it does mean only around 70-85% of the energy in the feed is available to the animal - 6-15% commonly being lost as gases (mainly methane) and 6-7% as heat.

The Reticulum

Small in comparison to it, the reticulum is a continuation of the rumen with a honeycomb structure. The reticular epithelium is thrown into folds that form polygonal cells which gives it a reticular, honey comb appearance with numerous small papillae stud in the interior floors of the cells. Microbial fermentation continues as the feed moves through the reticulum and into the omasum - a globe-shaped structure containing page-like folds of tissue from which water and some nutrients are absorbed.

The Omasum

Moving through the omasum, the mixture of feed and rumen micro-organisms becomes progressively drier. Excessive intake of minerals or low quality fibre (such as sunflower hulls) can cause compaction of the omasum (Bowen, 2003).

The Abomasum

Finally the abomasum or 'true stomach' secretes hydrochloric acid and digestive enzymes to begin breaking down feeds that have escaped microbial digestion together with microbes excreted from the rumen. From the stomach the digesta moves into the small intestine where most of the digestive enzymes are secreted to break down both feed and microbial nutrients into simpler nutritional building blocks. These are absorbed across the intestinal lining and into the bloodstream through small finger-like projections (villi) which increase its surface area (Bowen, 2003).Bacterial fermentation of some undigested feed occurs in the final section of the digestive tract - the large intestine - which also absorbs both VFAs and water.

2.8.1 Rumen Digestions

Digestion in the rumen accounts for 60-70% of the total digestion in ruminants and is accomplished by the populations of microorganisms that benefit from a symbiotic relationship with their host animal. Fermentation is a means of energy production under anaerobic conditions and is the metabolic process used by microorganisms in animal digestive tracts. The rumen is thus analogous to a fermentation vat where microorganisms ferment the feed substrates ingested by the animal. The kinds and amounts of microorganisms present in the rumen vary greatly, but are generally divided into bacteria, protozoa and fungi. Bacteria are the most abundant microorganisms present in the rumen (on the order of 10^{10}-10^{11} bacteria/ml) and represent about half of the microbial mass in the rumen (Ørskov and Ryle, 1990, Van Soest, 1994). They are the most important contributors to rumen digestion (Van Soest, 1994). Because protozoa are much larger than bacteria, they may account for up to 40% of the microbial mass even though their relative numbers (10^{5}-10^{6}) and metabolic contribution are small (Ørskov and Ryle, 1990, Van Soest, 1994). Fungi represent up to 8% of the rumen microbial mass though their metabolic contribution is poorly understood (Ørskov and Ryle, 1990, Van Soest, 1994). Carbohydrates are the main substrates used by rumen microorganisms to supply their energy needs, although soluble proteins can be hydrolyzed and the resulting amino acids can also be fermented for energy (Ørskov and Ryle, 1990).

Carbohydrates in the rumen can be divided into three main classes: water soluble carbohydrates, starches and structural carbohydrates. Water-soluble carbohydrates (WSC) are simple sugars such as sucrose that are soluble in the rumen fluid. Water-soluble carbohydrates are found in the cell contents and do not significantly vary between

forage species although the WSC content decreases with plant maturity (Beever and Mould, 2000). Starch, a form of energy storage for the plant, is composed of a varying ratio of amylose and amylopectin, neither of which is very soluble and both of which take longer to digest than simple sugars (Van Soest, 1994). Grains such as corn and barley contain a large quantity of starch relative to grasses; Starches are fermented by amylolytic bacteria which are principally *Bacteriodesamylophilus, Selenomonasruminatium,* and *Streptococcus bovis*(Theodorou and France, 1993). Structural carbohydrates consist of cellulose, hemicellulose and pectin; pectin being the most rapidly degraded and hemicellulose being the least rapidly degraded (Merchen and Bourquin, 1994). The main cellulolytic bacteria found in the rumen are *Bacteroidessuccinogenes, Ruminococcusalbus, R. flavefaciens,* and *Eubacteriumcellulosolvens*(Theodorou and France, 1993). Hemicellulose is degraded by some of the same species as those that degrade cellulose as well as *Butyrivibriofibrisolvens*and *Bacteriodesruminicola.*

The protein content of a feed can be divided into two fractions in terms of their fate in the rumen. The first fraction is rumen degradable protein, which consists of any protein that is broken-down in the rumen before it is passed into the lower digestive tract. Once a protein has been hydrolysed into its constituent amino acids, they can either be incorporated into the microbial protein mass or fermented for energy into volatile fatty acids (VFA) and ammonia. The ammonia can then be used by the microbial population for *de novo* protein synthesis; a process that is favored by amylolytic bacteria (Beever and Mould, 2000). If excess ammonia is produced, it is absorbed across the rumen and excreted in the urine; precluding any advantages of feeding high protein diets. Microbial

protein passes into the lower tract and is digested and absorbed by the host animal. In general, microbial protein provides the majority of the host's amino acid supply. The other protein fraction is rumen undegradable protein, which consists of protein that passes through the rumen and is subsequently digested in the lower tract. In forages, factors that affect the degradation of protein in the rumen include plant maturity, method of conservation, physical processing and whether the forage is a grass or a legume (Merchen and Bourquin, 1994).

2.8.2 Effects of feed type on rumen digestion.

There are mainly five products of microbial fermentation: acetate, propionate, butyrate, methane and carbon dioxide in a descending order. Acetate, propionate and butyrate represent the major VFAs produced in the rumen providing 50- 80% of the host animal's energy(Merchen and Bourguin, 1994). Carbon dioxide and methane on the other hand are waste gasses eructed accounting for the largest energy lost by fermentation process. Therefore, the most efficient feeding strategy in the rumen will utilize maximally VFAs and microbial mass production while reducing waste (carbon dioxide and methane) production. The proportion of VFA synthesized in the rumen varies with diet, microbial rates, feeding level and rumen pH (Lopez *et al.*, 2000). High forage diets result in the production of higher amounts of acetate and butyrate while high starch diets result in higher proportion of propionate production though acetate remains dominant (Beever and Mould, 2000). Acetate is mostly not affected by the liver and it supplies the major source of energy by either being oxidized to ATP or stored in long chain fatty acids. Propionate on the other hand, travels to the liver where it is converted to glucose.

The pH of the rumen undergoes diurnal fluctuations and reflects the balance of acid production and absorption as well as the buffering function provided by bicarbonates in the saliva (Van Soest, 1994). VFA production increases after feeding resulting in a depression in rumen pH. As the rate of VFA production decreases and absorption continues in the hours between feeding, the rumen pH will rise again. The rumen pH of ruminant fed a predominantly forage diet is generally higher, in the range of 6.2-7, than those fed diets with larger proportions of concentrates with rumen pH ranging from 5.5-6.5 (Kolver and de Veth, 2002). Yang *et al*., (2002) showed that pH below 6.2 affect negatively the rate of fiber digestion, but state that activity of cellulolytic bacteria in particular is depressed when rumen pH falls below a pH of 6.2. The depression in fiber digestion is a result of decline in cellulolytic bacteria multiplication as well as inhibition of the process of cellulolysis itself which is attributed to the sensitivity of cellulase to low pH.Cellulolysis and cellulolytic bacteria multiplication are slowed below the pH of 6 and the processes can be altogether halted at pH below 5.6 (Ørskov and Ryle, 1990). Many amylolytic bacteria, such as *S.bovi*have optimal pH ranges that are lower than those of their fiber-digesting counterparts (Ørskov and Ryle, 1990). It has also been shown that depression total VFA production correlates with a low rumen pH (Yang *et al.*, 2002).

Under conditions of large available quantities of starch, *S.bovi*in particular can account for large drops in rumen pH. When growing slowly, *S. bovi*ferments starch into VFA. In contrast, when large quantities of starch are available *S. bovi*has the ability to grow much more rapidly and produces lactate instead of a VFA as its fermentation end product (Krause and Oetzel, 2006). Thus as the pH of the rumen declines after feeding, the rumen

environment shifts from favoring those bacteria that degrade fiber to those that degrade starches.

Outside of the effect that fermentation of starch has on the rumen pH, there is evidence to suggest that the type and composition of the carbohydrate component of the diet can affect the rate and extent of fiber digestion.

CHAPTER 3

3.0 MATERIALS AND METHOD

3.1 Experimental Site

The experiment was carried out at the Teaching and Research Farm, Department of Animal Science, Ahmadu Bello University Zaria, Kaduna State. Zaria is located within the Northern Guinea Savanna Zone between latitudes 110^{o} 12' N and longitudes 70^{o} 33' E; at an altitude of 610m above sea level (Wikipedia, 2015). Rainfall ranges from May to September with a mean annual rainfall of 700 – 1400mm per annum. Dry season commences around the middle of October and ends in February. This is followed by relative hot weather from March to April prior to the rain (IAR, 2015).

3.2 Experimental Diets and Animal Feeding

DelintedWhole cotton Seed (WCS) and undecorticated, undelintedCotton Seed Cake (CSC) were each included in the diets at different levels of 10, 20 and 30%, such that there were six diets in all. Other ingredients included were maize offal, rice bran, brewer's dried grain, molasses, bone meal and salt as shown in table 3.1. The diets were formulated to contain 14% CP. Animals were housed and fed individually, four (4%) percent of their body weights throughout the trial period at 08.00 hour daily.

Table 3.1:Ingredients Composition of Experimental Diets

Parameters	WCS			CSC		
	10	20	30	10	20	30
Maize offal	20	15	10	23	21	19
WCS	10	20	30	-	-	-
CSC	-	-	-	10	20	30
BDG	26	21	16	23	15	7
Rice offal	40	40	40	40	40	40
Molasses	2	2	2	2	2	2
Bone meal	1.5	1.5	1.5	1.5	1.5	1.5
Salt	0.5	0.5	0.5	0.5	0.5	0.5
Total	100	100	100	100	100	100
Crude protein	14	14	14	14	14	14
Cost #/kg feed	41.45	43.55	45.65	42.25	45.15	48.05

3.3 Experimental Design

The Twenty four bucks were randomly allocated to six dietary treatments of four animals per treatment and assigned randomly to one of the six diets. The treatment consisted of inclusion levels of either whole cotton seed(WCS) or cotton seed cake(CSC) at 10, 20 and 30 % in a 2 × 3 factorial arrangement in a completely randomized design (three levels of inclusion and two forms of cotton products).

3.4 Experimental Animals and Animal Management

Prior to the arrival of animals, the pens were cleaned and disinfected. On arrival, the animals were quarantined for 4 weeks; and treated with ivomectin (Ivomec®) and antibiotics (Tetracycline LA) against internal and external parasites and bacterial infection and were vaccinated against PPR with TCRV. The experimental animals were allowed to adjust to their housing and feed for a period of 2 weeks before commencement of the study. Animals were housed individually in pens made of concrete floors. Fresh

clean water was supplied *ad libitum* throughout the experimental period and the animals were weighed fortnightly during the course of the study which lasted for 90 days.

3.5 Digestibility Trial

At the end of the feeding trial, three goats were randomly selected from each treatment and housed in individual metabolism crates for easy faecal and urine collection, as described by (Osuji*et al.*, 1993). The animals were allowed 14 days of adjustment to the conditions of the metabolism crate before the commencement of the collection period which lasted for five days.

Known weight (4% of body weight) of the experimental diets was offered daily and water was provided *ad libitum*to the bucks. Daily faecal output was weighed and 10% of each day'sfaecal collection was sub-sampled and oven dried at 60^{o}C for 48hours for the determination of dry matter voided. Daily collections were later bulked, milled, sub sampled and stored in plastic bottle, until when required for laboratory analysis.Daily total urine output was collected over 20mls of 0.1N H_2SO4 in plastic buckets placed under the metabolic crate. A 10% aliquot of the total daily urine output was taken from each buck, bulked and stored in the refrigerator pending analysis.

For the digestibility study, feed intake and feacesvoided by individually animals were used while; feed intake, feaces voided and urine out puts were used for determining the nitrogen balance.

3.6 Haematological Studies

Blood samples were collected from three animals in each treatment by puncturing animals through their left jugular veins at the onset, middle and end of the growth trial

using hyperdemic syringe (5mls) for determination of haematology and serum biochemical indices such as blood glucose, albumin, Urea nitrogen, total protein, packed cell volume, white blood cell, red blood cell and differential count.

3.7 Carcass Characteristics

At the end of the digestibility study, three replicates of animals from each treatment were randomly picked for the study. The animals were starved for 12 hours before slaughtering and dressing. After slaughtering, organs were removed according to normal dressing procedures (Abdullah *et al*., 1998), carcasses and non- carcasses (edible and non-edible offal) components were appropriately measured. Carcasses were split longitudinally to obtain left and right halves and weighed, the left half was further disjointed into eight standard cuts: leg, chump, loin, neck, breast, mid rib, main rib and arm (shoulder) as shown in figure 1.

3.8 Histopathology of the liver and small intestine

At the end of the carcass evaluation, the livers from the slaughtered animals were collected and taken to the Pathology Department, Faculty of Veterinary Medicine Ahmadu Bello University Zaria. The livers were sub-sampled, placed in a formaldehyde fluid for storage, dipped in 80% alcohol for three days. Cross sections of preserved livers were prepared using standard paraffin-embedding techniques. Samples were sectioned at 7µm thickness and stained with haematoxylin and eosin (Gu and Li, 2004).

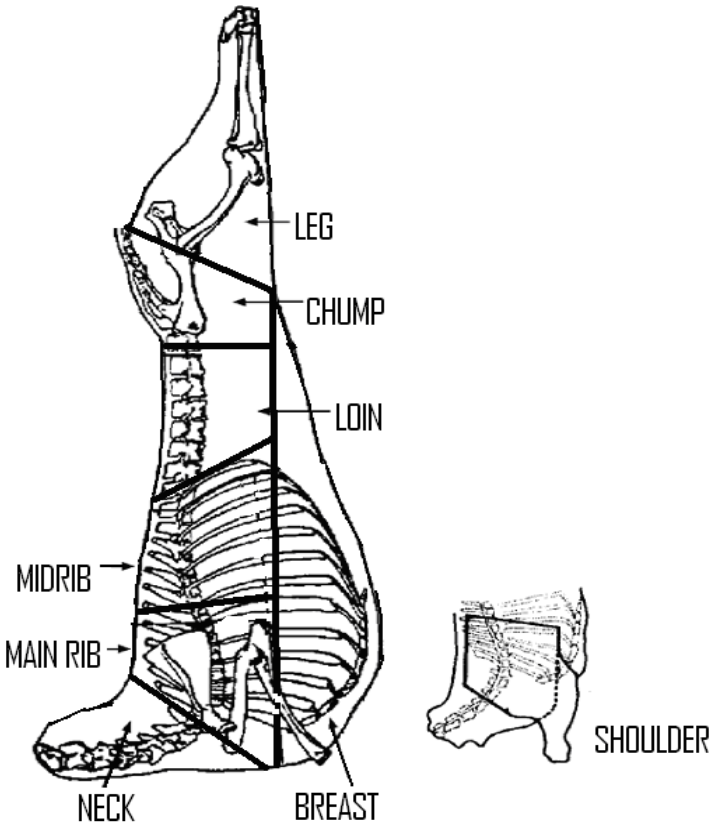

Figure 1: Carcass joints (modified from Calheiros and Neves, 1968)

3.9 Chemical Analysis

Whole cottonseed, Cottonseed cake, experimental diet, fecal samples were analyzed for dry matter (DM), crude protein (CP), crude fibre(CF), ether extract (EE), ash and nitrogen free extract (NFE), according to the method of AOAC (2005). The fibre fractions, acid detergent fibre (ADF) and neutral detergent fibre (NDF) were determined according to the method described by Van Soest*et al*., (1991). Urine samples were analyzed for nitrogen using the simple micro-Kjeldahl distillation method of AOAC

(2005). The analysis was conducted in the biochemistry laboratory, Department of Animal Science Ahmadu Bello University, Zaria.

3.10 Statistical Analysis

Data collected on feed intake, weight changes, nutrients digestibility, nitrogen balance, blood and serum metabolites, and carcass characteristics were analyzed using the GLM procedure of SAS (SAS, 2002). Means were separated using Duncan Multiple Range Test (Duncan, 1955). The following model were used,

$$\mathbf{Y_{ij} = \mu + C_i + L_j + (CxL)_{ij} + e_{ijk}}$$

where:

μ=overall mean,

C_i = Effect of i^{th} cotton product (i = whole cotton seed or Cotton seed cake),

L_j = Effect of j^{th} level of inclusion (j = 10, 20, 30)

CxL = interaction between the Cotton product and level of inclusion

e_{ijk}= Random error

CHAPTER 4

4.0 RESULTS

4.1 Effect of Cotton Products on Growth Performance

4.1.1 Table 4.1 shows the main effect of cotton products on growth performance of Red Sokoto bucks.

Feed intake (FI) was 3131.2g and 3414.9g for bucks fed WCS and CSC respectively. Initial average weight of the bucks was 8.79 and 8.63kg for WCS and CSC respectively. The final weightswere 9.5 and 10.46kg for WCS and CSC respectively which were all non-significant. Total weight gain (1.133kg and 1.833kg) and average daily weight gain (12.50g and 20.371g) of bucks were significantly different ($p<0.05$) for WCS and CSC inclusion respectively.

4.1.2 Levels on Growth Performance of Red Sokoto Bucks

Table 4.2 shows the main effect on inclusion level of cotton products on growth performance of Red Sokoto bucks. There was significant($p<0.05$)difference for feed intake (3227.9, 2790.0 and 3801.3g), total weight gain (1.13, 2.00 and 1.31kg) and average daily gain (12.50, 14.58 and 12.22g) in bucks fed diets containing 10, 20 and 30% inclusion of both cotton products (WCS and CSC) while the initial weight (8.61, 8.63 and 8.86kg) and final (9.75, 10.00 and 10.19kg) weights had no significance($p>0.05$) amongst bucks.

Table 4.1: Main Effect of Cotton Products on Growth Performance of Red Sokoto Bucks

Parameters	Cotton products		SEM
	WCS	CSC	
Feed intake(g)	3131.2	3414.9	273.60
Initial weight (kg)	8.79	8.63	0.52
Final weight (kg)	9.50	10.46	0.59
Total weight gain(kg)	1.13^{b}	1.83^{a}	0.27*
Average daily gain (g)	12.5^{b}	20.37^{a}	3.06*
FCR(kgDMI/kg gain)	2.78	1.86	

[a,b,c,] Means with different superscript across treatment differ significantly SEM Standard error of means FCR= Feed conversion ratio, NS= non significance, *= significance.

Table4.2: Effect of Inclusion Levels of Cotton Products on Growth Performance of Red Sokoto Bucks

Parameters	Inclusion level (%)			SEM
	10	20	30	
Feed Intake(g)	3227.9[a]	2790.0[b]	3801.3[a]	335.28*
Initial Weight (kg)	8.61	8.63	8.86	0.63
Final Weight (kg)	9.75	10.00	10.19	0.72
Total Weight Gain (kg)	1.13[b]	2.00[a]	1.31[b]	0.33*
Average Daily Gain(g)	12.50[b]	14.58[a]	12.22[b]	3.75*
FCR(kgDMI/kg gain	2.87	1.40	2.90	

[a,b,c,] Means with different superscript across treatment differ ($p<0.05$) significantly, SEM Standard error of means
FCR= Feed conversion ratio, NS= non significance, *= Significance.

4.1.3 Interaction Effect of Cotton Products and inclusion levels on growth performance

Table 4.3 shows the interaction effect of cotton products and inclusion level on growth performance of Red Sokoto bucks. The result obtained is similar to that of the main effect of inclusion level where there is significant ($p<0.05$) difference for Feed Intake (3254.25, 2703.50, 3435.75, 2876.50 and 4166.75g), Total Weight Gain (0.75, 2.00, 0.63, 1.50, 2.00 and 2.00kg) and Average Daily Gain (8.33, 22.22, 6.95, 16.67, 22.22 and 22.22g) across the treatments. Bucks fed 30 and 10% inclusion level of WCS had the lowest weight gain with 20% inclusion level of WCS being the best for the group, whilebucks fed 20 and 30% inclusion of CSC had the highest weight gain with no significance in Initial Weight (8.63 to 8.75kg) and Final Weight (9.38 to 10.75kg) for all treatments respectively.

4.2 Effect of Cotton Products on Digestibility

4.2.1 Main effect of cotton products on the digestibility of Red Sokoto Bucks

Table 4.4 shows the main effect of cotton products on nutrient digestibility of the experimental animals. Parameters measured (dry matter, crude protein, organic matter, neutral detergent fibre, acid detergent fibre, ether extract and lignin did not differ significantly ($p>0.05$) although they differ numerically. Bucks treated with CSC had better digestibility in most parameters except for ether extract (EE), 93.10 and 92.54% for WCS and CSC treated groups respectively.

Table 4.3: Interaction Effect of Cotton Products on Growth Performance of Red Sokoto Bucks

Parameters	WCS			CSC			SEM
	10	20	30	10	20	30	
FI(g)	3254.25[a]	2703.50[d]	3435.75[a]	3201.50[b]	2876.50[c]	4166.75[a]	474.02*
IW(kg)	8.63	8.75	8.75	8.63	8.75	8.75	0.90
FW(kg)	9.38	9.50	9.48	10.13	10.75	10.75	1.02
TWG(kg)	0.75[b]	2.00[a]	0.63[c]	1.50[a]	2.00[a]	2.00[a]	0.48*
ADG(g)	8.33[b]	22.22[a]	6.95[b]	16.67[a]	22.22[a]	22.22[a]	5.31*
FCR(kgDMI/kg gain	4.34	1.35	5.50	2.13	1.44	2.08	

[a,b,c,] Means with different superscript across treatment differ ($p<0.05$) significantly, FI= feed intake, IW= initial weight, Fw= final weight, TWG= total weight gain, ADG= average daily gain, FCR= feed conversion ratio.

Table 4.4: Main Effect of Cotton Products on Nutrient Digestibility of Red Sokoto Bucks.

Parameters (%)	Cotton products		SEM
	WCS	CSC	
Dry Matter	57.82	60.29	3.40
Organic Matter	56.48	58.88	3.55
Crude Protein	72.05	73.18	2.06
Neutral Detergent Fiber	63.18	64.39	3.01
Acid Detergent Fiber	70.15	70.47	2.91
Lignin	68.80	74.16	3.02
Ether Extract	93.10	92.54	0.72

4.2.2 Main effect of inclusion levels on digestibility of Red Sokoto Bucks

Table 4.5 shows the main effect of inclusion level of cotton products fed to Red Sokoto bucks. The digestibility of most parameters measured as obtained in Table 4.5differed significantly ($P<0.05$) except for lignin digestion (68.99, 76.19 and 69.24%) which was similar across treatment group. Bucks fed 20% inclusion of WCS and CSC had a significantly ($P<0.05$) higher digestibility while bucks fed 10% inclusion level had the least digestibility in all the parameters measured.

4.2.3. Interaction effect of cotton products and inclusion levels on digestibility

There was significant ($p<0.05$) effect on all parameters measured for the interaction effect of cotton products and inclusion levels on nutrient digestibility as shown in table 4.6 where bucks fed 20% CSC inclusion level performed better followed by bucks fed 30% CSC, 10 and 20% WCS inclusion and 10% CSC inclusion level being the least. Dry matter (DM) digestibility ranged from 36.79 to 80.78%, OM 34.60 to 79.96%, CP 53.16 to 87.91%, NDF; 46.39 to 80.09%, ADF; 48.96 to 88.19%, lignin (63.02 to 87.90% and EE; 87.17 to 96.61% respectively for all treatment groups.

Table 4.5: Main Effect of Inclusion Levels on Nutrient Digestibility of Red Sokoto Bucks

Parameters (%)	Inclusion level of Cotton products			SEM
	10	20	30	
Dry Matter	49.84[c]	67.35[a]	59.99[b]	4.17*
Organic Matter	48.04[c]	66.48[a]	58.51[b]	4.35*
Crude Protein	63.73[b]	78.08[a]	76.05[a]	2.52*
Neutral Detergent Fibre	57.51[b]	68.58[a]	65.26[a]	3.69*
Acid Detergent Fibre	61.71[b]	76.86[a]	72.37[a]	3.56*
Lignin	68.99	76.19	69.24	3.70
Ether Extract	90.26[b]	94.58[a]	93.61[a]	0.88*

[a,b,c,] Means with different superscript across treatment differ significantly ($p<0.05$), NS= non significance, *= significance.

Table 4.6: Interaction effect of cotton products and inclusion level on digestibility of Red Sokoto bucks

Parameters	WCS			CSC			SEM
	10	20	30	10	20	30	
(%)							
Dry Matter	62.89^{b}	53.90^{d}	56.67^{c}	36.79^{e}	80.78^{a}	63.30^{b}	5.90*
OM	61.48^{b}	53.60^{c}	54.94^{c}	34.60^{d}	79.96^{a}	62.07^{b}	6.16*
CP	74.28^{b}	68.23^{c}	73.61^{b}	53.16^{d}	87.91^{a}	78.47^{b}	3.57*
NDF	68.62^{b}	57.08^{c}	63.85^{b}	46.39^{d}	80.09^{a}	66.67^{b}	5.21*
ADF	74.45^{b}	65.52^{c}	70.47^{b}	48.96^{d}	88.19^{a}	74.25^{b}	5.04*
Lignin	74.95^{b}	64.48^{c}	66.96^{c}	63.02^{d}	87.90^{a}	71.53^{b}	5.23*
EE	93.35^{b}	92.55^{c}	93.39^{b}	87.17^{d}	96.61^{a}	93.82^{b}	1.25*

^{a,b,c,} Means with different superscript across treatment differ significantly ($p<0.05$) OM=Organic matter, CP=Crude protein, NDF =Neutral detergent fiber, ADF= Acid detergent fiber EE= Ether extract SEM =Standard error of means

4.3 Effect of Cotton Products on Nitrogen Balance

4.3.1 Main effect of cotton products on nitrogen balance of Red Sokoto bucks

Table 4.7 shows the main effect of cotton products on nitrogen balance. Significant effect was observed in Nitrogen Intake (8.02 and 6.92 g/day), FaecalNitrogen (2.69 and 1.99g/day) and total nitrogen excreted TNE (4.17 and 3.09 g/day) in bucks fed WCS and CSC respectively, while urinary nitrogen, nitrogen retained, nitrogen absorbed and nitrogen retained as percent intake had no significance ($p>0.05$) . WCS treated groups had higher values for most parameters measured but low retention of nitrogen as percent intake.

4.3.2 Main effect of inclusion levels on nitrogen balance

Table 4.8 shows the effect of inclusion level of cotton products fed to Red Sokoto bucks. There was an increase in nitrogen intake with increase in inclusion level in that, 30% inclusion had the highest value (8.30 g/day), followed by 10% (7.15 g/day) and 20% (7.06 g/day) inclusion levels. A decrease with inclusion level was observed for fecal nitrogen (2.78, 1.93 and 2.30 g/day) and urinary nitrogen (1.58, 1.50 and 0.78 g/day) in a linear manner. Nitrogen retained (2.78, 3.62 and 5.21 g/day), nitrogen absorbed (5.21, 6.18 and 7.17 g/day) and nitrogen retained as percent intake (36.38, 53.24 and 62.40%) had linear increase with increase in inclusion levels. Total nitrogen excreted had no significant difference ($p>0.05$) although they varied numerically in a decreasing linear manner (4.36, 3.44 and 3.09 g/day) for 10, 20 and 30% inclusion level respectively.

Table 4.7: Main effect of cotton products on Nitrogen balance

Parameters (g/day)	Cotton products		SEM
	WCS	CSC	
N intake	8.08[a]	6.92[b]	0.48*
Fecal N	2.69[a]	1.99[b]	0.23*
Urinary N	1.47	1.10	0.42
Total N excreted	4.17[a]	3.09[b]	0.57*
Nitrogen retained	3.91	3.82	0.52
Nitrogen absorbed	6.53	5.84	0.44
Nitrogen retained as % intake	48.43	53.02	6.02

[a,b,c,] Means with different superscript across treatment differ significantly ($p<0.05$), N= nitrogen, SEM =Standard error of means, NS= non significance, *= significance.

Table 4.8: Main effect of inclusion levels of cotton products on nitrogen balance

Parameters(g/day)	Inclusion level			SEM
	10	20	30	
Nitrogen intake	7.15[a]	7.06[b]	8.30[a]	0.59*
Fecal Nitrogen	2.78[a]	1.93[b]	2.30[a]	0.29*
Urinary Nitrogen	1.58	1.50	0.78	0.51
Total Nitrogen excreted	4.36	3.44	3.09	0.70
Nitrogen retained	2.78[c]	3.62[b]	5.21[a]	0.64*
Nitrogen absorbed	5.21[b]	6.18[a]	7.17[a]	0.53*
N retained as % intake	36.48[b]	53.24[a]	62.4[a]	7.38*

[a,b,c,] Means with different superscript across treatment differ significantly ($p<0.05$), N= nitrogen, SEM =Standard error of means, NS= non significance, *= significance ($p<0.05$).

4.3.3 Interaction effect of cotton products and inclusion levels on nitrogen balance

Table 4.9 shows the interaction effect of cotton products and inclusion levels on nitrogen balance. There were significant($p<0.05$) differences in all the parameters measured except for urinary nitrogen which ranged from 0.57 to 1.98 g/day. Nitrogen intake ranged from 5.54 to 8.76 g/day with 10% WCS inclusion being the highest followed by 30% CSC inclusion level, 30 and 20% WCS inclusion levels, 20%(6.67) CSC and 10% (5.54g/day) CSC inclusion levels with 10% CSC inclusion level being the least.

4.4 Effect of Cotton Products on Blood and Serum Metabolites

4.4.1 Main effect of cotton products on blood and serum metabolites

Table 4.10, the total protein (6.563, 7.431g/dL), PCV (26.8, 34.333%), hemoglobin (8.84, 11.417g/dL), RBC (4.473, 5.833×10^{6}) and neutrophils (59.6, 77.167%) values of WCS and CSC respectively showed significant difference ($p <0.05$), while values obtained for other differential count, albumin (17.40 and 22.50umol/l), glucose (9.43 and 5.45umol/L) and blood urea nitrogen (51.80 and 62.98mmol/L) had no significant ($p>0.05$) difference.

4.4.2 Main effect of inclusion levels of cotton products on blood and serum metabolites

Table 4.11 shows the main effect of inclusion level of cotton products on blood metabolites of Red Sokoto bucks. Significant differences were observed in blood urea N (69.33, 42.53 and 58.44mmol/L), albumin (12.33, 23.33 and 23.33g/L), PCV (29.89, 26.44 and 34.11%), hemoglobin (10.03, 8.79 and 11.13g/dL) and nuetrophils (72.33, 62.44 and 67.44%) at 10, 20 and 30% inclusion levels respectively while total

Table 4.9: Interaction effect of cotton products and inclusion levels on Nitrogen balance

Parameters (g/d)	WCS			CSC			SEM
	10	20	30	10	20	30	
N intake	8.76[a]	7.46[a]	8.04[a]	5.54[b]	6.67[b]	8.56[a]	0.83*
Fecal Nitrogen	2.72[a]	2.90[a]	2.45[a]	2.84[a]	0.97[b]	2.16[a]	0.41*
Urinary N	1.87	1.98	0.57	1.29	1.02	0.99	0.73
Total N excreted	4.59[a]	4.89[a]	3.02[a]	4.13[a]	1.99[b]	3.16[a]	0.99*
N retained	4.16[a]	2.57[b]	5.01[a]	1.40[b]	4.67[a]	5.40[a]	0.91*
N absorbed	7.21[a]	5.75[b]	6.64[a]	3.22[c]	6.60[a]	7.70[a]	0.76*
N retained as % intake	47.72[b]	35.51[b]	62.07[a]	25.24[c]	70.96[a]	62.87[a]	10.43*

[a,b,c,] Means with different superscript across treatment differ ($p<0.05$) significantly, N= nitrogen, SEM =Standard error of means, NS= Non significance, *= significance.

Table 4.10: Main Effect of Cotton Products on Some Blood Metabolites of Red Sokoto Bucks

Parameters	Cotton seed type		SEM
	WCS	CSC	
Total protein (g/day)	6.563[b]	7.431[a]	0.25*
Blood urea N (mmol/L)	51.80	62.98	7.73
Albumin (umol/L)	17.40	22.50	2.76
Glucose (mmol/L)	9.43	5.45	4.19
PCV (%)	26.80[b]	34.33[a]	1.08*
Hemoglobin (g/dL)	8.84[b]	11.42[a]	0.53*
RBC($\times 10^6$)/L	4.47[b]	5.83[a]	0.18*
WBC ($\times 10^9$)/L	5.25	6.83	0.84
Neutrophil (%)	59.60[b]	77.17[a]	1.61*
Lymph (%)	1.20	2.50	0.72
Monocytes (%)	0.13	0.250	0.09
Eosinophil (%)	0.00	0.58	0*
Basophil (%)	1.07	0.83	0.66

[a,b,c,] Means with different superscript across treatment differ significantly ($p<0.05$), PCV= pack cell volume, RBC= red blood cell, WBC= white blood cell, N=nitrogen, SEM= standard error means.

Table 4.11: Main effect of inclusion levels of cotton products on blood metabolites of Red Sokoto bucks

Parameters	Inclusion level			SEM
	10	20	30	
TP(g/day)	7.09	6.84	7.02	0.20
BUN (mmol/L)	69.33^{a}	42.53^{b}	58.44^{a}	9.97*
Albumin (umol/L)	12.73^{b}	23.33^{a}	23.33^{a}	3.57*
Glucose (mmol/L)	12.73	4.90	5.36	5.41
PCV (%)	29.89^{b}	26.44^{c}	34.11^{a}	1.39*
Hemogloblin (g/l)	10.03^{a}	8.79^{b}	11.13^{a}	0.53*
RBC($\times10^{6}$)/L	4.98^{b}	4.59^{c}	5.87^{a}	0.24*
WBC($\times10^{6}$)/L	6.72	4.51	6.62	1.08
Nuetrophil (%)	72.33^{a}	62.44^{c}	67.44^{b}	2.08*
Lymph (%)	2.89	1.22	1.22	0.93
Monocyte(%)	0.33	0.22	0.00	0.11
Eoesinophil (%)	0.78	0.00	0.00	0.00*
Basophil (%)	1.44	1.11	0.33	0.85

^{A,b,c,} Means with different superscript across treatment differ significantly ($p<0.05$), PCV= pack cell volume, RBC= red blood cell, WBC= white blood cell, N=nitrogen, TP= total protein, BUN= blood urea nitrogen, SEM= standard error means.

Protein (7.09, 6.84 and 7.02 g/day), glucose (12.73, 23.33 and 23.33mmol/L), WBC (6.72,4.51 and 6.62 $\times 10^6$/L) and other differential counts had no significant differences.

4.4.3 Interaction effect of cotton products and inclusion levels on blood and serum metabolites

Table 4.12also shows significant($p<0.05$) differences observed on parameters measured for interactions between the cotton products and inclusion levels except for blood urea N and monocytes count.

4.5 Effect of Cotton Products on Carcass Characteristics

4.5.1 Main effect of cotton products on carcass characteristics

Table 4.13 shows the effect of cotton products on carcass characteristics of Red Sokoto bucks. Results obtained showed no significant ($p>0.05$) effect of cotton products on dressing percentages (37.26 and 36.06%), left hot carcass weight (3.35 and 3.33kg) , most internal and external organs.However, the full stomach (1.92& 1.49) and tail (4.78 & 7.11) ofbuck carcasses fed WCS and CSC respectively showed significant difference($p<0.05$).

4.5.2 Main effect of inclusion level on carcass characteristics

Table 4.14 shows the effect of inclusion level of cotton products on carcass characteristics of Red Sokoto bucks. There was significant ($p<0.05$) effect of inclusion levels on live weight (8.83, 7.58 and 9.83kg), slaughter weight (8.67, 7.35 and 9.50kg), dressed weight (7.60, 5.99 and 7.91kg) and left hot carcass weight (3.30, 2.74 and 3.97kg), empty small intestine (352.17, 374.83 and 424.83g) and lungs (94.0, 81.67 and 109.83g) at 10, 20 and 30% inclusion levels respectively while other internal and external organs had no significant ($p>0.05$) effect

Table 4.12: Interaction effect of cotton products and inclusion levels on blood metabolites of Red Sokoto bucks.

Parameters	WCS			CSC			SEM
	10	20	30	10	20	30	
TP (g/day)	7.35^{b}	5.40^{d}	6.96^{c}	6.87^{c}	8.45^{a}	7.09^{b}	0.351*
BUN (mmol/L)	61. 00	25.00	56.00	86.00	51.30	63.33	12.25
Albumin (umol/L)	13.50^{c}	20.00^{b}	20.00^{b}	10.00^{c}	25.00^{a}	30.00^{a}	4.368*
Glucose (mmol/L)	16.97^{a}	2.67^{c}	5.28^{b}	4.27^{b}	6.02^{b}	5.50^{b}	6.628*
PCV (%)	28.67^{c}	11.33^{d}	32.67^{b}	32.33^{b}	34.00^{a}	37.00^{a}	1.705*
Hemoglobin (g/l)	9.68^{c}	3.77^{d}	10.53^{b}	10.73^{b}	11.30^{a}	12.33^{a}	0.647*
RBC($\times 10^{6}$)/L	4.78^{c}	1.93^{d}	5.43^{b}	5.37^{b}	5.62^{b}	6.73^{a}	0.288*
WBC($\times 10^{6}$)/L	6.47^{a}	2.00^{c}	5.65^{b}	7.33^{a}	5.77^{b}	8.57^{a}	1.320*
Neutrophil (%)	73.50^{b}	23.33^{e}	63.83^{d}	70.00^{c}	82.00^{a}	74.67^{b}	2.546*
Lymph (%)	1.67^{b}	0.00^{d}	1.33^{c}	5.33^{a}	1.83^{b}	1.00^{c}	1.134*
Monocyte(%)	0	0	0	2.333	0	0	0*
Basophil (%)	1.83^{a}	0.67^{b}	0.50^{d}	0.67^{b}	1.33^{c}	0.00	0.136*

^{a,b,c,d,} Means with different superscript differ significantly ($p<0.05$) across treatment, PCV= pack cell volume, RBC= red blood cell, WBC= white blood cell, N=nitrogen, SEM= standard error means.

Table 4.13: Main effect of cotton products on carcass characteristics of Red Sokoto Bucks.

	Cotton products		
Parameters	WCS	CSC	SEM
Final weight(kg)	9.22	8.26	0.89
Slaughter weight(kg)	9.92	7.89	0.81
Dressed weight(kg)	7.52	6.52	0.66
Hot carcass weight(kg)	3.35	3.33	0.32
Dressing percentage (%)	37. 26	36.06	3.27
Head(g)	819.44	744.44	69.69
Skin(g)	527.78	527.78	53.72
Feet(g)	327.78	288.89	29.27
Full stomach(kg)	1.92[a]	1.49[b]	0.20*
Empty stomach(g)	330.67	301.78	32.57
Empty S. intestine(g)	401.00	366.33	48.29
Large intestine(g)	106.89	84.78	12.27
Heart(g)	38.78	40.11	4.13
Kidney(g)	39.11	38.00	3.99
Liver(g)	153.00	143.56	17.39
Lungs(g)	98.33	92.00	10.69
Trachea (g)	84.56	79.78	9.19
spleen (g)	12.44	13.11	1.50
Testes (g)	52.11	60.33	7.75
Tail(g)	4.78[b]	7.11[a]	1.09*
Bladder(g)	22.00	20.22	2.40

[a,b,c,] means with different superscript across treatment differ significantly ($p<0.05$), WCS= whole cotton seed, CSC= cotton seed cake, SEM= standard error means.

Table 4.14: Main Effect of Inclusion Level on Carcass Characteristics of Red Sokoto Bucks

Parameter	Inclusion level			
	10	20	30	SEM
Live weight(kg)	8.83[a]	7.58[b]	9.83[a]	1.08*
Slaughter weight(kg)	8.67[a]	7.35[b]	9.50[a]	0.99*
Dressed weight(kg)	7.60[a]	5.99[b]	7.91[a]	0.81*
Left Hot carcass weight(kg)	3.3[a]	2.74[b]	3.97[a]	0.38*
Dressing percent (%)	37.42	32.15	40.42	4.00
Head (g)	804.2	691.70	850.00	85.35
Skin(g)	541.67	475.00	566.67	65.79
Feet(g)	320.83	266.67	337.50	35.84
Full stomach(kg)	1.757	1.658	1.708	0.24
Empty stomach(g)	309.00	296.83	342.83	39.88
Empty S. intestine(g)	352.17[c]	374.83[b]	424.00[a]	59.15*
Large intestine(g)	86.00	105.33	96.167	15.65
Heart(g)	39.5	37.17	41.67	5.05
Kidney(g)	37.50	36.5	41.67	4.89
Liver (g)	147.88	136.17	160.83	21.30
Lungs(g)	94.0[a]	81.67[b]	109.83[a]	13.09*
Trachea(g)	75.17	77.83	93.50	11.26
Spleen (g)	11.83	11.5	15.0	1.84
Testes (g)	66.5	38.67	63.5	9.49*
Tail (g)	5.5	5.17	7.17	1.34
Bladder (g)	24.00	20.17	19.17	2.94

[a,b,c] means with different superscript across treatment differ significantly ($p<0.05$), WCS= whole cotton seed, CSC= cotton seed cake, SEM= standard error means.

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4.5.3 Interaction effect of cotton products and inclusion level on carcass characteristics

Table 4.15 shows the interaction effect of cotton products and inclusion levels on carcass characteristics of Red Sokoto bucks. There were significant ($p<0.05$) effect on all parameters measured, highest weight values were obtained at 30% CSC inclusion level with 20% CSC inclusion level being the least weight value.

4.6 Effect of Cotton Products on Prime cuts of Carcass of Red SokotoBucks

4.6.1 Main effect of cotton products on prime cuts of Red Sokoto bucks

Table 4.16 showed that cotton products had no significant effect ($p<0.05$) on loin (123.89 and 122.22g), breast (133.33 and 136.11g), neck (155.56 and 158.33g), mid rib (130.56 and 133.33g) and arm (363.89 and 361.11g) but showed significant ($p<0.05$) differences in the leg, chump and main rib weights. Diets containing WCS had significantly higher values (452.78, 122.78 and 155.56g) than CSC (430.56, 113.89 and 150.00) respectively.

4.6.2 Main effect of inclusion levels of cotton products on prime cuts

From table 4.17, there was significant ($p<0.05$) difference for all parameters measured leg (445.83, 383.33 and 495.83g), chump (125.83, 95.83 and 133.33g), loin (128.83, 95.00 and 145.83g), breast (137.50, 104.17 and 162.50g), neck (158.33, 145.83 and 166.67g), mid rib (137.50, 104.17 and 154.17g), main rib (158.83, 108.33 and 191.67g) and Arm (366.67, 291.67 and 429.17g) were better for 30% inclusion level, followed by 10 and 20% respectively.

Table 4.15: Interaction Effect of Cotton Products on Carcass Characteristics of Red Sokoto Bucks

Parameters	WCS	CSC

	10	**20**	**30**	**10**	**20**	**30**	SEM
Live weight(kg)	9.03^{a}	9.33^{a}	9.36^{a}	8.63^{a}	5.83^{b}	10.30^{a}	1.53*
Slaughter weight(kg)	8.87^{a}	9.33^{a}	9.39^{a}	8.47^{a}	5.83^{b}	9.80^{a}	1.41*
Dressed weight(kg)	7.45^{a}	7.48^{a}	7.64^{a}	6.87^{a}	4.50^{b}	8.18^{a}	1.15*
Hot carcass weight(kg)	3.13^{b}	3.41^{a}	3.51^{a}	3.48^{a}	2.07^{c}	4.44^{a}	0.55*
Dressing percentage (%)	34.53^{a}	39.85^{a}	37.42^{a}	40.30^{a}	24.45^{b}	43.43^{a}	5.66*
head (g)	791.67^{a}	833.33^{a}	833.33^{a}	816.67^{a}	550.00^{b}	866.67^{a}	120.71*
Skin (g)	466.67^{c}	600.00^{a}	516.67^{b}	616.67^{a}	350.00^{d}	616.67^{a}	44.62*
Feet (g)	333.33^{a}	316.67^{a}	333.33^{a}	308.33^{a}	216.67^{b}	341.67^{a}	50.69*
Full stomach (kg)	1.75^{a}	2.12^{a}	1.89^{a}	1.76^{a}	1.20^{b}	1.53^{a}	0.36*
Empty stomach(g)	303.00^{a}	382.67^{a}	306.33^{a}	315.00^{a}	211.00^{b}	379.33^{a}	56.41*
Empty s. intestine(g)	340.33^{a}	468.67^{a}	394.00^{a}	364.00^{a}	281.99^{b}	454.00^{a}	83.66*
Large intestine(g)	92.00^{b}	141.00^{a}	87.67^{b}	80.00^{b}	69.67^{c}	104.67^{a}	22.14*
Heart (g)	36.67^{b}	44.33^{a}	35.33^{b}	42.33^{a}	30.00^{c}	48.00^{a}	7.15*
Kidney(g)	32.00^{b}	46.67^{a}	38.67^{a}	43.00^{a}	26.33^{b}	44.67^{a}	6.91*
Liver(g)	159.00^{a}	161.33^{a}	132.67^{a}	136.67^{a}	105.00^{b}	189.00^{a}	30.12*
Lungs(g)	79.67^{b}	94.33^{a}	121.00^{a}	108.33^{a}	69.00^{c}	98.67^{a}	18.52*
Trachea(g)	73.33^{a}	95.33^{a}	85.00^{a}	77.00^{a}	60.33^{b}	102.00^{a}	15.93*
Spleen (g)	10.00^{b}	13.33^{a}	14.00^{a}	13.67^{a}	9.67^{b}	16.00^{a}	2.60*
Testes (g)	53.00^{b}	48.33^{b}	55.00^{a}	80.00^{a}	29.00^{c}	72.00^{a}	13.43*
Tail (g)	3.67^{c}	6.00^{b}	4.67^{bc}	7.33^{a}	4.33^{bc}	9.67^{a}	1.89*
Bladder(g)	21.67^{a}	28.67^{a}	15.67^{b}	26.33^{a}	11.67^{b}	22.67^{a}	4.16*

^{a,b,c,d} means with different superscript across treatment differ significantly ($p<0.05$), WCS= whole cotton seed, CSC= cotton seed cake, SEM= standard error means.

Table 4.16: Main Effect of Cotton products on Prime Cut Quality of Red Sokoto Bucks.

Parameter(g)	Cotton type		
	WCS	CSC	SEM
Leg	452.78[a]	430.56[b]	3.811*
Chump	122.78[a]	113.89[b]	1.977*
Loin	123.89	122.22	2.120
Breast	133.33	136.11	2.060
Neck	155.56	158.33	2.552
Mid rib	130.56	133.33	2.035
Main rib	155.56[a]	150.00[b]	2.152*
Arm	363.89	361.11	3.687*

[a,b,c] means with different superscript across treatment differ significantly ($p<0.05$), WCS= whole cotton seed, CSC= cotton seed cake, SEM= standard error means.

Table 4.17: Main Effect of Inclusion Levels on Prime Cut Quality of Red Sokoto Bucks

Parameter(g)	Inclusion level			
	10	20	30	SEM
Leg	445.83[b]	383.33[c]	495.83[a]	4.66*
Chump	125.83[b]	95.83[c]	133.33[a]	2.42*
Loin	128.33[b]	95.0[c]	145.83[a]	2.59*
Breast	137.50[b]	104.17[c]	162.50[a]	2.52*
Neck	158.33[b]	145.83[c]	166.67[a]	3.12*
Mid rib	137.50[b]	104.17[c]	154.17[a]	2.49*
Main rib	158.33[b]	108.33[c]	191.67[a]	2.63*
Arm	366.67[b]	291.67[c]	429.17[a]	4.51*

[a,b,c] means with different superscript across treatment differ significantly ($p<0.05$), WCS= whole cotton seed, CSC= cotton seed cake, SEM= standard error means.

4.6.3 Interaction effect of cotton products and inclusion levels on prime cuts of Red Sokotobucks

Table 4.18 shows the interactions of cotton type and inclusion levels on standard cuts of carcass. Neck weight was not significantly ($p>0.05$) different, while other parameters measured were significantly ($p<0.05$) different with 30% CSC inclusion level having the best cuts and 20% CSC being the least.

4.7 Effect of Cotton Products on Organ Functions

From the histopathology examination of livers and small intestines analysis, it was observed that severe damage was done on both the livers and the small intestines. In the liver of animals fed either WCS or CSC, there was edema, vacuolation of cells, focal inflammation of hepatic cells, congestion of blood vessels with the destruction of liver cells, degeneration of hematocytes, fabroiplacia and presence of fasiola in some few samples. There was also, severe damages made on the small intestine both at the ileum and duodenum segments revealing dematous villi, enteritis with severe infiltration of villia cells, severe disconnection of cells, enlarged villous, absence of epithelial cells, edema, necrosis of villia, nuetrophilic infiltration, infraritis and some degree of parasite infestation (although their presence wasn't due to the ingestion of cotton products).

Table 4.18: Interaction Effect of Cotton Products and Inclusion Level on Prime Cut of Red Sokoto Bucks.

Parameter(g)	WCS			CSC			
	10	20	30	10	20	30	SEM
Leg	441.67[a]	450.00[a]	466.67[a]	450.00[a]	316.67[b]	525.00[a]	75.46*
Chump	126.67[a]	116.67[a]	125.00[a]	125.00[a]	75.00[b]	141.67[a]	20.31*
Loin	140.00[a]	106.67[b]	125.00[a]	116.67[b]	83.33[c]	166.67[a]	23.34*
Breast	141.67[b]	133.33[a]	125.00[c]	133.33[a]	75.00[d]	200.00[a]	22.05*
Neck	150.00	166.67	150.00	166.67	125.00	183.33	33.85
Mid rib	141.67[a]	125.00[c]	125.00[c]	133.33[b]	83.33[d]	183.33[a]	21.52*
Main rib	158.33[b]	133.33[c]	175.00[a]	158.33[b]	83.33[d]	208.33[a]	24.06*
Arm	366.67[a]	316.67[b]	408.33[a]	366.67[a]	266.67[c]	450.00[a]	70.63*

[a,b,c,d] means with different superscript across treatment differ significantly ($p<0.05$), WCS= whole cotton seed, CSC= cotton seed cake, SEM= standard error means.

CHAPTER 5

5.0 DISCUSSIONS

5.1 Effect of Cotton Products on the Growth Performance of Red Sokoto Bucks

The result obtained for the non-significance in final and initial weight agrees to the report of Absalan*et al*., (2011) although animals were fed lower inclusion levels (0-16%) of cotton seed. Nunes*et al*., (2010) in a comparative study of cottonseed and cornmeal as control diet fed 0.5kg/animal/day to male crossbred goats reported significant differences in weight with cottonseed treatment(7.8kg) performing lower than the cornmeal diet(8.6kg). Also, Turki*et al*. (2011) in a study evaluating six dietary protein sources (oil seeds) on performance of western Baggara cattle fed isocaloric and isonitrogenous diet with 25% inclusion of urea-molasses treated diet containing the six protein sources,(cotton seed, sesame, sunflower, groundnut, guar germ and guar hull meals) reported cotton seed meal to have the highest live weight gain, feed conversion ratio efficiency and intermediate daily weight gain compared to the other protein sources. Similarly, Kandylis*et al*. (1999), in a comparative study of cotton seed meal to sunflower meal in total mixed ration with 20% inclusion levels observed no significant difference in average daily gain with 200-220g/day increase using 15kg Kargouniko sheep. Also, a comparative study of cottonseed meal, sesame seed meal and groundnut meal of 8% inclusion respectively also showed no difference in average daily intake. The low values obtained for average daily gain in this study agrees with the previous reports although significant differences were observed forfinal weight and feed conversion/ feed: gain ratiofor WCS and CSC based diets and also the inclusion levels. It can be related to the

low weight of animals/ ages of animals and diet composition with/or environmental factors.

The result of growth performance obtained in this study varied with those from literature reviewed in this study and could be as a result of differences in breed, species, age, diet composition and environment. In all parameters measured, values were lower; which could be that younger animals are more susceptible to gossypol toxicity (have lower resistance) which agrees with the report of (Calhoun *et al*., 1990; Solaiman, 2007).

5.2 Effect of Cotton Products on the Digestibility of Red Sokoto Bucks

The difference obtained in dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and ether extract (EE) between WCS and CSC diets could be as a result of higher fat content of WCS diets. The values obtained for digestibility of all parameters are similar to those obtained by (Polvise*t al*., 2010) who fed 3 and 6% inclusion levels of cotton seed meal on steers. However, the ADF and NDF values in percentages obtained in this study are lower than those reported in the previous literature while the values obtained in percentages for EE digestibility in this study were higher. Digestibility of nutrients increased as the level of cotton products increased across the diets. This is similar to the reports of Solomon *et al.* (2008) who reported higher digestibility with increased inclusion levels of cotton products in male Sidama goats fed cotton seed meal with low quality forage and also agrees with the report of (Alemu*et al.*, 2010). On the interaction between cotton products and inclusion levels, the Crude Protein digestibility obtained had similar but higher range (53.1- 87.91%) and

Organic Matter digestibility (34.6- 62.07%) to the report of Solomon *et al.(*2008) who reported 65-75% Organic Matter digestibility and 41-73% CP digestibility.

Generally, increasing WCS levels in the diet showed a decrease in digestibility of nutrients, on the other hand, increase in CSC levels showed an increase in digestibility although in no particular pattern. It can be stipulated that the variation observed in 20% inclusion of cotton products could be as a result of the physiological state (health status) of the experimental animals, nutrient composition or perhaps, the gossypol content.

5.3 Effect of Cotton Products on Nitrogen Balance fed to Red Sokoto Bucks

Nitrogen intake in WCS treated groups was generally higher even at inclusion levels and interaction effects compared to CSC treated groups. However, Nitrogen retained, Nitrogen absorbed and Nitrogen retained as percent intake were higher in CSC treated groups compare to WCS treated groups. The result obtained in Nitrogen retained, Nitrogenabsorbed and Nitrogen retained as percent intake on the effect of inclusion levels of cotton products on nitrogen balance showed a linear increase as cotton products increased. Similarly, on the interaction between cotton products and inclusion levels, there were variations in the values obtained for nitrogen retained, nitrogen absorbed and Nitrogen retained as percent intake in no particular pattern.

The poor retention of nitrogen had negative influence on the growth performance and even the carcass characteristics, which is as a result of damages done in the digestive tract especially in the small intestine where most of their walls (villi) were damaged as shown in the appendix of plates VII-XVIII. This suggest that WCS should not be fed to young animals in large quantities, as gossypol, cyclophenoic acid and other antinutritional

factors/component may be responsible for the result obtained. In this light, it could be suggested that cotton products be treated before feeding and other feed ingredients that are able to mask the effect of these antinutritional component of the cotton products be incorporated in the diets of growing bucks.

5.4 Effect of Cotton Products on Blood and Serum Metabolites of Red Sokoto Bucks

The results obtained for PCV and Hbare within the normal range 24-45% and 8-14% respectively except for values reported in 20% inclusion level of WCS (11.33 and 3.77%, respectively). All differential counts parameter are within the normal range; lymphocytes 40-75%, monocytes 0-4%, eosinophils 0-10%, basophils 0-2% as recorded by (Ganti, 1983). The RBC,WBC, lymphocytes values observed in this study are higher than those reported by (Solaiman, 2007) with no significant effect on the young bucks of goats fed with diets with the inclusion levels of 0-30% WCS.

Total protein concentration has been observed to be affected by sex and age of an animal although, the normal range for normal goats were given to be 60-75g/L and 64-79g/L (Radostis, 2000; Benjamin, 1989), result obtained from this study are within the normal range, with deviation in bucks fed 20% WCS, whichis lower in value (5.40g/dL),but 20% CSC diets fed to bucks had highervalue(8.45g/dL)when compared to WCS at 20% inclusion level. Solaiman, (2007) reported values ranging from 5.96-6.54. However, Oguz*et al.* (2006) reported higher values for serum urea (12.69- 14.21 mmol/L) at 0-37.5% inclusion level of WCS fed to lactating Holstein cows. Glucose concentration is regulated by hormone concentration in the blood. Kahn, (2005) recorded 48-76mg/dL of glucose as normal value, Sarkha*et al.* (2008) reported a mean of 3.78±0.74 mm/L stating

that young animals have higher glucose level than older animals irrespective of sex in the study of serum biochemical parameters on Raini goats in Iran. In this study, the glucose values obtained are within the range of 4.9-16.967mmol/L which is higher than those earlier stated. This increase could be as a result of metabolic activities to help stabilize the gossypol effect on the animals other than the simple reason of age and sex as reported by (Sarkha*et al.,* 2008) to be factors responsible for the values change of glucose in animals.

The albumin values obtained in this study differ from those values reported (27-39g/L) by (Benjamin, 1989; Smith 2002) although similar to the values obtained by (Sarkha*et al.*, 2008)23-51g/L which are higher. Solaiman, (2007) reported values of 3.77-3.95 g/L. However, it can't be concluded that albumin has no effect on animals because it can be influenced by age, (Sarkha, *et al.,* 2008) decreasing it level in the blood, it could also be affected by feed type (concentrate/forage) and the presence of toxic compounds. Urea provides a non-toxin means for excretion of ammonia generated by amino acid catabolism and intestinal microflora. The production of urea occurs almost exclusively in the liver and the failure is frequently related with the decrease in urea. Carlson, (2002), stated that renal failure or dehydration may lead to decrease in serum urea concentration. The result obtained in this has higher values of 25-86mmol/L compared to 7.64-15.28mm/L recorded by (Smith, 2002), 15.08±3.8 mm/L (Sarkha*et al.,* 2008) and 29.9-33.9 reported by (Solaiman, 2007).

5.5 Effect of Cotton Products on Carcass Characteristics of Red Sokoto Bucks

The carcass characteristics reported in this study are similar to that obtained by (Absalan*et al.,* 2011), who reported no significant effect of inclusion level of WCS at (0, 4, 8 and 16%), the dressing percentage were of higher values (50.6- 53.2%) than those obtained in this experiment whichcould be as a result of differences in inclusion levels of cotton products and species of animals used. It also agrees to the report of(Shija*et al.,* 2013) (47.15%) in the preliminary evaluation of slaughter value and carcass composition of indigenous sheep and goats from traditional production system in Tanzania comparing sheep and goats carcass quality.

The organs weights varied, with 30% CSC inclusion level having the highest values, followed by 20 and 30% WCS inclusion levels for most of the organ weights, which agrees with the report of (Absalan*et al.*, 2011). In comparing the result of (Absalan*et al.*, 2011) to this study, there was no fat deposit observed from all carcasses which could be as a result of specie difference since sheep are known to have more fat deposit than goats. It may also be due to the low weights at slaughter indicating that the animals merely maintained their body with no reservation for deposits or meat production.

5.6 Effect Cotton Products on Prime Cuts of Red Sokoto bucks

The leg had better muscle proportion followed by the arm, main rib, breast, neck, mid rib, loin and chump cuts in a decreasing order. The result obtained in this study is in agreement with the report of Shija*et al.* 2013), whoreported higher muscles proportions of goats in the leg and shoulder, although does not agree with the proportions obtained for other cuts as neck being the next to shoulder, loin, mid rib, breast, chump and main

rib respectively. The result is also in agreement to the report of Santos *et al.* (2008 who studied carcass composition and meat quality of equally mature kids and lambs and reported similar result of goats muscle proportion to that of Shija*et al.*, (2013). Sen*et al.*,(2004),however, reported higher muscles proportion of neck and shoulder of goats when comparing goats and sheep carcass composition in the study of carcass yield, composition and meat quality attributes of sheep and goats under semi-arid conditions.

Generally, factors such as breed, age and weight at slaughter, sex, species and diets of animals have being reported to affect carcass composition of ruminants (Guerrero *et al.*, 2013).

5.7 Effect of Cotton Products on Organ Functions

Theresult observed from the histopathology of organs is in agreement with those reported by some literatures;(Morgan et al., 1988, Holmberg et al., 1988, Risco*et al*., 1992 and Zelski et al., 1995 and Wang and Lei, 1987). Although the degree of severity varied with the form/type of cotton products and also the level offered, organs of animals fed WCS had severe manifestation which could have led to their low performance as a result of poor absorption of nutrient, weaken immune system and inadequate metabolism. Also, post mortem examination was carried out on the dead animals with these findings; matted perineum, hydropericardium (straw colored) 30mls that clots on standing, serious atrophy of pericardial fat, frothy exudation into entire length of trachea extending to the lungs, distended gall bladder and serious atrophy of perirenal fat and it was tentatively diagnosed that the animals suffered hydropericardium and pulmonary edema.

CHAPTER 6

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

A comparative study was carried out to determine the effect of different cotton products (Whole Cotton Seed and Cotton Seed Cake) and inclusion levels in feeding goats on the performance, blood and serum metabolites, carcass characteristics and histopathology of growing Red Sokoto bucks. Cotton products are being consumed by ruminants as a result of their high nutritional value, although in various forms and are more easily (better) utilized when fed to matured ruminants.

Twenty four (24) growing Red Sokoto bucks aged 7 to 9 months and weighing 8.625kg averagely were used for this study. Six complete diets were formulated to contain 14% crude protein comprising of 10, 20 and 30% inclusion levels of WCS and CSC with other ingredients. Experimental animals were randomly allotted to six dietary treatments of four animals per treatment group (WCS or CSC) in a 2 × 3 factorial arrangement in a completely randomized block design with 2 cotton forms and 3 inclusion levels (10, 20 and 30%).

Growth performance, nutrients digestibility, nitrogen balance, blood and serum metabolites, carcass characteristics and prime cuts of carcass were evaluated. The result from this study showed that bucks fed CSC performed better than those fed WCS.

6.2 Conclusion

This study showed that bucks fed CSC had better weight gain compare to bucks fed WCS. Similarly, bucks fed 20% inclusion level had better weight gain.

Digestibility of nutrient was higher in bucks fed CSC compared to bucks fed WCS where bucks fed 20% inclusion level had better digestibility compared to 30 and 10% inclusion levels.

Although bucks fed WCS had better nitrogen intake, Nitrogen retention was better in bucks fed CSC which was reflected in their growth performance/ weight gain.

Bucks fed WCS and CSC were not adversely harmed although their physiological state was compromised with time.

Also, bucks fed WCS had better carcass quality compared to bucks fed CSC in terms of dressing percentages and hot carcass weight although, 30% inclusion levels gave better quality. Similar result was obtained for prime cuts.

6.3 Recommendation

1. Twenty percent CSC inclusion level gave better results in terms of weight gain and nutrient digestibility thus, can be used in feeding growing bucks without adverse effect.

2. WCS should be included at 10% or below in the diet of growing bucks.

3. For better carcass quality in bucks, WCS should be used as it gave better yield compared to bucks fed CSC.

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APPENDIX

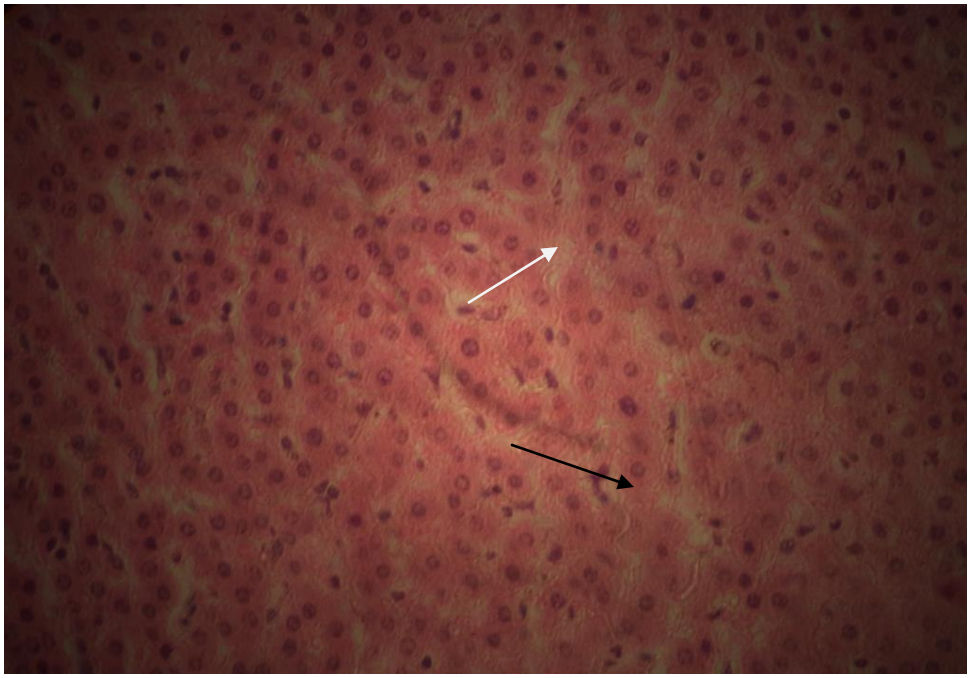


Figure I: Massive vacuolation, congestion with destruction of liver cells

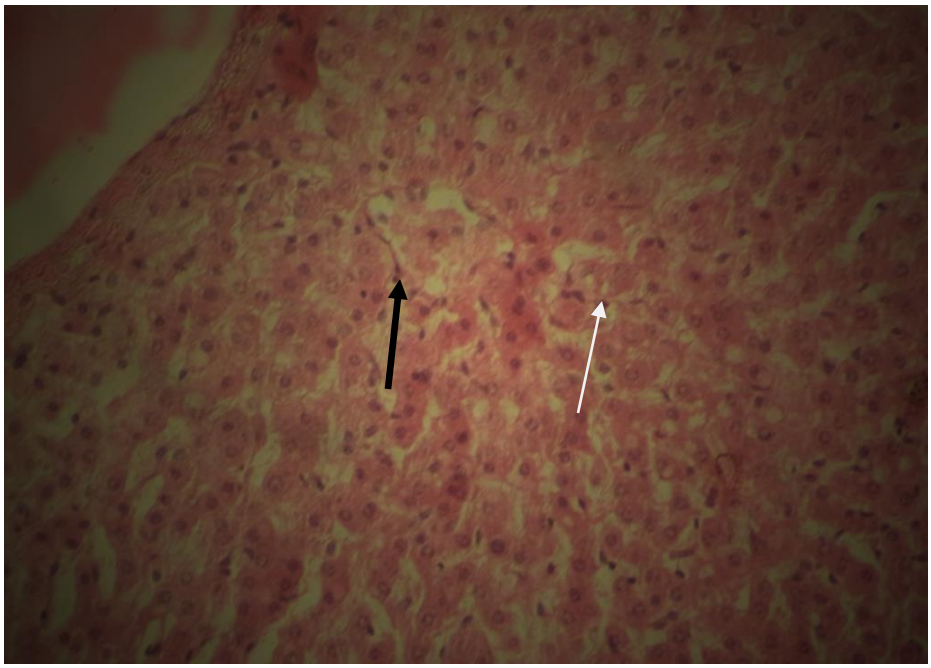


Figure II: Vacuolation, focal infiltration around the blood vesels, edema and congestion of liver cells

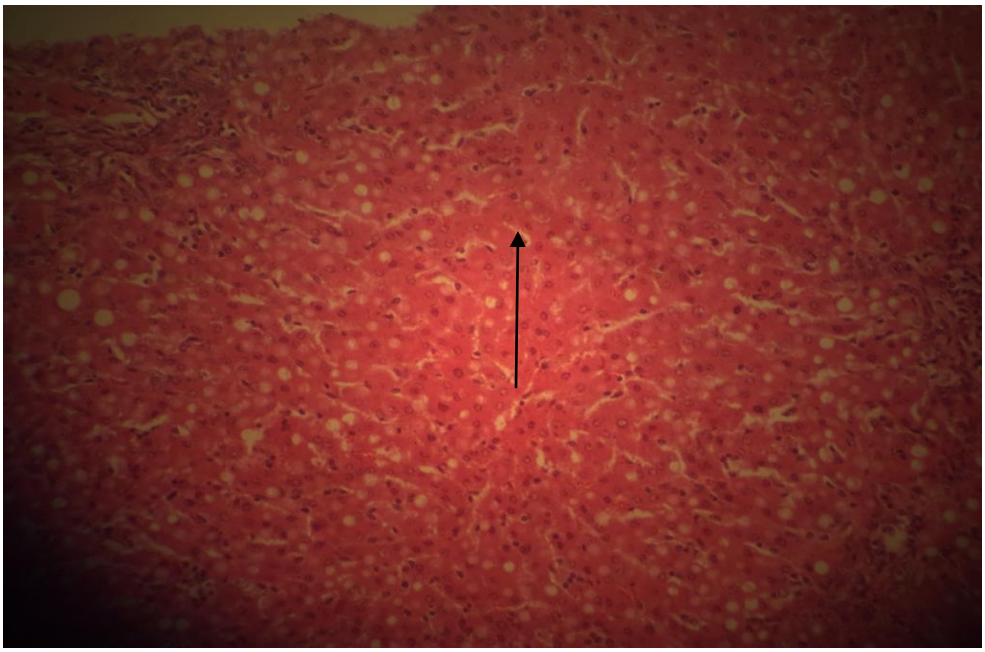


Figure III: Congestion of blood vessels, edema, and fibrous connecting tissues.

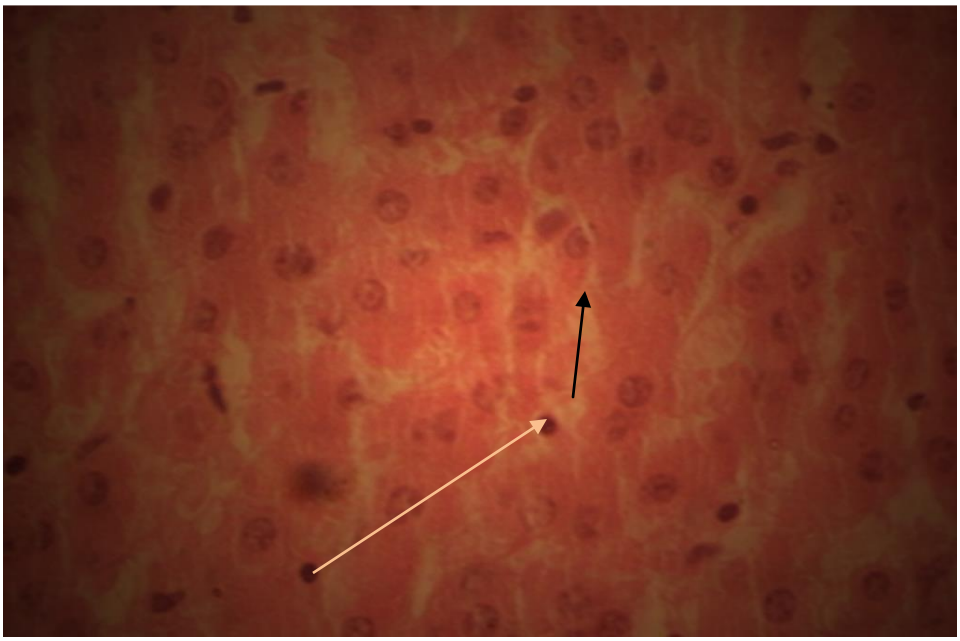


Figure IV: degeneration of hematocytes, edema, congestion and fat vacuolation

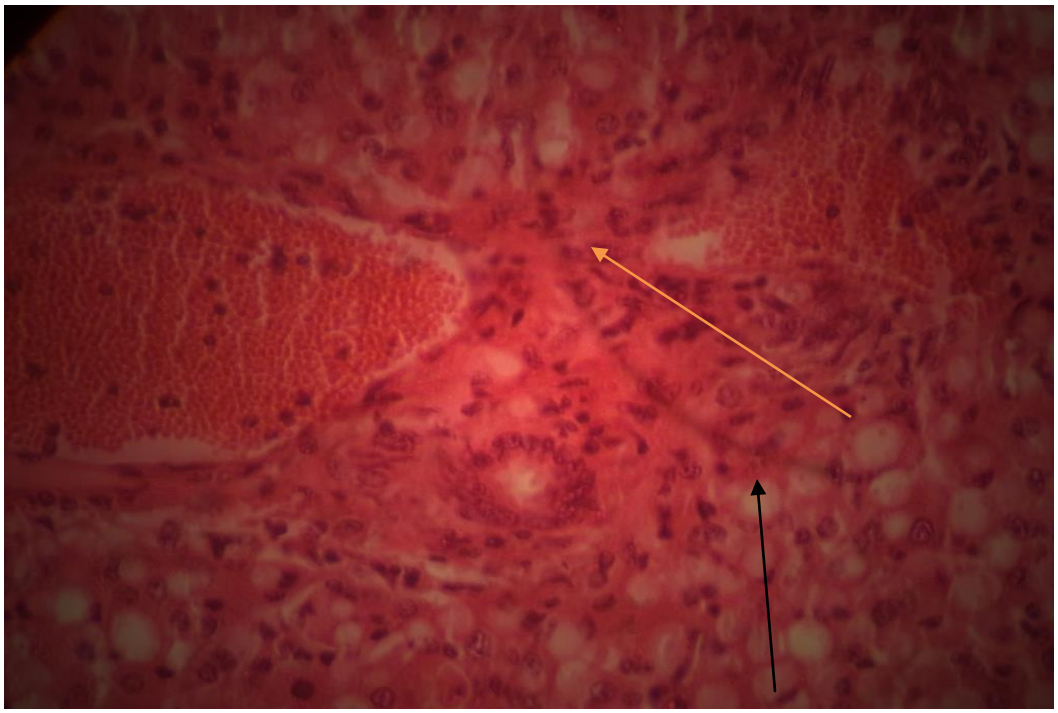


Figure V: Congestion of blood vessels, edema, focal inflammation of epathic cells and fabriosis of the liver.

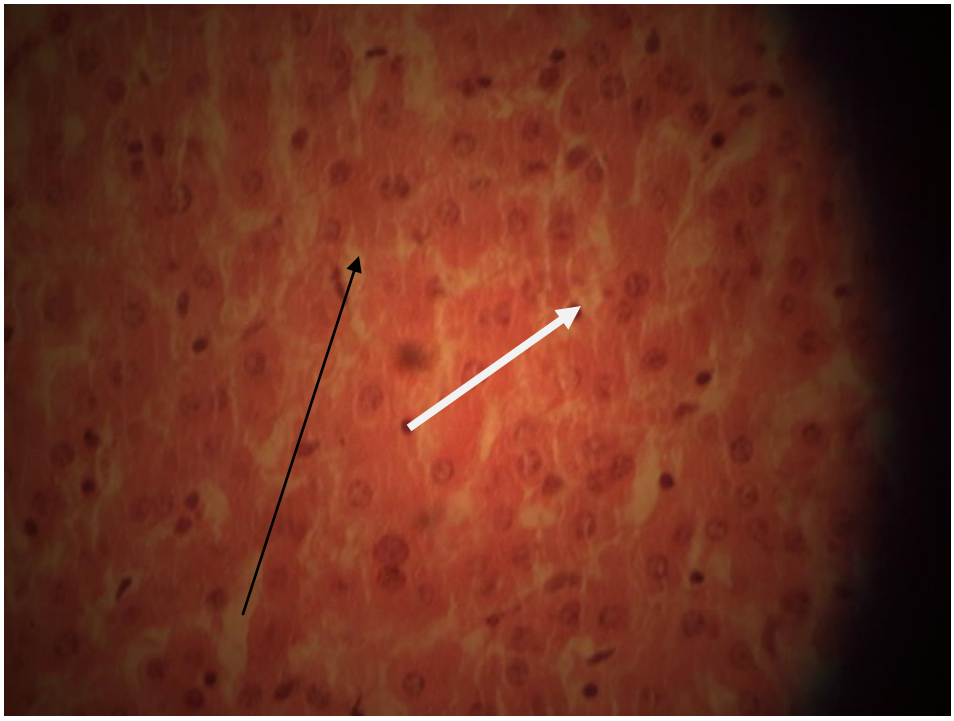


Figure VI: Congestion of blood vessels, edema, and presence of fat vacuoles in the liver.

Illeum

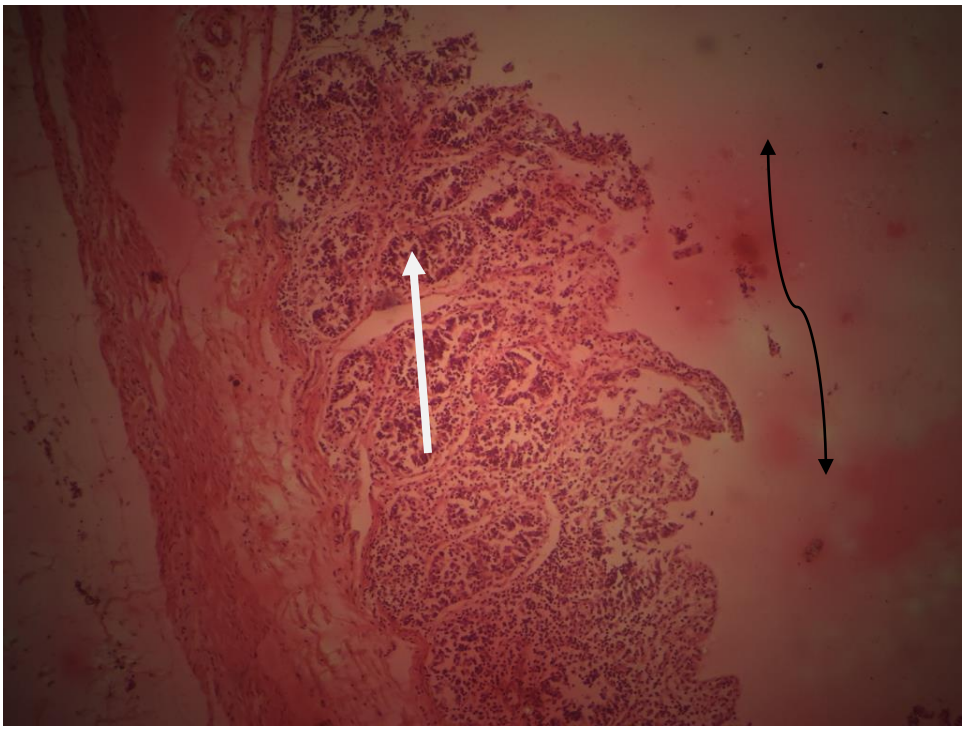


Figure VII: Severe disconnection, damatous villi, enteritis with severe infiltration of villia cells

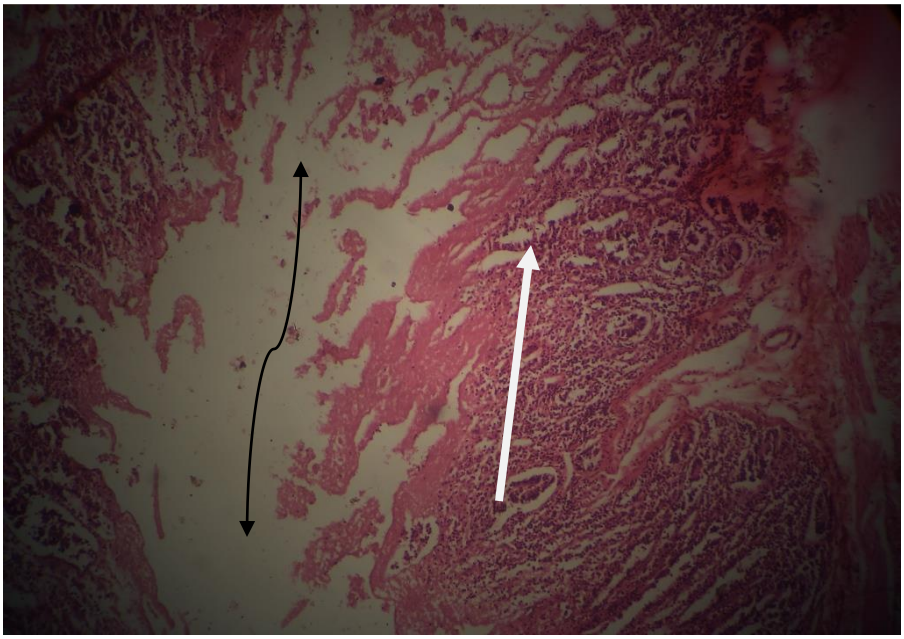


Figure VIII: Necrosis of villi and neutrophilic infiltration into the villi.

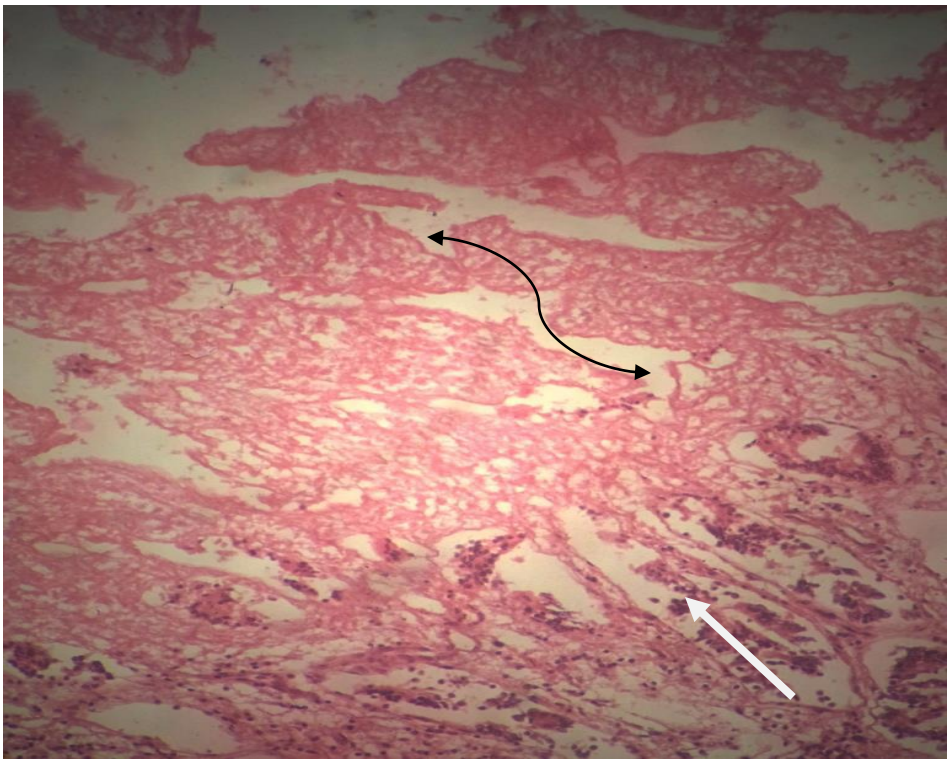


Figure IX: Necrosis, edema of the Villi system

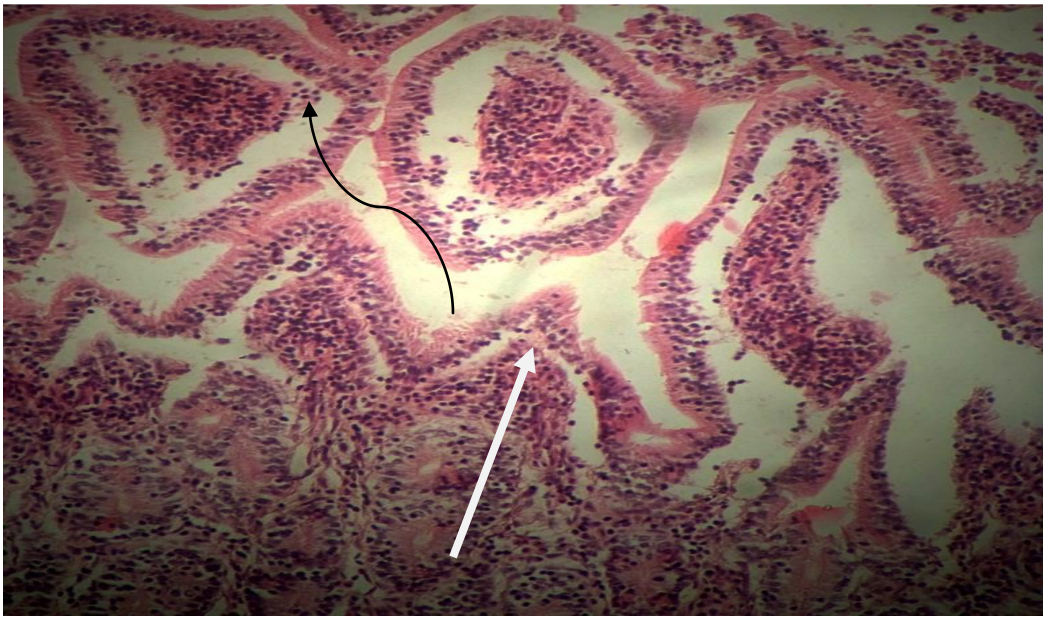


Figure X: Defragmented, infiltrated villi by inframentry cells although villi seem present. There is also a degree of fabriosis.

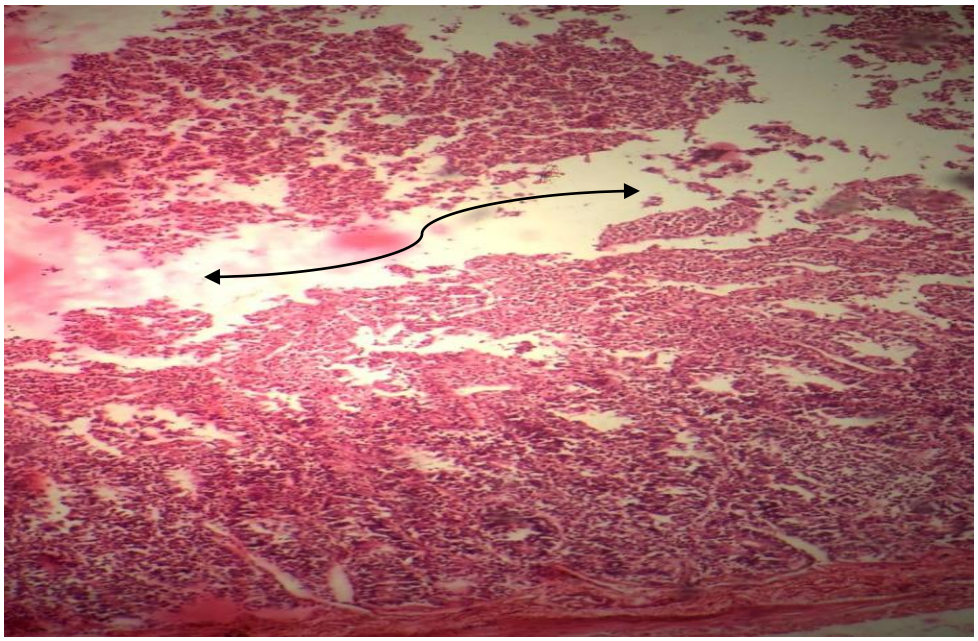


Figure XI: parasite infestation, disconnected villi cells with death of some, infiltration of edemic cell into the villi cells.

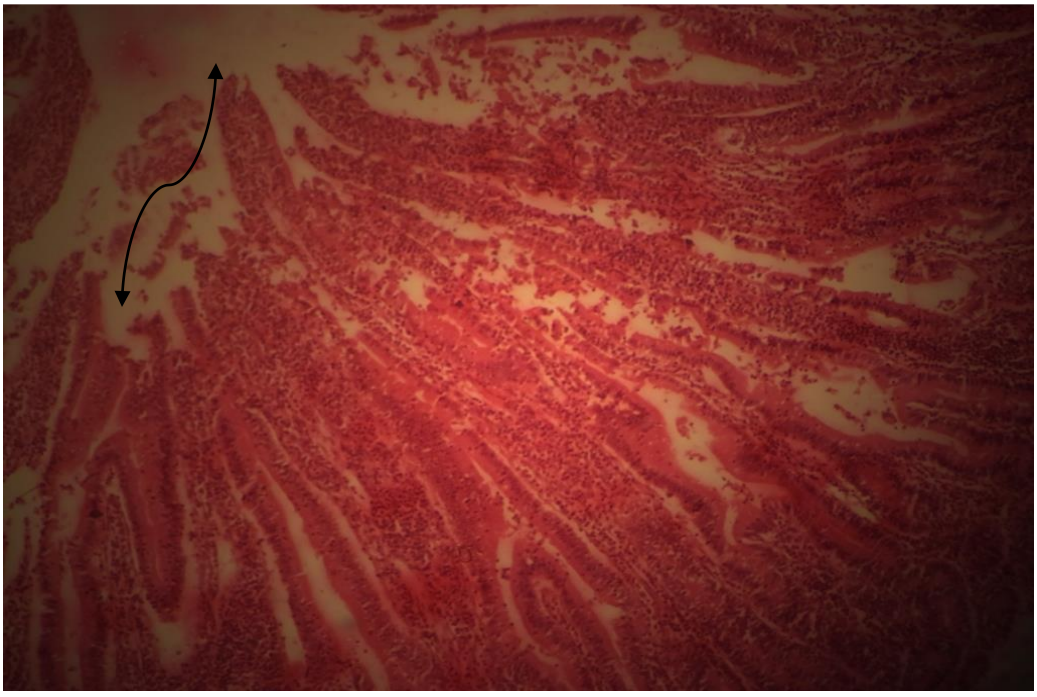


Figure XII: Inflammation of the intestine.

Duodenum

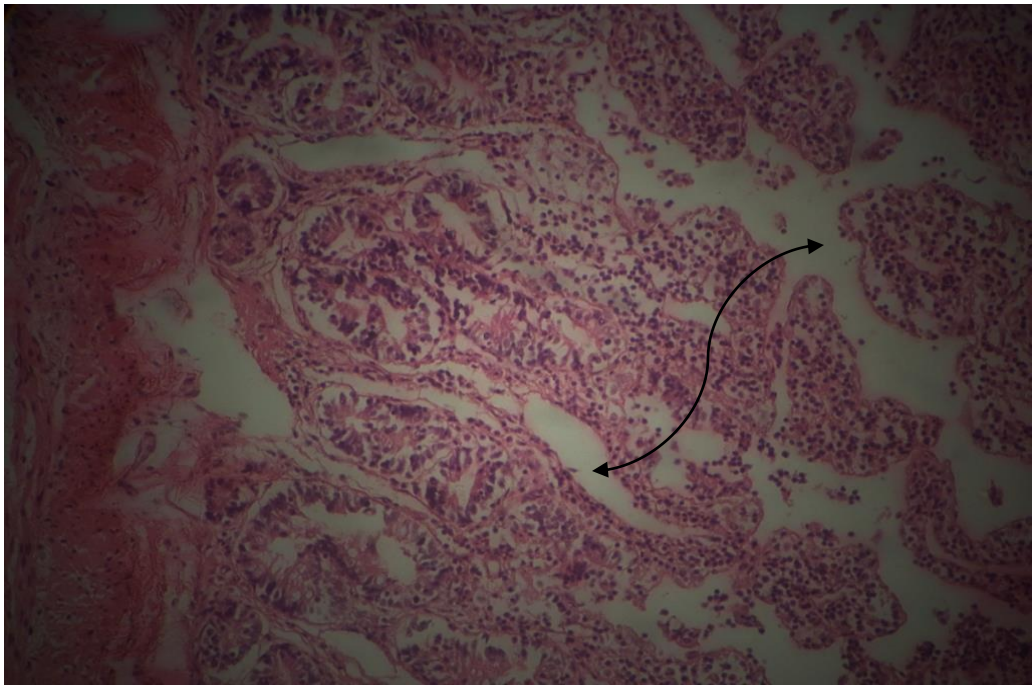


Figure XIII absence of epithelia cells, edematous villi, enteritis with severe infiltration of villi cells.

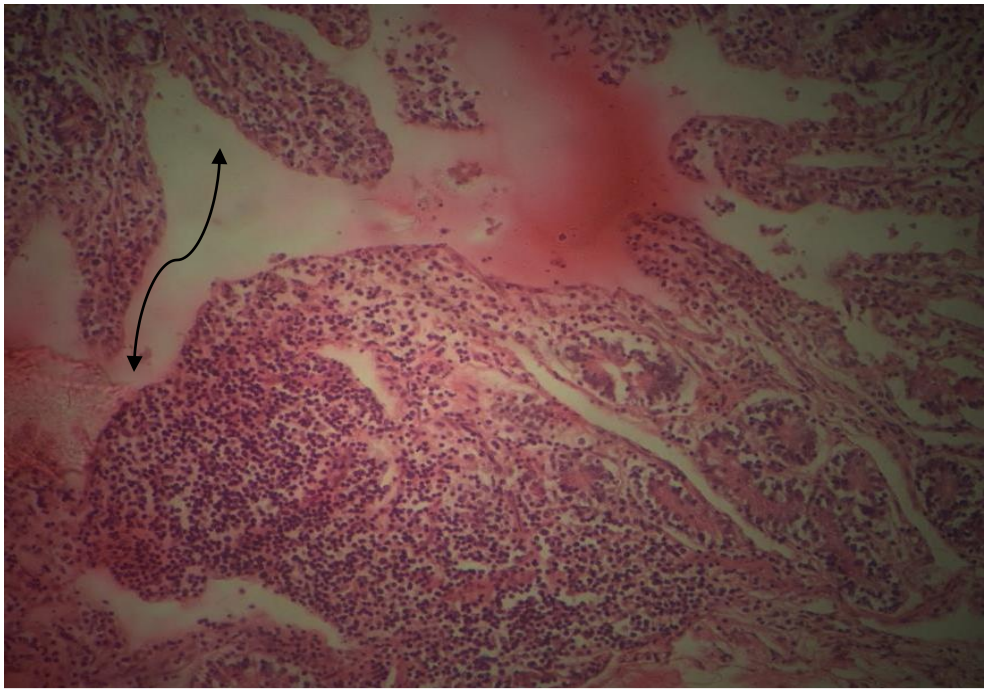


Figure XIV: enlarged villi with massive infiltration of abdominal cells, predominantly nuetrophils.

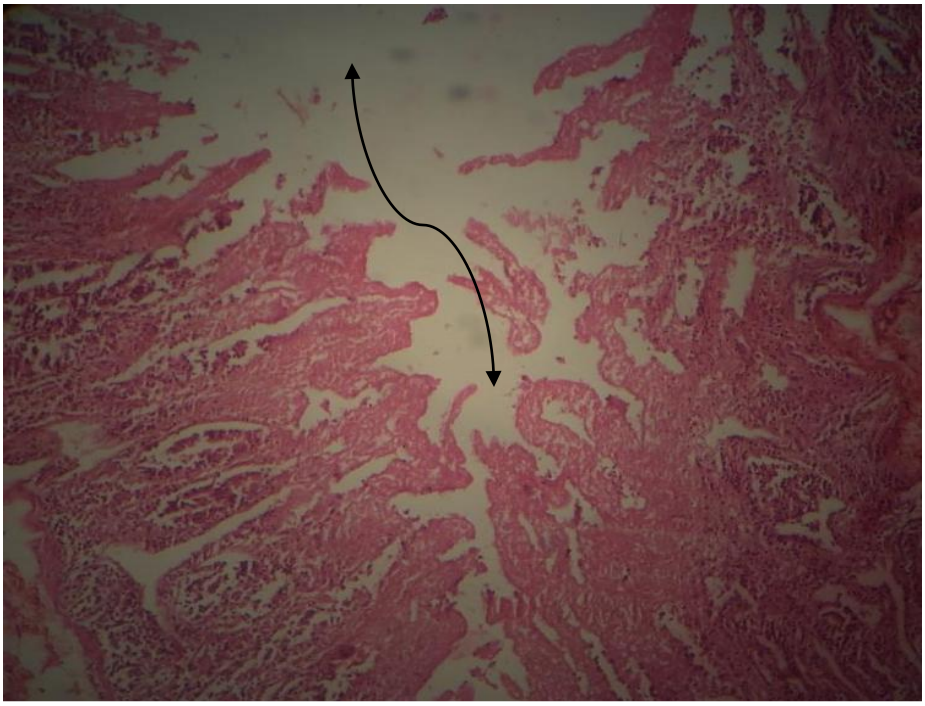


Figure XV: cells are separated from the parenchyma cells and edema infiltration.

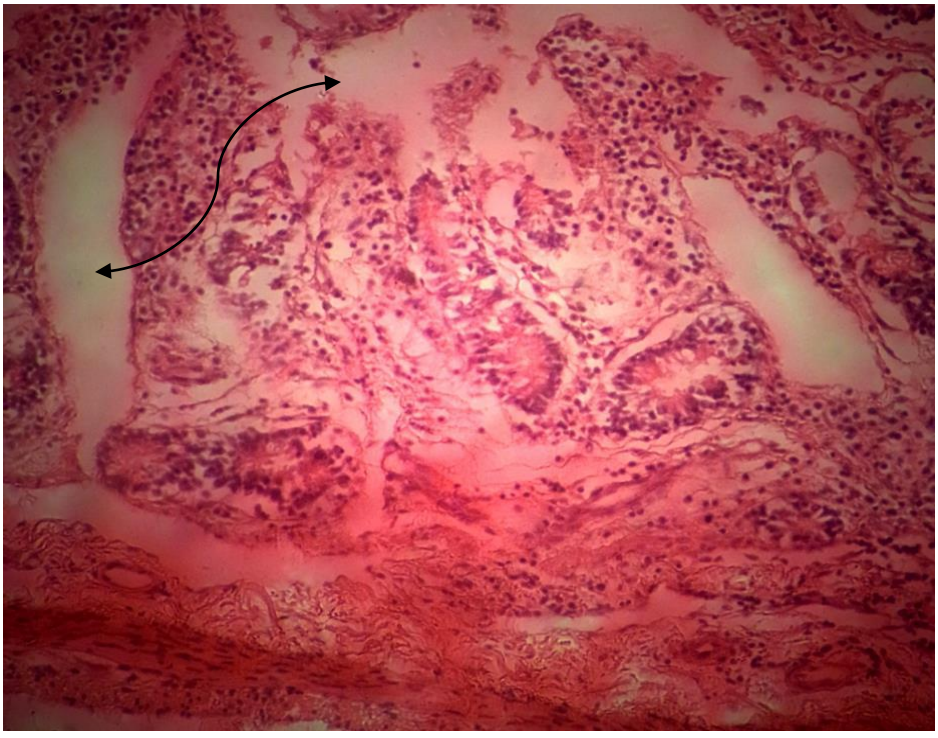


Figure XVI: Edema infiltration and a degree of fabriosis.

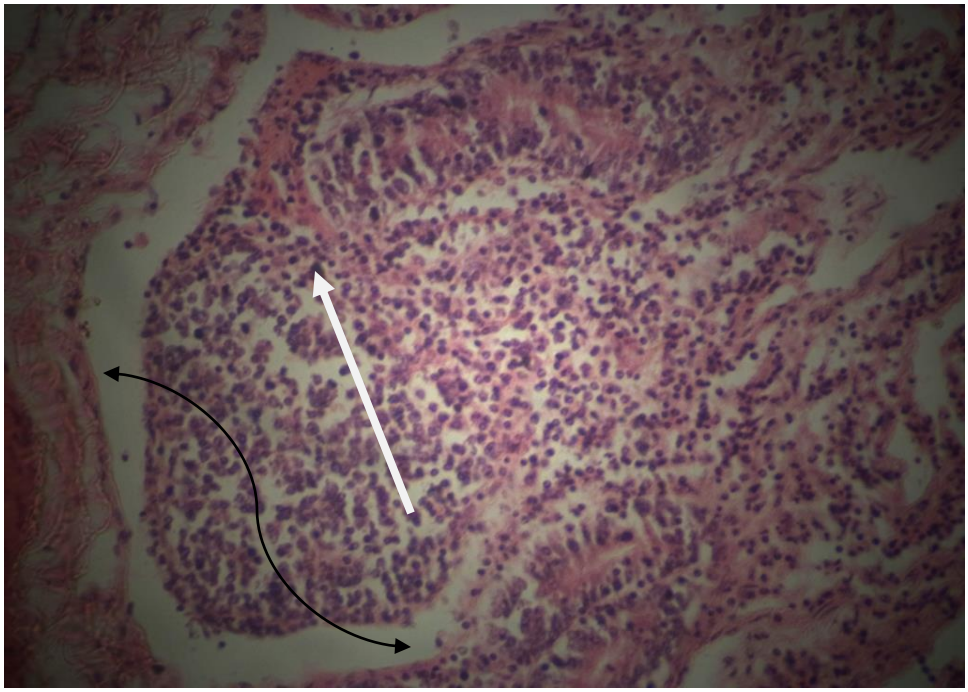
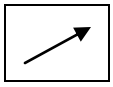


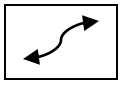
Figure XVII: parasite infestation, disconnected villi cells some death and infiltration.

Key



Fat vacuolation

Congestion of blood cells



Disconnection of villi