EFFECTS OF FEEDING DIETS CONTAINING UNDELINTED UNDECORTICATED COTTONSEED CAKE ON GROWTH, CARCASS CHARACTERISTICS AND REPRODUCTIVE PERFORMANCE OF FEMALE PIGS

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SEPTEMBER, 2011

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PhD/AGRIC/55494/04-05

A DISSERTATION SUMMITED TO THE POSTGRADUATE SCHOOL, AHMADU BELLO UNIVERSITY, ZARIA. NIGERIA

IN PARTIAL FULFILMENT OF THE AWARD OF DOCTOR OF PHILOSOPHY IN ANIMAL SCIENCE

DEPARTMENT OF ANIMAL SCIENCE

AHMADU BELLO UNIVERSITY, ZARIA NIGERIA

SEPTEMBER, 2011

DECLARATION

I hereby declare that the work in this dissertation titled "Effects of feeding diets containing undelinted undecorticated cottonseed cake on growth, carcasscharacteristics and reproductive performance of female pigs" has been carried out by me in the Department of Animal Science under the supervision of Professors T.S.B. Tegbe, S.O. Ogundipe and P.I. Rekwot.

The information derived from the literature has been duely acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at any university.

Joseph Olu Jegede	_____	_____
Name of student	Signature	Date

CERTIFICATION

This dissertation titled "EFFECTS OF FEEDING DIETS CONTAINING UNDELINTED UNDECORTICATED COTTONSEED CAKE ON GROWTH, CARCASSCHARACTERISTICS AND REPRODUCTIVE PERFORMANCE OF FEMALE PIGS" by Joseph Olu Jegede meets the regulation governing the award of the degree of Doctor of Philosophy of Ahmadu Bello University, Zaria and is approved for its contribution and literary presentation.

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Professor S.O. Ogundipe Member, Supervisory Committee	Date
Professor P.I. Rekwot Member, Supervisory Committee	Date
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AKNOWLEDGEMENT

I would like to express my gratitude and indebtedness to my team of supervisors, Professor T.S.B. Tegbe, Professor S.O. Ogundipe and Professor P.I. Rekwot for their valuable advice, guidance, counsel and contributions in the planning and execution of this work. I will remain grateful to all of you. I want to sincerely thank the Director of the National Animal Production Research Institute (NAPRI) Ahmadu Bello University(ABU), Shika-Zaria for providing the funds and facilities to carry out this research work. I want to also express my sincere appreciation to the Ahmadu Bello University, Zaria for giving me the opportunity for this educational development.

I appreciate the co-operation and contributions of all staff of Swine Research Programme, National Animal Production Research Institute, A.B.U., Otukpo, Benue State. The immense contributions of Professor T.S.B. Tegbe, Messrs I.S. Adama,O.O. Adikwu, David Ogbe, Adakole Idoko, Joseph Adikwu, Peter Ede, Daniel Ogwola, Clement Enenche and Yusuf Ohaba are highly appreciated.

I like to appreciate the following people for their technical assistance during the course of this work: Alhaji Bello Sani, Mr. Nuhu Sani, Mohammed K. Suleiman, Gbenga Folade, Monday Agbonika and Bala Hassan all of NAPRI Central Laboratory Services; Mr. S.I.B. Bolaji, Miss. B. Aderibigbe and Mr. Y. Lekwot all of NAPRI Animal Reproduction Laboratory, Dr. M. Bisala and Mr. Peter Kujang of the Pathology and Microbiology Department, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria for the histopathological analysis. I am also grateful to the staff of the University Farm and the Meat Processing Laboratory, Department of Animal Science, Ahmadu Bello University, Zaria for their technical contributions during the course of this work. Iam most grateful to Professor I.A. Adeyinka for his advice, encouragement and assistance in the statistical analysis of the data. The contributions of Mrs. Ruth Ojo, Mrs. Hafsat Ibrahim, Messrs Musa Tanko, Longji P. Pewar and Kaka Ayodele are highly appreciated.

I am sincerely grateful to my friends, Professor J.T. Amodu, Dr.S.B. Afolayan and Mr. S.O. Adewole for their valuable advice, encouragement and contributions during the course of this work. My sincere and special appreciation goes to Professor P.O. Okaiyeto (of blessed memory) for his brotherly advice, encouragement

andcontributions.My special appreciation also goes toProfessors J.O.O. Bale, C.A.M Lakpini, A.M. Adamu, O.O. Oni, J.U. Ikhatua, O. W. Ehoche, Doctors D.D. Dung, and M.O. Orunmuyi (Mrs.) for their advice, contributions and encouragement. I wish to express my appreciation to the Head, Department of Animal Science, A.B.U., Zaria,Professor G.S. Bawa and all staff of theDepartment for their co-operation during the course of this work.

I am most grateful to my wife, Mrs. G. R. Jegede, my children- Oluwamuyiwa, Tolulope, Foluke and Olayinka, my brothers - Mr. R.O. Jegede, Mr. Johnson Ojo Jegede, my sister and her husband –ColonelGbenga and Mrs. Elizabeth Lasisi and Mr. and Mrs. S.B. Egbeneye for their prayers, encouragement, support and understanding at all times in the course of this work.

Above all, I am most grateful to God Almighty for His protection, blessings and mercy on me and all members of my family and for the success of this work. May His name be praised for ever, AMEN.

ABSTRACT

Three trials were conducted to evaluate the effects of feeding diets containing 0,10,20 or 30% undelinted undecorticated cottonseed cake (UUCSC) on growth, carcass characteristics and reproductive performance of female pigs. In the first experiment, twenty-four crossbred (Large White X Hampshire) grower pigs of average initial weight of 16.4kg live weight were fed 18% crude protein (CP) diets containing 0, 10, 20 or 30% UUCSC. There were two pigs per pen and three replications of the four treatments in a randomized block design trial. Pigs were fed at 5% of body weight daily. The trial lasted for 63 days. In a second trial, pigs were fed 0, 10, 20 or 30% UUCSC during the weaner, grower, growing-finishing and the reproductive phases. Twenty-four crossbred (Large White X Hampshire) weaner pigs of average initial weight of 12.7 kg were randomly assigned to pens on the basis of initial weight group. There were two pigs per pen and three replications in a randomized block design. Pigs were fed 18% CP during the weaner phase at 6% body weight daily and 16% CP diets at 5% body weight during the grower and growing-finishing phases. Pigs were housed on concrete floor pens and each phase lasted for 42 days. At the end of the growing-finishing study blood was collected from the gilts. Twelve gilts were selected (one gilt per pen) and slaughtered for carcass and organ histopathologcal analyses. There were no significant differences in terms of feed intake, weight gain and feed to gain ratio for all classes of pigs in the trials. There were significant decreases ($P<0.05$) in terms of feed cost per kilogramme and feed cost per kilogramme gain. All blood measurements examined were similar across the dietary treatments. The dressing, shoulder, ham and loin percentages were not affected by dietary treatments. The loin-eye area decreased ($P<0.01$) while back fat thickness increased linearly ($P<0.01$) as UUCSC increased in the diets. Liver, kidney and spleen yields of pigs fed the 30% UUCSC diet were significantly ($P<0.05$) lower

compared to those on other diets. The histopathological studies of the various organs of pigs fed 30% UUCSC diets indicated that the liver showed hepatic degeneration and necrosis while the kidney, heart, spleen, ovary and lymph node showed lesions compared to pigs fed other dietary treatments. Twelve gilts from the above study were fed the experimental diets, bred and maintained until piglets were weaned for the reproductive study phase. Reproductive parameters were similar on the diets. The apparent digestibility of nutrients and nitrogen balance were studied using 12 crossbred (Large White X Hampshire) weaner pigs of average initial weight of 12.0 kg. There were 3 replications of the four treatments in which UUCSC was fed at 0, 10, 20 and 30% levels in 18% CP diets. Pigs were housed in crates in a randomized block design trial. Pigs were fed at 4 and 6% of body weight respectively during the two periods, each made made up of a 7 – day adjustment and collection periods of faeces and urine. The UUCSC analysed contained 93.50% dry matter, 26.0% crude protein, 8.50% ether extract, 13.22% nitrogen free extract and 4250 kcal/kg gross energy. The apparent digestibility coefficients of dry matter, crude protein, ether extract and crude fibre were significantly reduced by the levels of UUCSC fed in the diets. Nitrogen intake was similar on all diets. Nitrogen retention was significantly ($P<0.01$) reduced by the levels of UUCSC in the diets of the weaner pigs. For good carcass UUCSC should be fed at 20% inclusion rate in the diets of female pigs. It was concluded that UUCSC can be fed to young and adult female pigs at 20 and 30% inclusion rate respectively without adversely affecting their growth performance, reproductive indices and physiological state.

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CHAPTER ONE

1.0 INTRODUCTION

In Nigeria, modern methods of swine production are relatively still at a very low level. Pigs are exceptional in the broad context of Nigerian livestock production, since significant numbers are kept in small-holder (or semi-intensive) production systems. Nonetheless, the majority of the pigs are still kept in villages under the traditional management systems. The three major systems of pig husbandry in Nigeria include extensive (scavenging), semi-intensive and intensive (Ogunfowora *et al*., 1980). In Nigeria, as in most other African countries, pigs play a minor role in meat production compared to other classes of livestock.However, Nigeria ranks second in pig population in Africa and pork contributes about 4.5% of the total meat consumption in Nigeria. (Adebambo, 1982; Pathiraja *et al*., 1986).

In spite of the negative image of pigs in some parts of the country, the industry enjoys the support and patronage of many Nigerians from the middle belt, west, and eastern parts of the country. Because of the abundant feed resources in Nigeria especially crop residues and agro-industrial byproducts, there is a comparative advantage for pig production. The abundant supply of groundnut cake during the days of groundnut pyramids of Kano and rapid fecundity of the pig contributed to making pig production the choice of accelerated meat production by the United African Company. This explains why of all places in Nigeria. Kano city once hosted the largest pig farm in the world (Dafwang *et al.,* 2010). According to him, this was necessitated by the need to supply meat to the army units that were flown from Kano to North Africa during the Second World War. The farm grew into a very large scale pig farm during the 50s and

60s at which time the meat was being shipped by rail from Kano to Lagos which was the capital and commercial centre of Nigeria (Dafwang *et al.,* 2010).

Some individuals and a few companies have made efforts to establish commercial swine production; but such efforts have been hampered by non-availability of feedstuffs. Feed cost accounts for 70-75% of the total cost of pig production (Ogunfowora *et al*., 1980). The problem of feed shortage has, however, been compounded by the ever-increasing prices of the conventional feedstuffs such as grains and oil seed cakes (groundnut cake and soyabean meal) used in the formulation of swine rations. Also pigs and poultry compete with man for the available feed grains (Ogunfowora *et al*., 1980). Consequently any feeding regime that will reduce feed cost will ultimately result in reduction of total cost of production and increase the profit margin. In order to keep the livestock industry in operation, producers have often had to use other less known and cheaper non-conventional protein sources such as palm kernel cake and cottonseed cake (Nwokolo *et al*., 1977; Nzekwe and Olomu, 1984; Ikurior and Fetuga, 1985; Onwudike, 1986; Ogundipe *etal*., 1990; Jegede *et al*., 1994; Adeyemo and Longe*,*2007).

Cotton is an important cash crop grown mainly in the Northern part of Nigeria. The processing of cotton results in a number of by-products that are valuable feed ingredients for livestock. These include the products of ginning (gin trash and whole cottonseed), cottonseed processing (delinted cottonseed, hulls, linters and cottonseed meal or cake) and cotton textile milling (cotton dust and waste).

Species and varieties of cottonseed plants differ in concentrations of gossypol present in seeds. The presence of gossypol in the seeds has restricted the feeding of whole cottonseeds to non-ruminant animals. Hence the feeding of cottonseed cake (CSC), a by-product of cottonseed processing, to monogastric animals is limited (Abou-Donia,

1989). Cottonseed cake/meal is a non-conventional protein source (25-45% crude protein) and a good source of energy.

The regular inclusion of undelinted undecorticated cotton cake (UUCSC) in the diets of monogastric animals is limited by its content of a naturally occurring toxic polyphenolic compound, *gossypol*, which has both anti-nutritional and infertility properties when fed at high levels (Lipstein and Bornstein, 1964, Clawson *et al*., 1975; Randel *et al.,*1992).

The continuous ingestion of gossypol has been reported to result in physiological abnormalities in pigs which include anorexia, hypertrophy and dilation of the heart (Smith, 1957; Hale *et al*., 1958). In the males of both ruminant and non-ruminant animals, gossypol toxicity results in infertile sperms and depressed sperm counts (Randel *et al*., 1992).

The toxic effects, particularly in females, overshadow the infertility effects observed in many non-ruminant species. Gossypol seems to disrupt estrous cycles, pregnancy and early embryonic development in female monogastric animals (Randel *et al*., 1992).

The quality of cottonseed cake varies a lot depending on the methods of extraction and the concentration of gossypol in the meal. It is also influenced by the method of oil extraction (Goetch and Owens, 1985; Ikurior and Fetuga, 1984). The UUCSC is cheaper than the major protein sources (groundnut cake and soybean meal) which are commonly used in the formulation of rations for monogastric animals in Nigeria.

The objectives of the present study are:

- To study the effects of UUCSC diets on growth, carcass characteristics and organ weights of female pigs.
- To investigate the effects of feeding diets containing UUCSC on the reproductive performance of female pigs.

- To evaluate the effects of feeding UUCSC diets on blood indices of pigs.
- To evaluate the digestibility of nutrients by weaner pigs fed UUCSC diets.

CHAPTER TWO

2.0 REVIEW OF LITERATURE

2.1 Pig Production in Nigeria

In Nigeria, as in most African countries, swine plays a minor role in meat production compared to other classes of livestock. This is because the swine industry has not yet developed like the ruminant and poultry industries. Pigs are therefore, rarely used for meat purposes by majority of the populace in Nigeria. The Nigerian pig population according to RIM (1992) stood at 3.406 million while FAO (2002) puts it at 5.1 million. The estimated world pig population is 939,318,700 and most of these are found in the tropical zones of the world (FAO, 2002; Holness 2005).

Pigs are sometimes dubbed as walking meat factories, because of the various advantages derived from them in the tropical regions of the world. Whatever the farming system used (extensive, semi-intensive or intensive) and whatever the scale (small, medium or large scale), the world trend is towards the consumption of more white meat than red meat. Thus the potential for increased meat production from pigs in the developing economy is enormous (Ogunfowora *et al*., 1980; CTA Spore, 2007).

When compared with other livestock, pigs have some major advantages which include:

- Conversion of concentrated feeds to meat twice as efficiently as the ruminant animals.
- They are highly prolific and can produce about 16-20 piglets per year with two farrowings in a year.
- They have shorter generation interval compared to cattle.

- If confined, maximum use can be made of their manure and effluent (as fertilizer, aquaculture or biogas).
- The pork is particularly suitable for industrial processing with longer shelf life.
- Quicker turn-over rate on investment compared with cattle and a dressing percentage of 70-75% compared to 50-55% for ruminants.
- Their relatively small size, when compared with cattle, provides for more flexibility in marketing and consumption.

The constraints to pig production include:

- Believers of the Islamic and Jewish faiths are forbidden to eat pork.
- Pigs are regarded as unclean animals hence some people do not eat pork.
- As monogastric animals, pigs compete directly with humans for cereals and oilseeds.
- Since they are raised close to human habitation, their effluent may cause a pollution problem.
- Because of their enormous fat deposits and the problem of cholesterol, some people do not eat pork.
- Pigs are vulnerable to a range of bacterial, viral and parasitic diseases (some of the later are communicable to humans).

There is evidence that pig production in Nigeria has a bright potential. It is also claimed that pigs can be successfully and economically raised in the tropics because building costs are low and heating facilities required for young pigs are minimal. Pigs can thus be protected against any harsh climatic environment by the provision of good housing facilities (Devendra and Fuller, 1989; Eusebio, 1990). The major problems in pig production in the tropics are high cost of feeds and the continuous danger of diseases (Church and Pond, 1992; Holness,2005). Some of these problems can be overcome

bythe application of new technology and management practices. There are also new informative research findings on the utilization of cheaper non-conventional feedstuffs which can be used to replace the expensive cereals and oilseed meals in swine diets. The provision of balanced diets for highly productive pigs is a logical solution to the problem of low population of pigs and low animal protein intake in Nigeria.

2.2 Cotton Production in Nigeria

Cotton is widely cultivated throughout the tropics and sub-tropical regions of Africa, Asia, Australia and America. Cotton belongs to the family *Malvaceae* and genus *Gossypium* having about 40 species of annual, perennial and small trees (Frywell, 1969; Faulkner, 1974). The British Cotton Growers Association started commercial cotton production in Nigeria in 1902 with the aim of supplying cotton lint to Lancashire Cotton Industry in the United Kingdom. According to Choyce, (1968) the production of improved varieties of cotton in Nigeria started with the introduction of an American upland type called "Allen long staple" from Uganda in 1912. Through breeding and selection of this variety, the Nigerian Allen and later the Samaru Allen were developed. Several commercial varieties (Samaru 26J, Samaru 68, Samaru 70 and Samaru 71) were developed from Samaru Allen which is the basic stock in Nigerian Breeding Programme (Choyce,1968).

Cotton is predominantly produced in the North Western and North Eastern zones of Nigeria. The North Western zone comprising Kaduna, Katsina, Zamfara, Sokoto, Kebbi, Jigawa and Kano States accounts for about 65% of the total cotton in Nigeria while the North Eastern zone comprising Borno, Adamawa, Bauchi and Gombe states account for 30% of the total cotton production in Nigeria. The remaining 5% comes from the North

Central zone of Nigeria comprising Kwara, Niger, Kogi, Nasarawa, Taraba, Benue and Plateau states (Choyce, 1968; Faulkner, 1974).

The processing of cotton results in a variety of co-products and by-products that are valuable in the textile and livestock industries. These include the products of ginning (gin trash, gin motes and whole cotton seeds), cotton seed processing (delinted cottonseed, cottonseed hulls, cotton linters and cottonseed meal or cottonseed cake), and cotton textile milling (cleaning and carding waste, cottonseed mill sweeps and cottonseed dust). Whole cottonseed is a good source of protein, energy and phosphorus. Cottonseed, meal or cake is primarily a protein and phosphorus source while cottonseed hulls, gin trash and textile mill waste are primarily roughage or fiber sources (Rogers *et al*., 2002).

The whole cottonseed is made up of about 9% cotton lint which is a short cellulose fibre used in paper manufacturing and other cellulose applications,25% is the hull which is usedas ruminant feed and other specialized industrial applications, 16% is crude cotton oil which is used for salad and other lipid applications for human consumption. The bulk of theseed (45%) is the cottonseed meal, a high protein supplement used in animal feeds. Theremaining 5% is attributed to waste. Whole cottonseed can be fed to adult ruminant animals either alone or in combination with other feedstuffs and does not require any processing.

The major impediment in the use of cottonseed and cottonseed byproducts is that they contain a naturally occurring polyphenolic compound called *gossypol*. Gossypol gives some levels of protection to the plant against insect pest attack. The seed of *Gossypiumbarbadense (L)* contains more gossypol that the seed of *Gossypium hirsutum*

(L). The Nigerian varieties of cotton are hybrids of the staple types of *G. hirsutum* (Faulker, 1974).

2.3 Chemical Composition of Whole Cottonseed

The whole cottonseed is a by-product of cotton gin-industry and has sufficient feeding value for ruminants (Chandler, 1992). There are two types of commercial cottonseed namely, high-lint whole cottonseed ("Short staple") and low-lint whole cottonseed ("Long staple" Pima seed). On a dry matter basis, low-lint whole cottonseed contains about 50 – 100g/kg less fiber, with higher fat and protein content than the high-lint whole cottonseed (Ariel, 1998; Rogers, *et al*., 2002).

Whole cottonseed is a unique feedstuff that contains high concentration of energy 14MJ/kg, digestible fiber, protein (22-24%) and phosphorus (Bernard, 1999). On the average, whole cottonseed is about linter, 12.21, hull, 18.24 and kernel, 70.32% (NRC, 1990; NRC,1998; Mujahid *et al*., 2000). These authors reported that whole cottonseed has about 17.74% fiber and 4.27% ash content while the average contents of the following: calcium 0.12%, phosphorus 0.07%, magnesium 0.09%, potassium 0.15%, sodium 0.025%, chlorine 0.03%, iron 141.35 mg, zinc 24,55 mg, copper 18.65 mg and manganese 27.12, mg. The whole cottonseed is not fed to monogastric animals because of the presence of gossypol in it (Rogers *et al*., 2002).

2.4Nutrient Composition of Cottonseed Cake

The nutrient content of cottonseed meal or cake varies depending on the process used in extracting the oil. Compared to those produced 25 -30 years ago, cottonseed meals produced today are shown to be higher in crude protein, magnesium, potassium, and sulphur and lower in crude fiber, copper and manganese. Generally speaking, the major effect of extraction process is on the fat content. As a rule, the mechanically extracted

cottonseed meal tends to have higher residual oil content than either the pre-pressed solvent or direct solvent extracted cottonseed meal (Calhoun *et al*., 1995).

The crude protein content of pre-pressed and direct solvent extracted cottonseed meal varies between 41 – 45% depending on the method of extraction (NRC, 1998). According to Tanksley, (1990) the most common is 41% crude protein products even though some Official Feed Definitions require a minimum of 36% crude protein for both the cake and meal cottonseed products. Some workers have reported values of between 24 and 26% crude protein content for undecordicated cottonseed cakes and meals (Oyenuga, 1968; Ranjhan, 1990; Balogun *et al*., 1990; Aduku, 1992; Lamidi, 2006). Cottonseed cake is high in lysineand it is also adequate in other essential amino acids. The following ranges of percentage values had been recorded for arginine 4.40 – 6.63, lysine, 1.57 – 1.79, methionine, 0.62 – 0.73, cystine, 0.64 - 0.78, tryptophan, 0.51 – 0.57, threonine, 1.44 – 1.52, isoleucine, 1.27 – 1.56, leucine, 2.50 – 2.74, histidine, 1.15 – 1.45 and valine,1.80 -2.05% (NRC, 1990; NRC, 1998; NCPA, 2002).

The energy content of cottonseed cake depends on the method of oil extraction of the whole cottonseed. The meals produced by the mechanical oil extraction have higher energy values compared with those produced by solvent oil extraction. The range values of 4200 – 4600 kcal/kg have been reported for gross energy of cottonseed meal samples (NRC 1998; NCPA, 2002)

Analyses have shown that the fat and crude fiber contents of cottonseed meal samples ranged between 4.0 – 9.6% and 10.2 – 18.4% respectively, while the ash content is between 6.2 and 6.8% (NRC, 1998; NCPA, 1999). Cottonseed meal is said to be rich in phosphorus with value ranging between 1.14 and 1.20%. The values of various minerals recorded for samples of cottonseed meal are calcium, 0.16 – 0.22%,

magnesium, 0.56 – 0.66%, iron, 0.01 – 0.03%, potassium,1.40 – 1.68%, and sodium, 0.04 – 0.14% (Ranjhan, 1990; NRC, 1998; NCPA, 1999).

2.5 Occurrence and Distribution of Gossypol

Gossypol is a yellow colouring matter or pigment occurring, so far as it is known, only in the genus *Gossypium* of the order *Malvaceae*. According to Adams *et al*., (1960), the name "*gossypol*" was coined in the year 1899 from "*gossiypium phenol*" $C_{12}H_{30}O_8$ to indicate its origin and chemical nature (Figure 1). TheIUPAC name is 2, 2'-Formyl-1, 6,7-trihydrox-5-isopropyll-3-methlynaphthalene (*Wikipedia, 2010*). Gossypol and other similar pigments are contained in discrete sub-epidermal gland (or resin gland) dispersed in the root barks, stems, leaves and seeds of cotton plants (Randel *et al*., 1991). The pigment gland occurs in greater amounts in the roots than in the seeds and much smaller amounts in other parts of the cotton plant. The pigment gland is about 2.4 – 4.8% of the weight of the kernel.

Gossypol is not peculiar to cotton plant alone but it is present in many other plants belonging to the order *Malvaceae*. Okro, a member of this order, contains 3.2mg of gossypol per 100g of the dried seed. This level falls within the acceptable food levels of 0.045% free gossypol according to the United States Food and Drug Administration (USFDA) or 1.2% total gossypol by FAO (NCPA, 1999).

Apart from gossypol proper, about 14 other gossypol pigments or derivatives are reported in the extracts of cottonseed, cottonseed oil and cottonseed meal. Boatner, (1948) observed that only six of these pigments have been isolated and characterized in more or less purified forms. These include gosspurpurin (purple), diaminogossypol (yellow), gossyfulvin (orange), gossyverolurin (green) and gossycaerulin (blue).

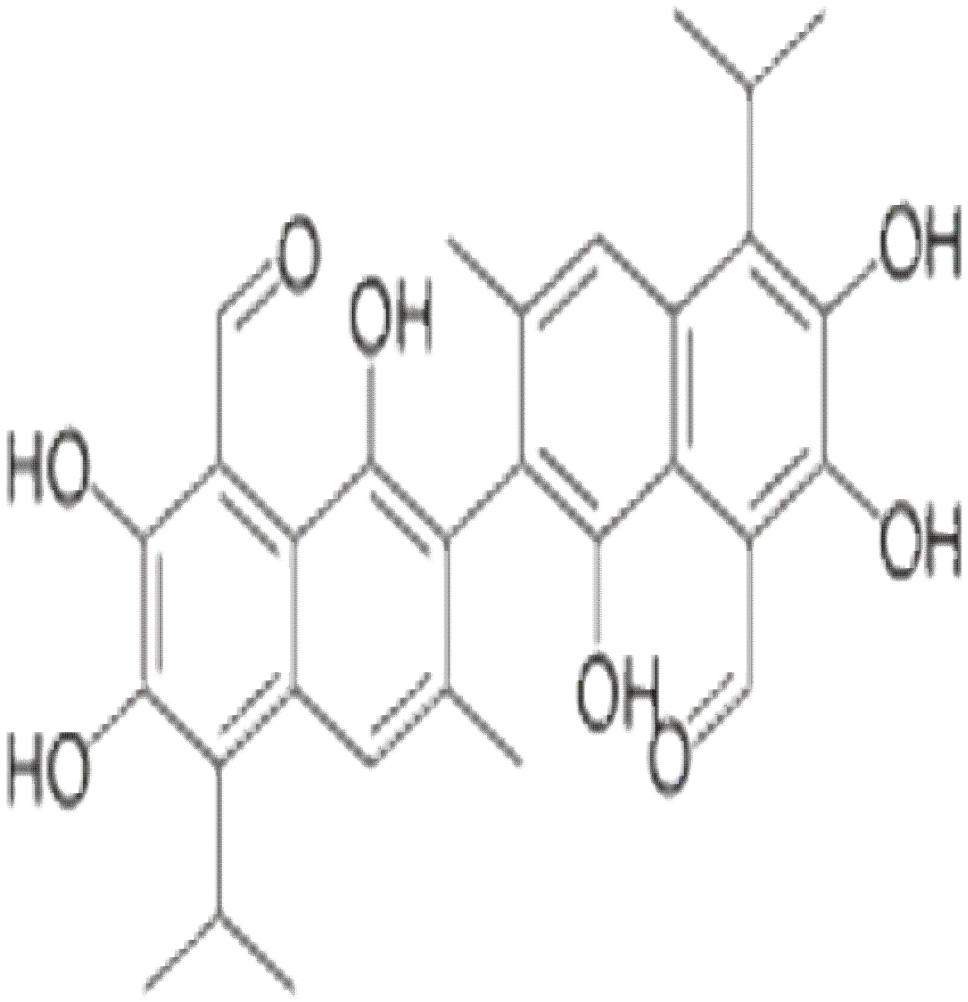


Figure 2.1: Chemical structure of gossypol.
IUPAC Name: 2,2'-Formyl-1,6,7-trihydrox-5-isopropyll-3-methlynaphthalene.
Source: Wikipedia-Gossypol: http://en.wikipedia.org, (2010).

Gossypol, a polyphenolic compound in cotton plants, is localized in the pigment glands found in all parts of the plants but highly concentrated in the seeds. Some workersreported that gossypol levels in the cottonseed and plant vary with the species, varieties, fertilization, growing conditions, location and insect pressure (Boatner, 1948; Pons *et al*., 1953).

Smirnova, (1934) showed that the average content of gossypol pigments of all varieties of a given species is a characteristic of the species while different varieties of a given specie may differ with respect to the content of gossypol pigments when the seeds are grown under the same condition. Boatner, (1948) observed that *Gossypium barbadense* seeds contained more gossypol and gossypurpurin than the seeds of *Gossypiumhirsutum*. Framptom *et al*. (1960) reported that the total gossypol contents of seeds from several species of cotton plants range from 0.13 – 1.14%. The gossypol content of cottonseed might be affected by the species and variety of the cottonseed plant (Pons *et al*., 1953). Climatic conditions have also been demonstrated to have influence on gossypol levels. A direct relationship exists between high rainfall areas and gossypol content, whereas an inverse relationship has been observed between areas with high average temperatures and gossypol content (Pons *et al*., 1953). Other factors affecting the gossypol content of cottonseed include regional soil conditions, water supply, amount and composition of fertilizer applied and any major changes in plant growth during the vegetative growth (Pons *et al*., 1953; Morgan, 1989).

Calhoun *et al*. (1991) stated that although much variability in gossypol content exists, the gossypol content of the seeds from commercial varieties grown has not changed appreciably in the last 50 years. Pons *et al*. (1953) evaluated the gossypol content of

whole cotton seed from eight varieties in 13 locations in 1950s and found a gossypol range from 0.36% to 1.7%. In the 1970s, a mean gossypol content of 1.32% (range 0.59 – 2.35%) was found in cottonseed kernels (Pondey and Thejapa, 1975).

In Nigeria, Ikurior and Fetuga, (1984) showed that the average free gossypol values range from 1.145 for S72 to 1.28% for S77. The total gossypol was found to be higher than 1.21% and 1.25% obtained for S71 and S72 varieties respectively. These workers stated that 80 – 98% of the gossypol exists as free gossypol. According to Boatner, (1948) the presence of gossypol affords the cotton plant some protection against predators such as insects and field mice that might otherwise feed on these plants and their seeds.

Free gossypol, according to Rogers *et al*., (2002), is that part of the total gossypol in cottonseed that is physiologically active. Bound gossypol levels are calculated by subtracting the free value from the total value. These workers stated that when feeding cottonseed meal, it might be appropriate to analyze for free gossypol. Gossypol exists naturally as a mixture of two stereoisomers because of the restricted motion about the bond that joins the two naphthalene groups of the molecules. The isomers are referred to as the (+) and (-) gossypol (Framptom*et al*., 1960; Smith, 1965). The (-) isomer (free form), according to these workers, seems to have the greatest biological activity and is responsible for the toxic effects in animals, but the (+) isomer (or bound form) is not toxic to the animals after ingestion.

2.6 Effects of Processing ofWhole Cottonseed onGossypol Content

Currently, there are three methods of processing cottonseed meal or cake from whole cottonseeds, namely mechanical extraction (screw processing), pre-pressed solvent extraction and direct solvent extraction. These methods use different

temperatures, pressures and cooking times. All the three forms of cottonseed meal produced have similar nutritional values (Jones, 1981; Goetch and Owens,1985). Jones (1981) and Rogers *et al.* (2002), stated that when cubed or pelleted, cottonseed meal is also known as cottonseed cake. The cake is the residue of the mechanical extraction and retains higher oil compared to the meal. During processing, the rupture of the pigment glands containing the gossypol and other complex polyphenols allow the binding of these highly reactive compounds with the components of the meal. Thus the portion of gossypol which has combined with the sulphur containing amino acids in protein during condensation of gossypol is known as bond *gossypol* while the remaining uncombined gossypol is called free *gossypol* (Pons and Hoffpauir, 1957; Bernardi and Goldblatt, 1969).

The concentration of free gossypol in cottonseed meal is influenced by the method of oil extraction. Jones (1981) reported the following representative values of free and total gossypol content for screw pressed (0.04 and 1.02%), pre-pressed solvent extracted (0.05 and 1.13%) and direct solvent extracted (0.30 and 1.04%) cottonseed meals. This is an indication that although total gossypol content does not differ greatly, the physiologically active free gossypol content is much greater in direct solvent-extraction method than in the other two processes. Rogers *et al*., (2002) stated that higher temperatures and pressures favour the formation of stable bonds between gossypol and other molecules.

2.7 Fate of ingested gossypol

The metabolic fate of gossypol has been the subject of a number of investigatons. It is generally believed that the ingested bound gossypol is stable and it is eliminated essentially unchanged by the monogastric animals and is therefore not deleterious to the

animals(Bressani *etal*., 1964). These workers observed that some bound gossypol is librated during passage through the gastro-intestinal tract of dogs. Bound gossypol in the diet can cause an increase in the faecal nitrogen level compared to controls and can decrease absorption of amino acids, increase rate of passage of digesta and inhibit the action of gossypol proteolytic enzymes (Lyman and Midmeri, 1966; Albrecht *et al*., 1972;Jones and Smith, 1977; Tanksley, 1990).

The biological half-life of gossypol for hen is 30 hours (Abou-Donia and Lyman, 1971), for swine and rat are respectively 78 and 23 hours (Abou-Donia and Dieckett, 1975). These workers indicated that addition of iron in the diets of these animals reduced the half-life of gossypol. Lyman and Midmeri, (1966) reported the recovery of radioactive gossypol in the faeces and tissues of chicks fed gossypol labeled ^{14}C. About 87.3% of the $^{14}C$was found in the faeces and only 8.9% in the tissue; approximately one-half (4.4%) was found in the liver, almost as much as in the muscles, 1.6% in the blood and less amount in the kidney; lung, heart, brain and spleen. They observed that gossypol ingested by the laying hen was largely excreted in the faeces and less amount in the uric acid.Much of the absorbed gossypol in the laying hens was transmitted to the egg and a small proportion was deposited in the tissue. In swine, Lyman and Midmeri (1966), reported higher proportion of gossypol ^{14}C recovered in the tissue (25.10%) and 61.60% in faeces. They concluded that the higher absorption of gossypol from the gastrointestinal tract of pigs compared to chicks is probably responsible for greater sensitivity of the pigs, with larger concentration of gossypol in the liver. The greatest amount of free gossypol accumulation was also observed in the liver followed by kidney and lastly the heart when lambs were fed whole cottonseed or cottonseed products for a long time (Nikokyris *et al.,* 1991).

For humans who have consumed gossypol containing products, toxicity may occur if the concentrationof gossypol is higher than 250 mg per kg maximum level of free gossypol established by the Food and Drug Administration of United States of America (Jones, 1988). Carter *et al*. (1977), gossypol is an appetite depressant which is recommended for treating obesity and a close clinical surveillance that extended over two years in Guatemala and six months in Peru failed to disclose any evidence of toxicity in children fed food containing cottonseed protein.

2.8 Effects of Mineral Supplementation on the Toxicity of Gossypol in Nutrition The use of cottonseed meal as a protein supplement for monogastric animals has been markedly limited because of the deleterious effects resulting from the residual free gossypol (Hale *et al*., 1958; Smith and Clawson, 1966). Efforts have been made to minimize these effects by various treatments such as moist cooking (Sewell *et al.,* 1943), supplementing the diet with minerals (Withers and Carruth, 1915; Gallup, 1928; Gallup and Reder, 1934) and by feeding high levels of protein (Hale *et al.*, 1958). Results from previous studies indicated that calcium and iron have some detoxifying effects on gossypol (Withers and Carruth, 1917;Gallup, 1928; Bressani *et al.,* 1966). These effects according to Smith, (1965) can be critically evaluated since methods are now available for the determination of free and bound gossypol in the tissues of animals.

According to Phelps *et al.*(1965) andBrahma *et al. (*1967), several iron salts had been used successfully in counteracting the undesirable gossypol effect in earlier trials conducted between 1912 and 1953 with swine, laying hens, rats and rabbits. These workers stated that of all the iron salts used in these earlier studies, the following have shown some degree of promise: ferrous sulphate (heptahydrate), ferric ammonium

citrate, ferric citrate, and ferrous ammonium sulphate. Studies have also been carried out on the effects of iron and of calcium hydroxide alone and in combination on the performance of pigs fed diets containing gossypol and on the accumulation of gossypol in the organs. The feeding of calcium hydroxide alone or in combination with iron salts in the diets of pigs was very effective in the prevention of gossypol toxicity (Gallup and Reder, 1934; Smith and Clawson, 1966).

Bressani *et al.* (1966) conducted several studies with swine and observed that ferrous sulphate addition to diets containing gossypol caused a decrease of 40% of the gossypol toxicity while the addition of 1% calcium hydroxide and 0.1% ferrous sulphate reduced free gossypol to 73%. Cabell and Stevenson, (1966) studied the effect of orally administered iron salts on the performance of swine and rats fed gossypol. They indicated that the addition of iron salts in the diets of these monogastric animals was completely effective in preventing toxic symptoms in the animals.

The toxicity of gossypol in swine is characterized by lesions of the heart, lungs, small intestine and the liver and enlargement of these organs. But iron alone or combined with calcium decreased the lesions and enlargement of these organs (Bressani *et al.,* 1966; Jones, 1988). These workers indicated that haemoglobin concentration and haematocrit of the blood of the pigs decreased as a result of gossypol toxicity. Also the hair of animals consuming cottonseed flour with and without single mineral additives became depigmented. The presence of iron and calcium in the diets protected the animals in all respects even against colour depigmentation. Smith and Clawson (1966) observed that injected iron was not effective against dietary gossypol and that gossypol did accumulate in the liver, kidney, spleen and lymph nodes. But these conditions were reversed when diets containing 244 and 400 ppm of ferrous sulphate and free gossypol at a 1:1 ratio were fed to the animals. This was because this ratio gave complete

detoxification of the gossypol in the diet. It was concluded that the gossypol accumulated in the porcine liver varied inversely with the dietary iron level (Smith and Clawson, 1966).

2.9 Gossypol Toxicity in Livestock

Cottonseed meal has been used for many years as a protein supplement in animal rations. Due to a polyphenolic pigment, gossypol, present in the cottonseed meal, its use for monogastric animals has been limited. The tolerance of gossypol in monogastric animals depends upon the age and specie of the animals with older animals being less sensitive than younger animals (Randel *et al.,* 1992). The ruminants are somewhat more resistant to the toxic effects of gossypol. Gossypol toxicity is however, a potential problem when cottonseed products are fed to young ruminants with functionally undeveloped rumen. Studies indicated that the clinical signs and postmortem findings are similar to those observed in monogastric animals (Hollon *et al.*, 1958; Rogers *et al.,* 1975; Randel *et al.,* 1990; Randel *et al.,* 1992). Studies conducted by Reiser and Fu (1992) indicated that the ability of the ruminant to detoxify free gossypol was caused by the binding of soluble proteins within the rumen to free gossypol. This protein-bound gossypol was found to be physiologically inactive.

2.10 Clinical Signs of Gossypol Toxicosis

Since gossypol toxicosis is similar in presentation to other diseases caused by infections that are parasitic or nutritional in nature, a clinical diagnosis is rarely made. However, presumptive diagnoses are usually made when high doses of gossypol or cotton products are included in the rations of animals. Toxicosis caused by excessive consumption of cotton products by non-ruminants is related to gossypol poisoning (Randel *et al.,*1992). There are marked species differences in susceptibility to gossypol

toxicity. Thus, Abou-Donia, (1976) recommended a single oral dose LD50 (mg/kg of body weight) of 2,400 to 3,340 for rats, 500 to 950 for mice, 350 to 600 for rabbits, 280 to 300 for guinea pigs and 550 for swine.

The clinical signs of chronic ingestion of high levels of free gossypol in cottonseed meal or other cotton by-products by monogastric animals, pre-ruminants and ruminants are similar. These include laboured breathing, decreased growth rate, anorexia, weakness, abdominal distention and terminal convulsions (Smith, 1957; Korneygay *et al.,* 1961; Randel *et al*., 1992; Rogers *et al*., 2002). Gossypol toxicosis seems to have a cumulative effect and surviving animals have been reported to have remained unthrifty and have poor hair coats and distended abdomen. Rogers *et al*. (2002) reported that the clinical signs of gossypol toxicity in mature cattle included decreased dry matter in-take, decreased milk production, panting and elevated heart rate. Postmortem findings in swine indicated fluid accumulation in thoracic and peritoneal cavities, edema and congestions of liver, lungs and spleen and dilation and hypertrophy of the heart with degeneration of muscle fibres. Gossypol toxicity is also a potential problem when cottonseed products are fed to calves with functionally undeveloped rumens (Hollon *et al*., 1958; Smith, 1959; Rogers *et al*., 1975; Kerr, 1989). These workers reported that the signs and postmortem findings were similar to those observed in swine. Lindsey *et al.*(1980) and Smalley and Bicknell (1982), reported case studies of gossypol toxicosis in mature dairy cattle fed relatively high amounts of ammoniated whole cottonseed (2.7 to 4.5kg per cow per day). Postmortem examination revealed edema of the lungs and abomasum, presence of straw-coloured fluid in the thoracic and peritoneal cavities and degenerating hypertrophic muscle fibers in the heart. These effects in mature ruminants indicate that ingestion of free gossypol at high levels may overwhelm ruminal detoxication and hence result in the absorption of quantities of free gossypol that may

be potentially toxic (Lindsey*et al.,* 1980).Neser *et al*. (1988) in studies with pigs on gossypol poisoning observed that the postmortem examination revealed hepatic congestion, edema of the lungs, gall bladder and mesentery. Cardiac lesions including discolouration of heart muscle fibers as well as congestion and necrosis of the liver were also observed.

2.11 Endocrinology of Reproduction

The sex of mammal is fixed at the time of fertilization according to whether the cytoplasm of the ovum is penetrated by an x- or y- bearing spermatozoon (Hunter, 1980). Under the influence of its sex chromosome complement, the mammalian embryo undergoes anatomical modifications that lead to the differentiation of the male or female gonads (testes and ovaries respectively) and the male and female duct systems (the Mullerian and Wolffian ducts) respectively (Hunter, 1980).

The fetal reproductive system arises primarily from two germinal ridges on the dorsal side of the abdominal cavity and it can differentiate into male and female systems, a condition referred to as embryonic bisexuality (Hunter, 1980; Rekwot, 1999). According to these workers, the wolffian ducts, in the male, develop into epididymis, vas deferens and vesicular gland while the mullerian ducts atrophy. Similarly, in the female, the mullerian ducts develop into uterus, cervix and the anterior part of the vagina, while the wolffian ducts atrophy. The urogenital sinus differentiates into urethra, prostate cowpers glands and seminal vesicles while the genital tubercle and vestibular fold become the penis and scrotum respectively. In the females, the urogenital sinus become posterior vaginal and urethra while the genital tubercle and vestibular folds become clitoris and labia (Dziuk, 1977; Hunter, 1980).

Endocrinology is a branch of biological science that deals with the study of hormones and their receptors. Hormones are physiological organic chemical substances produced by certain specialised ductless glands (or cells) which are carried by the circulating system in order to stimulate or inhibit the functional activities of the target organs or tissues (Hunter, 1980; Niswender*et al.,*1995; Rekwot, 1999). According to these workers, the hormones of reproduction are divided into two groups based on type and action – primary and metabolic hormones. The primary hormones affect the spermatogenesis, ovulation, sexual behaviour, fertilisation, implantation, gestation, parturition, lactation and maternal behaviour. The metabolic hormones, on the other hand influence reproduction and are necessary for the well-being and metabolic state of the animal for example, growth, metabolism and development.The releasing factors or releasing hormones originate in the hypothalamus and control the synthesis and release of hormones from the anterior portion of the pituitary gland (adenohypophysis). The gonadotropic hormones produced in the hypophysis stimulate the secretion of sex steroid hormones (Niswender *et al.,* 1995).

2.11.1 Hypothalamic Releasing Hormones or Releasing Factors of Reproduction

The hypothalamus is a structure derived from the fore-brain and exerts its influence over the anterior pituitary gland (adenohypophysis) by means of neurosecretions (releasing hormones, RHs) from its cells (Hunter, 1980). The releasing hormones or factors are released into the capillary loops of the hypophyseal portal vessels and thus permit the control of secretory activities of the antrerior pituitary gland. These releasing hormones (RHs) include gonadotropin releasing hormones (Gn - RH) which stimulate the production or release of luteinizing hormones (LH) and follicle stimulating hormones (FSH). Thyroxin releasing hormone (TRH) stimulates the release of thyroxin stimulating hormones (TSH) and prolactin. Also included are the prolactin releasing and inhibiting

factors (PRF and PIF) which release and inhibits prolactin release by the hypothalamus (Hunter, 1980; Niswender *et al*., 1995;)

2.11.2Reproductive Hormones of Adenohypophysis:

The adenohypophyseal hormones which play the most important roles in reproduction are follicle stimulating hormones (FSH), luteinizing hormone (LH) and prolactin (Niswender *et al.,* 1995). According to these workers, FSH stimulates follicular growth and spermatogenesis while LH stimulates ovulation, formation of corpus luteum (CL) and secretion of progesterone (P4), estrogen and androgen. Prolactin plays a role in the maintenance of corpus luteum and secretion of progesterone. Prolactin also stimulates the development of mammary gland and milk secretion (Schroff *et al*., 1971).

2.11.3 Reproductive Hormones of Neurohypophysis (Posterior pituitary)

The only reproductive hormone that is stored and released by the posterior pituitary (neurohypophysis) is oxytocin. Oxytocin stimulates uterine contractions at parturition, milk ejection, sperm and ova transport in the uterus and oviduct (Niswender *et al.,* 1995).

2.11.4 Gonadal Steroid Hormones

The sources of the gonadal steroid hormones include placenta, ovary and testis. The hormones found in the placenta include human chorionic gonadotrophin (HCG), pregnant mare serum gonadotropin (PMSG) and placental lactogen (Niswender *et al.,* 1995). HCG has LH-like activity for maintenance of corporal lutea. The placental lactogen regulates the maternal nutrients to fetus (Hunter, 1980). According to these workers, the ovary produces estrogen and progesterone. Estrogen stimulates sexual behaviour and secondary sex characteristics in the female animal. It promotes the growth of the reproductive tract, uterine contractions, mammary gland development and

controls the release of gonadotropins. Progesterone, on the other hand, acts synergistically with estrogens in promoting estrous behaviour, prepares the uterine tract for implantation, maintains pregnancy and promotes the development of mammary glands (Hunter, 1980). Anderson, (1995) observed that the testis produces androgens (or testosterone) which is responsible for the development and maintenance of accessory sexual glands, secondary sexual characteristics, libido, spermatogenesis and anabolic effects.The thyroid gland secretes the thyroxine (or triidothyroxine) which maintains hypophyseal-gonadal relationship.

Other hormones and releasing hormones secreted by the hypothalamus and hypophysis include somatotrophin releasing hormone (STH-RH) adrenocorticotrophic hormone releasing hormone (ACTH-RH) from the hypothalamus; growth hormone (GH) or somatotrophic hormone (STH) from the adenohypophysis; vasopresin and adrenocorticotrophic hormone from the adrenal cortex (Hunter, 1980).

2.11.5 Folliculogenesis

The ovary is a dynamic organ and remains in the abdominal cavity of the mammal. It performs both an exocrine (egg release) and endocrine (estrogen and progesterone secretion) function (Hafez, 1995). The follicle is the ovarian compartment that enables the ovary to fulfil its dual functions of gametogenesis and steriodogenesis. Thus ovary may possess different component structures (ovarian follicles and corpora lutea) at various stages of development or regression. Hafez (1995) and Hunter (1980) observed that the development of ovarian follicles is often classified, for convenience by histological criteria according to the size; layers of granulosa cells; theca development and position of the oocyte surrounding cumulus oophorus. According to these workers, primodial follicles are oocytes (potential eggs) surrounded by germinal epithelium (flattened cells). These cells increase in number by mitosis and become secondary cells

(or follicles). Further growth, meiotic division and maturation of the secondary cells result in the graffian follicles. The growth of the follicles involves hormonally induced proliferation and differentiation of both theca and granulosa cells leading to the ability of the follicles to produce hormones such as FSH, LH, and estrogens (Hafez, 1995; Rekwot, 1999).

2.11.6 Spermatogenesis

Spermatogenesis is a series of complex cellular division and morphological changes leading to the formation of spermatozoa. This process involves three major steps: mitosis of spermatogonia to yield spermatocytes, meiosis of primary spermatocytes to yield spermatids and morphological changes of spermatids to yield spermatozoa (Hunter, 1980; Hafez, 1995; Rekwot, 1999). In the mammalian male, the germinal epithelium is located within the seminiferous tubules. The precursor cells of either male or female gametes, called *gonocytes,* originate from extra-embryonic endodermal tissue. These migrate to the gonadal zone where they differentiate either to oogonia or spermatogonia (Hafez, 1995).

The main endocrine glands involved in spermatogenesis are the hypothalamus, pituitary and testis. The thyroids and adrenal glands may be involved in the secondary role. Androgens are produced by the interstitial cells (Leydig) and seminiferous tubules. Androgens, under a feedback process, control LH production from the hypophysis. FSH stimulates production of androgen binding protein (ABP) by the sertoli cells. ABP helps to maintain a high level of androgen (Hunter, 1980; Hafez, 1995).

2.11.7 Puberty

Puberty is referred to as the age of the female at which estrus if first detected and is followed by characteristic ovarian activities in the non-pregnant animal (Hunter, 1980).

According to Ramirex (1973), the direct cause of sexual maturation at puberty is a rise in the output of pituitary hormones leading to an increase in size and activity of the ovaries. He noted that underlying this process, is a form of maturation of the hypothalamo-pituitary axis permitting changes in neuro-secretion and thereby secretion of the gonadotrohic hormones.According to Thibault and Levasseur (1995), age at puberty differs with breed of animals while environmental factors do modify age at first estrus. Social factors such as presence of opposite sex and a high plane of nutrition hasten the age at puberty. The body weight and organ growth are said to affect the age at puberty of ewes and heifers but gilts are not affected by these factors (Ramirex, 1973; Hunter, 1980). The age at puberty of the cow is 9 – 13 months; sheep 5 – 10 months, pig 5 -7 months and horse 15-24 months (Hunter, 1980).

In the male, it is much more difficult to determine the exact time of puberty because the first differentiation of spermatogonia precedes release of the seminiferous tubules by a month or more, and sperm transport from testes to vas deferens needs at least two weeks (Thibault and Levasseur, 1995).

2.11.8 Estrous Cycle

Estrous cycle is a process which occurs in mature female mammals, in the absence of a successful mating; undergo a repeated series of ovarian changes, particularly in the secretion of steroid hormones that influence both the reproductive tract and the animal's sexual behaviour (Hunter, 1980). According toHunter (1980) and Anderson(1995), the onset of estrus is characterized by gradual changes in sexual behavioural patterns (restlessness, mounting other animals, lordosis response), vulva responses, (swelling, pink-red colouring) occasionally mucous discharges, immobility in the presence of a

mature male and arching the back. Sexual receptivity lasts for an average of 48-72 hours in the gilt and sow

The estrous cycle is divided into two very unequal phases – luteal and follicular phases. The luteal phase extends from the formation of the corpus luteum after ovulation until its regression at the end of the cycle. The follicular phase involves a rapid development of the follicles and begins when the corpus luteun regresses and ends with estrus and the ovulation of one or more graafian follicles (Hunter, 1980; Thibault and Levasseur, 1995). These workers noted that the luteal phase lasts 14-15 days in the ewe and 16-17 days in the cow and sow The follicular phase is short: 2-3 days in the ewe and goat; 3-5 days in the cow and sow.Hunter (1980) observed that the length of the cycle in pig is 21 days (range: 19-23 days) while the range in cow is 20-21 days and 16-17 days in the ewe and goat. Also the time of ovulation occurs 24-30 hours after the onset of estrus in the ewe, doe and cow and 35-45 hours in the sow. The pig is polyestrous throughout the year; only pregnancy or endocrine dysfunction interrupts this cyclicity.

2.11.9 Luteal Phase (metestrus and diestrus)

Following ovulation, the granulosa cells in the raputured follicles grow and divide under the influence of FSH and LH to form corpus luteum (Hafez, 1995). He noted that the secretion of progesterone increases as the corpus luteum develops. Once the corpus leteum has developed completely and the secretion of progesterone reaches maximum, the function of the corpus luteum continues only a few days unless the sow is pregnant. In the non-pregnant sow, progesterone production diminishes rapidly and corpus luteum begins to regress. The regression of corpus luteum is influenced by prostaglandins (PGF_{2x}) (Hafez, 1995; Niswender *et al,* 1995). These workers observed that once the luteal regression has occurred, the sow is ready to repeat the estrous cycle in its entirety.

2.11.10 Follicular Phase (proestrus and estrus)

Under the influence of Gn-RHs, FSH, LH and prolactin are secreted into the circulation and transported to the ovary. FSH and LH stimulate the production of estrogens by the follicles (Hafez, 1995). Hunter, (1980) noted that the follicular phase is characterised by rapid follicular growth under the influence of FSH. Progesterone acts synergistically with estrogens to bring about estrus behaviour in the female. Also during the period of rapid follicular growth and the concentrations of estrogens, the sow shows estrous behaviour or sexual receptivity.

2.11.11 Hormonal Regulation of Reproduction

Hormonal interactions are responsible for regulation of reproductive processes in domestic animals. The hypothalamus exerts its influence over the anterior pituitary by means of neuro-secretions from specific group of cells. The releasing hormones are secreted by the hypothalamus and these influence the release of gonadotropic hormones from adenohypohysis, FSH and LH stimulate follicular growth and estrogen secretion (Hunter, 1980; Niswender *et al*., 1995). According to these workers, estrogens can have both positive and negative feedback effects on the hypothalamus or adenohyphophysis. Ramirex, 1973 observed that LH causes ovulation and acts synergistically with prolactin for development and maintenance of the corpus luteum and secretion of progesterone. Progesterone may exert a negative feedback on gonadotrophin secretion at the hypothalamic oradenohypophyseal level.

2.12 Effects of Gossypol on Reproduction

In the 1930s and 1940s not a single childbirth was reported over a period of 10 years in one area in China. It was reported that owing to economic reasons the villagers in that area had switched from cooking with soybean oil to cottonseed oil (Liu, 1957). Later in

the 1960s, in many rural areas of China, villagers exhibited fatigue and felt burning sensations on the extremities. They called the disease “burning fever”. It was also shown that these villagers were using crude cottonseed oil for cooking (Liu and Segal, 1985). Several years later, many afflicted couples experienced fertility problems, women suffered from amenorrhea and men were impotent. These findings led to clinical studies and further animal investigations.

2.12.1 Female Reproduction

Some workers observed that in monogastric species, gossypol seems to disrupt estrous cycles, pregnancy and early embryo development in females. The probable mechanisms include an endocrine effect in the ovary as well as a cytotoxic effect on the uterus or embryo. The female ruminant species seem to be relatively insensitive to the anti-fertility effect of gossypol, howeverin-vitro data indicate some inhibition of embryonic development and ovarian steroidogenesis (Abou-Donia, 1976; Randel *et al*., 1992; Rogers *et al*., 2002).

Reports indicate that sows receiving cottonseed meal (24.2%) of the diet for about 94 days before farrowing have fewer live piglets and fewer piglets surviving for 21 days (Spruill *et al*., 1971). In another study, these workers used the same diet containing 0.1% free gossypol for 42 days before farrowing and found no effect on farrowing rate or viability of the pigs. It is possible that the earlier sow fed for 94 days before farrowing received the gossypol during the critical time. The average gestation length of swine is 114 days, and embryonic attachment only becomes complete 25 to 26 days after ovulation hence, the decrease in litter size and viability of the pigs. Eisele ,(1986) reported that sows and gilts fed diets containing from 0.02 to 0.136% free gossypol had 70 – 72% failure of conception and produced stillborn piglets or had reduced litter sizes.

Several investigators have reported that female rats displaying normal estrous cycles when treated with gossypol acetic acid (GAA) subsequently displayed a low number of normal 4-5 days estrous cycles. Length of estrous cycle was longer in GAA-treated than in control rats. Estrous cycles did not cease completely and ovulation was not inhibited (Wu *et al*., 1981; Gu and Anderson, 1985; Randel *et al*., 1992). Bender *et al*. (1988) reported no gross or morphological abnormalities in ovarian, uterine, adrenal or vaginal tissues of non-mated GAA-treated rats. Administration of GAA to rats beginning post-implantation (day 6) has not resulted in abortion or any ill effects on the fetus (Lin *et al*., 1985).

2.12.2 Male Reproduction

The anti-fertility effect of gossypol has been studied extensively in males of monogastric species. The effects of gossypol in the males are both dose- and time-dependent. According to Randel *et al*. (1992) at effective doses, gossypol causes males to be infertile because of sperm immobility and depressed sperm counts. Specific mitochondrial damage in the tails of spermatozoa seems to render them immotile and extensive damage to germinal epithelium may be responsible for depressions in spermatogenesis. Lin *et al*., (1986) fed diets containing 450 ppm of gossypol to boars for 30 days and found that the blood concentrations of testosterone were decreased.

In ruminant males fed diets containing gossypol, ejaculated sperm appears normal under light microscopy. The integrity of the membrane of the sperm cells may be damaged. Extensive damage to the germinal epithelium has been shown in both rams and bulls (Randel *et al*., 1992). Gossypol seems to be more damaging to reproductive functions in young ruminant males near puberty than in mature males(Rogers *et al*., 2002). Young bulls fed diets containing free gossypol in cottonseed meal (1.8g/day/bull) had live weight gains, lower scrotal circumferences and reached puberty at older ages compared

with those bulls on the control diet without cottonseed meal in their diets. In these studies, gossypol did not appear to reduce sperm quality and quantity (Randel *et al*., 1991; Chase *et al*., 1994; Rogers *et al*., 2002).

In trials conducted by several workers, the bulls fed 300 parts per million of free gossypol per day from cottonseed meal for 11 weeks had significantly lower percentage of normal spermatozoa compared with the control. The mid-piece abnormalities appeared to be the cause of decreased sperm motility. The percentage of "live" spermatozoa was not affected, an indication that gossypol can have deleterious effects on certain sperm structural components without destroying sperm membrane viability in bulls (Arshami and Ruttle, 1988; Chase *et al*., 1989; Jimenez *et al*., 1989). These workers indicated that ruminant males fed gossypol treated diets had similar seminiferous tubule diameters, lower number of germ cell layers, smaller Sertoli cell sizes and reduced Leydig cell sizes compared with the males fed control diet without cottonseed meal.

2.13Effects of Feeding Cottonseed Cake on Performance Characteristics of Pigs

Growth trials with weaner pigs (28 days old and 7.5 kg average initial weight) and growing-finishing pigs (19 to 97 kg) were carried out to evaluate the nutritional value of commercially processed glandless cottonseed meal (La Rue *et al*., 1985). In the trials cottonseed meal was substituted in 20% incremental rate from 0 to 100% of the soybean meal with added lysine. The results indicated that dietary level increments of cottonseed meal resulted in linear reductions in daily gain and linear increases in feed to gain ratio for pigs during starter and grower-finisher trials respectively. La Rue *et al*. (1985) concluded that cottonseed meal plus lysine can be used to replace at least 40% of the soybean meal diets without affecting the performance of the pigs.

Ikurior and Fetuga, (1988) substituted Nigerian processed cottonseed meal (41% crude protein) for groundnut cake in the diets of weaned-grower pigs fed the same protein diets and observed that there were no significant differences among treatments with regard to feed intake, weight gain and feed to gain ratio. These workers concluded that the Nigerian processed cottonseed meals could be combined in various proportions with groundnut cake to supply protein, or used simply up to 20% for weaned-grower pigs. Balogun *et al*., (1990) fed isonitrogenous diets containing 0, 10, 20 and 30% undecorticated cottonseed meal to weaner pigs in maize-soybean based rations. They observed that daily feed intake did not differ between treatments, daily gain and feed to gain ratio were similar between control and 10% levels but the control group gained more than the 20 or 30% groups ($P<0.05$). They showed that 10% was the optimum inclusion level of undecorticated cottonseed meal for weaner pigs.

The feed conversion ratio according to Ikurior and Fetuga (1985) was not significantly affected by dietary treatments. Feed to gain ratio in pigs has been found to be inversely related to increase in feed intake level because higher intake allows for increased body fat deposition (Blair *et al*., 1969). Moura and Lavorenti (1979) indicated that with increasing cottonseed meal in the diets of grower-finishing pigs, weight gain and feed efficiency decreased more markedly at the growing than at the finishing stage. They showed that at 100% replacement level of soybean meal with cottonseed meal, weight gain and feed efficiency were significantly inferior to 0, 25, 50 and 75% replacement levels.

Knabe *et al*. (1979) carried out feeding trials to show the effect of lysine, crude fiber and free gossypol in cottonseed meal on growing pigs fed sorghum and cottonseed meal basal diets. The diets contained lysine: 0.6, 0.70 or 0.8%, fiber: 3.0, 4.0, or 4.5% and free gossypol: 90, 300 or 500 mg/kg. Supplemental iron was added to all cottonseed

meal diets to give a 1 to 1 weight ratio of iron to free gossypol. They found that increasing lysine gave a quadratic increase in gain and feed intake and a linear increase in feed efficiency. Crude fiber had little effect on intake and gain but pigs given the diet low in fiber had better feed efficiency. The amount of free gossypol in the diets had no adverse effect on any performance trait.

Other workers observed that the inclusion of cottonseed meal in the diets of swine especially without iron supplementation resulted in reduced feed intake and suppressed pig growth and feed to gain ratio. These were attributed to the gossypol and amino acid imbalance of the diets (Hale and Lyman, 1957; Hale *et al.,*1958; Clawson *et al*., 1961; Clawson and Smith, 1966; Rincon *et al*., 1978). Fombad and Bryant (2004) conducted a trial to determine the effect of including cottonseed cake in the rations for weaner and grower pigs. They observed that cottonseed cake significantly reduced the voluntary feed intake and live weight gains. This result, according to the workers, was probably in part due to lysine deficiency and in part to the effect of free gossypol. It was found cost-effective to include cottonseed cake in starter and grower diets up to 300g per kilogramme in the tropics.

2.14 Effects of Feeding Cottonseed Cake on Carcass Characteristics and Organ Weights of Pigs

In a trial with growing-finishing pigs in which cottonseed cake replaced 0, 25, 50, 75 and 100% of the groundnut-maize based diets, Ikurior and Fetuga, (1985) observed that the percentages of lean meat, fat, bone and head of the pigs were not significantly affected by the dietary treatments. However, the percentage fat increased linearly from 18.12% in the control diet to 20.97% in diet with 100% cottonseed cake.The average weights of the heart, kidney and lungs were unaffected by cottonseed meal substitution in the diets. The liver weight however decreased significantly in diet with 100%

cottonseed cakeas compared to the other dietary treatments. It was concluded that at these cottonseed meal levels, gossypol would not constitute a hazard to the carcass quality and organ weights of the animals.

Moura and Lavorenti, (1979) supplemented soybean meal with 0, 25, 50, 75 and 100% cottonseed meal in a trial with grower-finishing pigs. They observed that there were no significant differences with regards to carcass yield or length. With increasing cottonseed in the diets, back fat thickness increased linearly and with 100% replacement level of cottonseed cake, percentages of ham and loin- eye area were significantly less than with the other treatments. A combination of the 50% each of soybean and cottonseed meal as the source of protein was recommended for feeding grower-finishing pigs. The feeding of cottonseed meal (38% crude protein) with 0.11% total gossypol to finisher pigs at 8 and 10% levels did not produce any significant differences in carcass quality compared with the soybean meal control diet (Baustad, 1974).

2.15 Effects of Feeding Cottonseed Cake Diets on Puberty, Estrous Cycle and Litter Size of Gilts and Sows.

Puberty is the age of the female at which estrus is first detected and is followed by characteristic cyclic ovarian activity in the non-pregnant animal(Hunter, 1980). In large farm animal species, the age at first behavioural oestrus begins some time before growth is completed and occurs at an earlier age in animals maintained under good conditions of nutrition. The age at puberty also varies with the breed of the animal, degree of inbreeding, environmental factors (such as stress) and presence of the male animal (Ramirex, 1973; Hunter, 1980; Rekwot, 1999).

Gilts exhibited first oestrus at about 150 – 210 days of age and the onset of estrous cycles in gilts appeared dependent more on age than on weight. Gilts maintained in large groups or isolated from boars have delayed puberty (Dziuk, 1977; Gu and

Anderson, 1995). In extensive studies, 110 weanling pigs of two groups were given diets containing 8 – 20% cottonseed meal containing 0.069% (690 ppm) free gossypol, Ling – yun *et al*. (1984) observed that as the free gossypol content of the diets increased, oestrus was delayed and mortality also increased. They noted that the amount of cottonseed meal in the diets of the sows did not affect body weight of piglets at birth and at the age of 30 days. These workers also reported that duration of oestrus and estrous cycle was 54.2, 55.9 and 54.0 hours and 19.9, 19.3 and 20.8 days respectively.

Love *et al*. (1990) observed that stepwise increases in the levels of cottonseed meal in sow diets from 5, 10, 20 and 40% significantly increased the incidence of premature farrowings (1.1 to 2.7%) and significantly reduced the mean gestation length from 114.07 $\pm$ 1.53 to 113.70 $\pm$ 1.59 days. They indicated that these results were attributed to the gossypol toxicity in the cottonseed meal fed to the sows.

According to Spruill *et al*. (1971) sows that received cottonseed meal (24.20% of the diet) containing 0.01% free gossypol during gestation period had decreased litter size, fewer live piglets and fewer piglets surviving for 21 days after farrowing. In studies conducted by Eisele (1986) with sows and gilts fed diets containing from 0.136 to 0.20% free gossypol, it was observed that the pigs had 72 to 77% conception failure and some of the animals that conceived either aborted, produced stillbirths or had reduced litter sizes (Eisele, 1986).

2.16 Effect of Feeding Cottonseed Cake on Blood Measurements

In a study with poultry, Rincon *et al.* (1978) fed a ration containing 50% cottonseed meal to which isolated cottonseed pigment glands were added to give various levels of free gossypol. They reported that the blood constituents were low in red cell count,

heamoglobin and serum albumin values but high in reticulocytes. Blood albumin is important for the control of osmotic pressure and hence blood volume. The results of investigations carried out by Danke and Tillman (1965) with ratsand those of Jarquin *et al.* (1966) with swine showed that the feeding of high levels of gossypol resulted in decreased levels of haemoglobin and haematocrit. The latter authors observed that the anaemia thus produced was microcytic (undersize red blood cells) and hypochromic (low haemoglobin level)in character. Brahma *et al.* (1967) indicated that the high levels of serum glutamic-oxalactoacetic transaminase observed in animals fed high levels of cottonseed meal decreased to normal values when the ration was supplemented with both iron and calcium.

In a study in which pigs were fed a diet containing 15% protein with or without 600 ppm free gossypol, Skutches *et al*. (1974) observed that pigs fed dietscontaining gossypol had reduced haemoglobin and haematocrit values by 9.2 and 7.5% respectively. The reductions occurred before pigs showed signs associated with gossypol activity. These authors observed that serum iron-binding capacity and total serum protein were reduced by 20% and the liver iron was less than that in normal pigs. They concluded that gossypol might have formed a complex with iron in the liver and the complex was secreted from the liver by the bile causing a fall in liver iron and that the ratio of free to bound gossypol deposited in the liver depended on the iron concentration in the liver.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Locations

Three trials were carried out at three locations. The first location was at the National Animal Production Research Institute, Swine Research Station, Otukpo, Benue State. Otukpo is located within the Tropical Guinea Savannah ecological zone of Nigeria, within latitudes 6^0 and 7^0 North and longitudes 6^0 and 7^0 East.The zone has two seasons: the wet season starts in April and ends in October with a mean annual rainfall of 1500mm. The peak of the rainfall is recorded between June and August with a mean relative humidity of about 80% and an average daily temperature of 26^0C. The dry season follows the raining season (November to March) with mean temperature of 29^0C and the average maximum temperature is about 34^0C (Nigerian Metrological Agency, 2007).

The other two trials were carried out at two locations. The second trial consisting of growth and reproductive performance trial using female pigswas carried out at the Teaching and Research Farm of the Department of Animal Science, Faculty of Agriculture, Ahmadu Bello University, Samaru – Zaria. The third trial, a digestibility study was carried out at the Ahmadu Bello University Teaching and Research Farm, Shika – Zaria. Both sites are located within the Northern Guinea Savannah ecological zone of Nigeria between latitudes 11^o and 12^0 North and between longitudes 7^0 and 8^oEast (Kowell,1968; Osuhor, 2007).

The zone has two seasons: the wet season starts in April/May and stabilizes by June and ends in mid-October. The mean annual rainfall is 1100 mm and the maximum temperature of between 27 and 35^oC depending on the season with a mean relative

humidity of 72%. The dry season lasts from November to April with mean daily temperatures ranging from 14 to 36^{o}C and a mean relative humidity between 20 and 37% (Kowell, 1968; Osuhor, 2007).

3.2 Experiment One: Effect of Feeding Diets Containing Undelinted Undecorticated Cottonseed cake (UUCSC) on Performance Characteristics of Growing-Finishing Pigs.

The objectives of this trial were to determine the effect of UUCSC diets on the growth performance of growing-finishing pigs as well as the economics of feeding UUCSC in swine diets.

3.2.1 Animals and Experimental Design

Twenty four crossbred Large White X Hampshire young gilts of average initial weight of 16.4 kg were obtained from the herd of Swine Research Programme, National Animal Production Research Institute (NAPRI), Otukpo, Benue State. Grower pigs were randomly assigned to pens based on initial weight groups. There were three replications of the four treatments. Treatments were randomly assigned to the pens within each replicate.The grower pigs were blocked on the basis of their initial weight groups. There were two grower pigs per pen in a randomized block design fashion.

3.2.2 Source of Feed Ingredients

The feed ingredients used in the studies were obtained from the store of the National Animal Production Research Institute (NAPRI), Shika-Zaria.

3.2.3Experimental Diets and Management of Animals.

Four isonitrogeneous diets were formulated to contain16%undelintedundecorticated cottonseed cake (UUCSC) was incorporated in the diets at 0, 10, 20 and 30% with the dietcontaining 0% UUCSC as the control diet (Table 3.1).

All thedietary treatments were formulated to meet the minimum nutrient requirements for growing-finishing pigs asrecommended by NRC (1998). The ingredient composition and the calculated analyses of the diets of the growing-finishing pigs are presented in Table 3.1. The proximate composition ofthe diets and the feed ingredients used in the rations are also shown in Table 3.2.

The grower pigswere maintained on concrete floor pens throughout the trial period. All animals were dewormedwith Ivomec^{R}at the rate of 1ml. per 33kg body weight prior to the commencement of the trial. The route of administration of the ivomec was intra-muscular. The grower pigs were fed at 5% body weight daily, one half at 8.00 hour and the other half at 16.00 hour. Water was made available to the animals all the time and left-over feed was weighed andrecorded daily. Pigs were weighed weekly and feed consumption adjusted accordingly. The performance of the animals was monitored in terms of feed intake, growth rate, feed to gain ratio and feed cost throughout the 63-day trial period.

Experiment Two: Effects of Feeding Undelinted Undecorticated Cottonseed cake (UUCSC) on Growth, Blood Measurements and Reproductive Performance of Female Pigs

The objectives of the study were:

- To determine performance of different classes of female pigs fed UUCSC diets.
- To evaluate carcass quality and organ weights of female pigs fed UUCSC diets.
- To study the blood indices and histopathology of organs of female pigs fed diets containing UUCSC.
- To study the economic analysis of pigs fed UUCSC based diets.

Experiment two was divided into four phases:

Table 3.1: Ingredient composition ofgrower-finisher diets containing undelinted undecorticated cottonseed cake (UUCSC)

	Levels of UUCSC, %			
Ingredients, %	0	10	20	30
Maize	43.45	38.20	32.96	27.71
Groundnut cake	22.15	17.40	12.64	7.89
Cotton seed cake	-	10.00	20.00	30.00
Maize offal	15.00	15.00	15.00	15.00
Wheat offal	16.00	16.00	16.00	16.00
Bone meal	2.50	2.50	2.50	2.50
Salt	0.35	0.35	0.35	0.35
Premix*	0.25	0.25	0.25	0.25
Lysine	0.20	0.20	0.20	0.20
Methionine	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00
Calculated analyses				
Crude protein, %	18.00	18.00	18.00	18.00
ME, kcal/kg	3240	3188	3068	2980
Crude fibre, %	6.76	8.90	11.05	13.42
Calcium, %	0.81	0.82	0.83	0.84
Phosphorus^{+}, %	0.76	0.83	0.85	0.88
Lysine , %	0.74	0.80	0.84	0.86
Meth + cys, %	0.52	0.57	0.62	0.66
Diet cost/kg, N	57.02	55.46	54.07	52.60

*Biomix grower premix contributed the following per kg of diet: vitamin A, 8,000 iu, vitamin D3, 1,500 iu, vitamin E, 7.0, mg, niacin, 15 mg, vitamin B1, 2.0 mg, vitamin B2, 2.5 mg, vitamin B12, 0.01 mg, vitamin K3 1.5 mg, pantothenic acid, 5.5 mg, folic acid, 0.5 mg, choline chloride, 175 mg, cobalt, 0.2 mg, copper, 3.0 mg, iodine, 1.0 mg, iron, 21 mg, manganese, 40 mg, selenium, 0.2 mg and zinc, 31 mg.
Met + cyst = methionine + cystine
ME = metabolizable energy
$^{+}$ = Available phosphorus , %

Table 3.2: Proximate composition of the major ingredients used in the grower-finisher experimental diets

Parameters	Ingredients,%								
	Maize	Ground nut Cake	Cottonseed cake	Maize offal	Wheat offal	Diet 1	Diet 2	Diet 3	Diet 4
Dry matter,%	91.50	91.72	93.82	90.90	91.20	92.65	93.80	93.15	93.20
Crude protein, %	8.80	44.88	26.02	11.20	16.10	16.00	16.10	16.20	16.26
Ether extract, %	5.20	7.36	8.50	6.10	4.50	7.45	7.51	7.60	7.70
Crude fibre, %	2.16	4.60	13.12	10.60	12.01	4.46	7.68	8.70	9.60
Ash, %	7.15	4.40	6.51	1.20	7.25	5.68	6.35	6.40	6.62
Nitrogen free extract, %	68.89	30.50	39.72	61.80	51.44	59.06	55.16	54.25	39.84
Gross energy, kcal/kg	4432	4090	4160	4090	3962	4120	4210	4252	4301

1. Weaner Pig Study

2. Grower Pig Study

3. Growing-Finishing Pig Study

4. Reproductive Study

3.3.1 Weaner Pig Study

3.3.2 Animals and Experimental Design

Twenty four crossbred Large White X Hampshire female weaner pigs of average initial weight of 12.7 kg were obtained from herds of swine in Samaru and Kaduna, Kaduna State. Weaner pigs were randomly assigned to pens based on their initial weight groups. There were three replications of the four treatments. Treatments were randomly assigned to pens within each replicate. The weaner pigs were blocked on the basis of their initial weight groups. There were two weaner pigs per pen in a randomized block design trial.

3.3.3 Experimental Diets and Management of Animals.

The feed ingredients used in this study were obtained from the store of the National Animal Production Research Institute, Shika-Zaria. Four iso-nitrogeneous diets formulated to contain 18% crude protein were fed to the experimental pigs. Undelinted undecorticated cottonseed cake (UUCSC) was incorporated in the diets at 0, 10, 20 and 30% levels with the diet containing 0% UUCSC serving as the control diet. The ingredient composition and the calculated analyses of the diets of the weaner pigs are presented in Table 3.3. The proximate compositions of the diets and the feed ingredients used in the rations are also shown in Table 3.4. All the dietary treatments were formulated to meet the minimum nutrient requirements forweaner pigs as

Table 3.3: Ingredient composition of weaner diets containing undelintedundecorticated cottonseed cake (UUCSC)

Ingredients, %	Levels of UUCSC, % 0	10	20	30
Maize	43.45	38.20	32.96	27.71
Groundnut cake	22.15	17.40	12.64	7.89
Cotton seed cake	-	10.00	20.00	30.00
Maize Offal	15.00	15.00	15.00	15.00
Wheat offal	16.00	16.00	16.00	16.00
Bone meal	2.50	2.50	2.50	2.50
Salt	0.35	0.35	0.35	0.35
Premix*	0.25	0.25	0.25	0.25
Lysine	0.20	0.20	0.20	0.20
Methionine	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00
Calculated analyses:				
Crude protein, %	18.02	18.00	18.00	18.00
ME, kcal/kg	3240	3188	3068	2980
Crude fibre, %	6.76	8.90	11.05	13.42
Calcium, %	0.81	0.82	0.83	0.84
Phosphorus^{+}, %	0.76	0.83	0.85	0.88
Lysine, %	0.74	0.80	0.84	0.86
Meth + cyst, %	0.52	0.57	0.62	0.66
Diet cost/kg, N	57.02	55.46	54.07	52.60

*Biomix grower premix contributed the following per kg of diet: vitamin A, 8,000 iu, vitamin D3, 1,500 iu, vitamin E, 7.0, mg, niacin, 15 mg, vitamin B1, 2.0 mg, vitamin B2, 2.5 mg, vitamin B12, 0.01 mg, vitamin K3 1.5 mg, pantothenic acid, 5.5 mg, folic acid, 0.5 mg, choline chloride, 175 mg, cobalt, 0.2 mg, copper, 3.0 mg, iodine, 1.0 mg, iron, 21 mg, manganese, 40 mg, selenium, 0.2 mg and zinc, 31 mg.

Met + cyst = methionine + cystine

ME = metabolizable energy

$^{+}$ = Available phosphorus

Table 3.4: Proximate composition of the major ingredients used in the weanerexperimental diets

Parameters	Ingredients,%								
	Maize	Groundnut cake	Cottonseed cake	Maize Offal	Wheat Offal	Diet 1	Diet 2	Diet 3	Diet 4
Dry matter, %	91.55	91.71	93.50	90.92	91.10	93.00	92.19	91.60	92.04
Crude protein, %	8.80	44.88	26.02	11.20	16.10	18.01	18.10	18.40	18.50
Ether extract, %	5.20	7.35	8.50	6.15	4.50	7.42	7.61	7.85	7.95
Crude fibre, %	2.15	4.65	13.15	10.60	12.00	4.40	7.20	9.16	10.00
Ash, %	7.15	4.40	6.50	1.20	7.25	5.70	6.40	6.65	6.75
Nitrogen free extract, %	68.95	31.20	39.22	61.77	51.24	57.38	52.98	49.54	48.84
Gross energy, kcal/kg	4430	4090	4240	4090	3960	4150	4280	4250	4360

recommended by NRC (1998). The diets were mixedin the Feed Mill in NAPRI, Shika-Zaria.

The pigs were maintained on concrete floor pens throughout the trial period. All animals were dewormed with Ivomec® at the rate of 1ml. per 33kg body weight prior to the commencement of the trial.The route of administration of the ivomec was intra-muscular.The weaner pigs were fed at 6% body weight daily, one half at 800 hour and the other half at 1600 hour. Water was made available to the animals all the time and left-over feeds were weighed and recorded daily. Pigs were weighed weekly and feed consumption adjusted accordingly. The performance of the animals was monitored in terms of feed intake, growth rate, feed to gain ratio and feed cost per kg gain throughout the 42-day trial period.

3.3.4 Grower Study

3.3.5 Animals and Experimental Design

The same sets of pigs that were used for the weaner pig study were also used for this phase of the trial. Twenty four crossbred Large White X Hampshire female grower pigs of average initial weight of 20.8 kg were obtained from herds of swine in Samaru and Kaduna, Kaduna state. Grower pigs were randomly assigned to pens based on their initial weight groups. There were three replications of the four treatments. Treatments were randomly assigned to pens within each replicate. The grower pigs were blocked on the basis of their initial weight groups. There were two grower pigs per pen in a randomized block design trial.

3.3.6 Experimental Diets and Management of Animals.

Four iso-nitrogeneous diets were formulated to contain 16% crude protein (Table 3.5). Undelinted undecorticated cottonseed cake (UUCSC) was incorporated in the diets at 0,

10, 20 and 30% levels with the diet containing 0% UUCSC serving as the control diet. The ingredient composition and the calculated analyses of the diets of the grower pigs are presented in Table 3.5. The proximate compositions of the diets and the major feedingredients used in the rations are also shown in Table 3.6. All the dietary treatments were formulated to meet the minimum nutrient requirements for grower pigs as recommended by NRC (1998). The diets were mixedin the Feed Mill in NAPRI, Shika. The grower pigs were maintained on concrete floor pens throughout the trial period. All the grower pigs were dewormed with Ivomec® at the rate of 1ml. per 33kg body weight prior to the commencement of the trial. The route of administration of the ivomec was intra-muscular. The grower pigs were fed at 5% body weight daily, one half at 8.00 hour and the other half at 16.00 hour. Water was made available to the animals all the time. Left-over feed was weighed and recorded daily. Pigs were weighed weekly and feed consumption adjusted accordingly. The performance of the animals was monitored in terms of feed intake, weight gain, feed to gain ratio and feed cost throughout the 42-day trial period.

3.3.7 Growing-Finishing Pig Study

3.3.8 Animals and Experimental Design

The same sets of pigs that were used for the grower pig study were also used for this phase of the trial. Twenty four crossbred Large White X Hampshire female pigs of averageinitial weight of 34.7 kg were obtained from herds of swine in Samaru and Kaduna, Kaduna State. The pigs were randomly assigned to pens based on initial weight groups. There were three replications of the four treatments. Treatments were randomly assigned to the pens within each replicate. The finisher pigs were blocked on the basis of their initial weight groups. There were two pigs per pen in a randomized bock design trial.

Table 3.5: Ingredient composition of grower and finisher diets containing undelintedundecorticated cottonseed cake (UUCSC)

	Levels of UUCSC, %			
Ingredients, %	0	10	20	30
Maize	39.20	33.94	28.69	23.44
Groundnut cake	18.10	13.36	8.61	3.86
Cottonseed Cake	-	10.00	20.00	30.00
Maize Offal	20.00	20.00	20.00	20.00
Wheat Offal	20.00	20.00	20.00	20.00
Bone Meal	2.00	2.00	2.00	2.00
Salt	0.30	0.30	0.30	0.30
Premix*	0.20	0.20	0.20	0.20
Lysine	0.10	0.10	0.10	0.10
Methionine	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00
Calculated Analysis				
Crude Protein, %	16.00	16.00	16.00	16.00
ME, Kcal/kg	2913	2905	2878	2862
Ether extract, %	5.08	5.38	5.56	5.91
Crude fibre, %	6.60	8.77	10.90	13.03
Calcium, %	0.70	0.80	0.81	0.82
Phosphorus^{+}, %	0.77	0.85	0.90	0.92
Lysine, %	0.60	0.62	0.72	0.81
Meth + cyst, %	0.62	0.74	0.86	0.88
Diet cost/kg, ₦	57.01	54.61	51.90	49.20

*Biomix breeder premix contributed the following per kg of diet: Vitamin A, 75.00 iu, Vitamin D14.06 iu, Vitamin E, 0.16 mg, Niacin, 0.01 mg, Vitamin B1, 0.10 mg, Vitamin B2, 0.04 mg, Vitamin B6, 0.02 mg, Vitamin B12, 0.04 mg, Vitamin K3, 0.01 mg, Vitamin B12, 0.04, Vitamin C, 0.28 mg, Pantothenic Acid, 0.06 mg, Folic Acid, 0.01 mg, Biotin 0.01, Choline Chloride, 3.75 mg, Cobalt, 0.01 mg, Copper, 0.02 mg, Iodine, 0.01 mg, Iron 0.13 mg, Manganese, 0.25 mg, Selenium, 0.0.01 mg, Zinc, 0.19 mg and antioxidant, 0.01mg

Meth + cyst = methionine + cystine

ME = metabolizable energy

$^{+}$ = Available phosphorus

Table 3.6: Proximate composition of the major ingredients used in the grower and finisher experimental diets

Parameters	Ingredients,%								
	Maize	Ground nut Cake	Cottonseed cake	Maize offal	Wheat offal	Diet 1	Diet 2	Diet 3	Diet 4
Dry matter,%	91.50	91.72	93.82	90.90	91.20	92.65	93.80	93.15	93.20
Crude protein, %	8.80	44.88	26.02	11.20	16.10	16.00	16.10	16.20	16.26
Ether extract, %	5.20	7.36	8.50	6.10	4.50	7.45	7.51	7.60	7.70
Crude fibre, %	2.16	4.60	13.12	10.60	12.01	4.46	7.68	8.70	9.60
Ash, %	7.15	4.40	6.51	1.20	7.25	5.68	6.35	6.40	6.62
Nitrogen free extract, %	68.89	30.50	39.72	61.80	51.44	59.06	55.16	54.25	39.84
Gross energy, kcal/kg	4432	4090	4160	4090	3962	4120	4210	4252	4301

3.3.9 Experimental Diets and Management of Animals.

Four iso-nitrogeneous diets were formulated to contain 16% crude protein. undelinted undecorticated cottonseed cake (UUCSC) was incorporated in the diets at 0, 10, 20 and30% levels with the diet containing 0 per cent UUCSC serving as the control diet (Table 3.5 above). All the dietary treatments were formulated to meet the minimum nutrient requirements for growing-finishing pigs as recommended by NRC (1998). The diets were mixedin the Feed Mill in NAPRI, Shika - Zaria.

The chemical compositions of the diets and the major feed ingredients used in the rations are shown in Table 3.6(section 3.3.6 above). Pigs were maintained on concrete floor pens throughout the trial period. All the gilts were dewormed with Ivomec® at the rate of 1ml. per 33 kg body weight prior to the commencement of the trial. The route of administration of the ivomec was intra-muscular. The pigs were fed at 5% body weight daily, one half at 8.00 hour and the other half at 16.00 hour. Water was made available to the animals all the time and left-over feeds were weighed and recorded daily. Pigs were weighed weekly and feed consumption adjusted accordingly. The performance of the animals was monitored in terms of feed intake, weight gain andfeed to gain ratio. The feed cost per kg gain was computed at the end of the 42-day trial period.

3.3.10 Blood Sampling.

Blood sampling was as described in section 3.2.4 above. Blood samples were collected four days before the termination of the experiment for haematological profile determination, which included packed cell volume (PCV), haemoglobin (Hb), white blood cells (WBC), neutrophils, eosinophils, basophils and lymphocytes. Blood samples were collected through the ear veins using 5ml syringe with 19G needles into sample

bottles containing Ethylene Diamine Tetra Acetic Acid (EDTA) as an anti-coagulant.The sera were separated by centrifuging at 7,000g (or 10,000 revolutions per minute). samples were preserved at -5^0 C until required for analysis (Dancie and Lewis, 1991; Benjamin, 1978).

3.3.11 Carcass Evaluation

At the end of the growing-finishing phase, 12 gilts were randomly selected (one gilt per pen) for carcass evaluation. Prior to slaughtering, pigs were fasted over-night for 18 hours but had access to water. Pigs were individually stunned using an electric stunner. The electrodes were applied at the back of the head and the current switched on for 10 seconds before the animals were bled. The pigs were bled by severing their jugular veins just below the head. The carcasses were scalded using hot water at 80°C temperature for five minutes and then dehaired using a dehairing machine. The carcasses were processed for data collection according to the procedure of Devendra and Fuller (1989) and Eusebio (1990). The carcasses were eviscerated. The visceral organs (lungs, liver, kidney, heart, spleen, ovary and lymph node) were excised. The carcasses were then cut into halves. The hind foot was removed from the hind leg 1.5 cm above the hock joint perpendicular to the shank line. The forefoot was removed slightly 1.5cm above the knee joint perpendicular to the line of the shank. The ham was removed by a cut between the second and third sacral vertebrate along the axis of the shank. The shoulder was removed by a cut between the second and third ribs (thoracic vertebrae) and perpendicular to the backline. The loin was removed by cutting across the tenth and eleventh ribs. The belly was removed by separating the loin through a cut of the tender loin 4cm from the backbone. All these measurements were weighed and expressed as percentages of the carcass weight. Back fat thickness was measured opposite the tenth rib and the junction between the second and third lumbar vertebrae

using a ruler. Loin-eye area was measured by tracing a cross-section of the right and left longissimus muscles posterior to the junction of the tenth rib (thoracic vertebra) counting from the anterior end of the carcass.

The weights of the visceral organs (liver, lungs, heart, kidneys, pancreas and spleen) and empty stomachs were taken using a weighing scale.All these measurements were expressed as percentages of the fasted weights. The contents of the gastro-intestinal tracts (small and large intestines) were removed before measuring their lengths with a measuring tape.

3.3.12 Histopathological Study

Tissue sections of the liver, kidney, lungs, spleen, heart and ovaries were taken and fixed in 10% buffered formalin and in Bouins fluid for 72 hours. The tissues were processed using technicon and sectioned at 5 to 6μm. The tissue sections were mounted on clean glass slides, dried at room temperature and stained with Haematoxylin and Eosin. This was cover-slipped and dried in an oven. The slides were examined microscopically (Olympus x 40 objective) the histopatholgical findings were recorded (Cole, 1986).

3.3.13 Reproductive Study

3.3.14 Breeding-Gestation-Farrowing-Weaning

All the pigs were monitored and checked for oestrus three times daily (at 8.00, 13.00 and 1700 hour) using an intact boar. This was carried out when the pigs were about 140 days of age (that is, grower phase) and was done in order to determine the age at puberty of all the female pigs. In this study, puberty is defined as the age at which the gilt allows a boar to mount her during heat period. The ages at puberty were recorded for all the twenty four female pigs.

At the end of the finisher phase, the remaining 12 gilts were used for reproductive study consisting of breeding, gestation, farrowing and weaning. The 12 gilts were fed the same ration (16% crude protein) as fed during the finisher phase and this was maintained until the end of the trial.

Any ofthe gilts that came on heat was bred by a boar. The same boar was used to breed all the gilts. After farrowing, the piglets were all weaned at the age of 42 days.The trial was terminated when the last sets of piglets were weaned. The following reproductive data were collected for analysis:- gestation length, litter size, stillbirths, number of piglets born alive, birth weight, mortality before weaning, age at weaning and weaning weight.

3.4 Experiment Three:Digestibility of Nutrients of Undelinted Undecorticated Cottonseed Cake (UUCSC) Diets Fed to Weaner Pigs.

The objectives of this trial wereto evaluate the apparent digestibility of nutrients of diets containing undelinted undecorticated cottonseed cake (UUCSC) and nitrogen balance by weaner pigs.

3.4.1 Animals and Experimental Design

Twelve crossbred Large White X Hampshire weaner pigs of average initial weight of 12.0 kg were obtained from the herd of Swine Research Programme,National Animal Production Institute located at the Ahmadu Bello University Teaching and Research Farm, Shika – Zaria,Kaduna State. Pigs were randomly allotted to metabolism crates and blocked based on their litter and initial weight-groups. Treatments were randomly assigned to the crates. There were three replications of the four treatments. One pig was housed per crate in a randomized block design trial.

3.4.2 Experimental Diets and Management of Animals.

The feed ingredients used in this study were obtained from the store of the National Animal Production Research Institute, Shika-Zaria. Four isonitrogeneous diets were formulated tocontain 18% crude protein. Undelinted undecorticated cottonseed cake (UUCSC) was incorporated in the diets at 0, 10, 20 and 30% levels with the diet containing 0% UUCSC serving as the control diet (Table 3.7). The chemical compositions of the diets and the major feed ingredients used in the rations are shown in Table 3.8. All the dietary treatments were formulated to meet the minimum nutrient requirements for weaner pigs asrecommended by NRC (1998). The diets were mixedin the Feed Mill in NAPRI, Shika - Zaria.

Pigs were kept in individual metabolism crates which allowed for separate collection of faeces and urine. Each crate (131cm x 71 cm) had a slatted metal floor to allow urine drain through into a big funnel that led urine into a collection bucket. Directly below the slatted metal floor was a metal screen (131 cm x 71 cm) on which faeces dropped and prevented it from getting into urine collecting bucket. The crates were equipped with feed and water troughs. The weaner pigs were dewormed with Ivomec® at 1ml per 33 kg of body weight prior to the commencement of the trial. The route of administration of the ivomec was intra-muscular. The experimental diets were offered at 4% and 6% of the body weight daily during the first and second periods respectively. Feed was offered twice daily with one-half of the daily allotment given at 8.00 hour and the second half at 16.00 hour. The feed was fed as gruel by mixing with 1 ½ times the weight of water. Refused or left-over feeds were collected and oven-dried at 52^{o}C for 24 hours, cooled to room temperature and the weights recorded. There were two collection and two adjustment periods of 7 days each of total collection of faeces and urine. Faeces were collected daily in the morning and the weights recorded. The faeces were oven-dried at

Table 3.7: Ingredient composition of weaner diets containing undelinted undecorticated cottonseed cake (UUCSC)

	Levels of UUCSC, %			
Ingredients, %	0	10	20	30
Maize	43.45	38.20	32.96	27.71
Groundnut cake	22.15	17.40	12.64	7.89
Cotton seed cake	-	10.00	20.00	30.00
Maize offal	15.00	15.00	15.00	15.00
Wheat offal	16.00	16.00	16.00	16.00
Bone meal	2.50	2.50	2.50	2.50
Salt	0.35	0.35	0.35	0.35
Premix*	0.25	0.25	0.25	0.25
Lysine	0.20	0.20	0.20	0.20
Methionine	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00
Calculated analyses				
Crude protein, %	18.00	18.00	18.00	18.00
ME, kcal/kg	3240	3188	3068	2980
Crude fibre, %	6.76	8.90	11.05	13.42
Calcium, %	0.81	0.82	0.83	0.84
Phosphorus^{+}, %	0.76	0.83	0.85	0.88
Lysine , %	0.74	0.80	0.84	0.86
Meth + cyst, %	0.52	0.57	0.62	0.66
Diet cost/kg, N	57.02	55.46	54.07	52.60

*Biomix grower premix contributed the following per kg of diet: vitamin A, 8,000 iu, vitamin D3, 1,500 iu, vitamin E, 7.0, mg, niacin, 15 mg, vitamin B1, 2.0 mg, vitamin B2, 2.5 mg, vitamin B12, 0.01 mg, vitamin K3 1.5 mg, pantothenic acid, 5.5 mg, folic acid, 0.5 mg, choline chloride, 175 mg, cobalt, 0.2 mg, copper, 3.0 mg, iodine, 1.0 mg, iron, 21 mg, manganese, 40 mg, selenium, 0.2 mg and zinc, 31 mg.
Met + cyst = methionine + cystine
ME = metabolizable energy
$^{+}$ = Available phosphorus , %

Table 3.8: Proximate composition of the major ingredients used in the weaner experimental diets

Parameters	Ingredients,%								
	Maize	Groundnut cake	Cottonseed cake	Maize offal	Wheat offal	Diet 1	Diet 2	Diet 3	Diet 4
Dry matter, %	91.55	91.71	93.50	90.92	91.10	93.00	92.19	91.60	92.04
Crude protein, %	8.80	44.88	26.02	11.20	16.10	18.01	18.10	18.40	18.50
Ether extract, %	5.20	7.35	8.50	6.15	4.50	7.42	7.61	7.85	7.95
Crude fibre, %	2.15	4.65	13.15	10.60	12.00	4.40	7.20	9.16	10.00
Ash, %	7.15	4.40	6.50	1.20	7.25	5.70	6.40	6.65	6.75
Nitrogen free extract, %	68.95	31.20	39.22	61.77	51.24	57.38	52.98	49.54	48.84
Gross energy, kcal/kg	4430	4090	4240	4090	3960	4150	4280	4250	4360

40^{o}C for seventy-two hours, weighed and bulked for each period. Urine was collected into plastic buckets containing 25ml Toluene and 25ml Concentrated Hydrochloric acid. Urine collected was pooled for each collection period, thoroughly mixed and an aliquot taken for later analysis. Pigs were weighed at the beginning and at the end of each adjustment and collection periods. The performance of the pigs was monitored in terms of feed intake, weight gain and feed to gain ratio.

3.5 Analytical Procedures

3.5.1 Proximate Analysis

Samples of major feed ingredients, experimental diets, faeces and urine were analyzed forproximate composition and gross energy according to the methods of AOAC (1995). The proximate analyses were carried out in Central Laboratory Services, NAPRI, Shika-Zaria.

3.5.2 Haematological Measurements

The bloodmeasurements analyzed included packed cell volume (PCV), haemoglobin (Hb), white blood cells (WBC) and leucocyte counts (lymphocytes, basophils, neutrophils, eosinophils and monocytes).They were analysed as follows:

Packed cell volume (PCV): Haematocrit values were determined by the microhaematocrit Haematocrit capillary tubes were placed in microhaematocrit centrifuge and centrifuged at 10,000 rpm for 2 minutes. The heights of the red cells were then read from a haematocrit scale and expressed as percentage volume of the packed cells in whole blood (Dacie and Lewis, 1991).

Haemoglobin concentration (Hb): 4.00 ml of Drabkin's solution were dispensed into clean test tubes to which was added 0.02 ml of blood samples. The blood counts were

thoroughly mixed and incubated for 15 minutes at room temperature for colour development. Then the optical density of each sample was read in a colorimeter against a blank Drabkin's solution in curette. The Hb concentration in each sample was then obtained (Kelly, 1979).

White blood cell count (WBC): Blood was drawn to the 0.5 mark in a white blood pipette and diluted on Turk's solution to give a dilution of 1:20. The contents of the pipette were mixed with the aid of a pipette shaker after which 1/5 of the volume of the solution was expelled. The total wbc count was then made in the four square millimetres of an improved Neubauer haemocytometer and the result multiplied by 50 (Jain, 1986; Lamb, 1981).

Leucocyte differential counts (LDC): smears of collected blood samples were stained with giemsa stain. The leucocytes were then estimated using an objective lens. The leucocyte differential counts(lymphocytes, neutrophils, eosinnophils, basophils and monocytes) were identified from their shapes and colour differentiations (Lamb, 1981).

3.5.3 Histopathological Study

The result of the histopathological examination of the selected visceral organs (liver, kidney, heart, lung, spleen, and lymph node) of the glits fed graded levels of UUCSC diets showed that the organs of gilts fed 30% UUCSC were severally affected by UUCSC. They showed visible lesions. The liver showed degeneration and necrosis while the kidney, heart, spleen and ovary showed lesions. Gilts on other diets were free from all lesions.

3.5.4 Statistical Analysis

All the data collected were analyzed using trend analysis of the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS, 2000) software package. The

means were separated using Duncan's Multiple Range Test of the same SAS software package (Duncan, 1955).

The design of the experiment was the randomized block design. The model for the analysis of variance was:

$Y_{ij} = \mu + t_i + e_{ij}$

Where Y_{ij} = observation

μ = overall means of observations of interest

t_i = The fixed effect of $_{ith}$ treatment ($_i$ = 1,2,3,4)

e_{ij} = Random error (identical and indepently normally distributed with zero mean and constant variance).

CHAPTER FOUR

4.0 RESULTS

4.1 Proximate Compositions of Ingredients and Experimental Grower-Finisher Diets

The proximate compositions of the major ingredients used and of the test diets for thegrower and finisher pigs are presented in Tables 3.2. The determined analysis showed that the samples of undelinted undecorticated cottonseed cake (UUSC) contained dry matter, 93.82; crude protein, 26.02; ether extract, 8.50; crude fibre, 13.15; ash, 6.51; nitrogen free extract, 39.72% and gross energy, 4160 kcal per kg. The crude proteincontents of maize, groundnut cake, maize offal and wheat offal were 8.80, 44.88, 11.20 and 16.10% respectively.

The chemical compositions of the grower-finisher diets (Table 3.2) showed that the following ranges of dry matter, 92.65 – 93.80; crude protein, 16.00 – 16.26; ether extract, 7.45 – 7.70; crude fibre, 4.46 – 9.60; ash, 5.68 – 6.62; nitrogen free extract, 39.84 – 59.06%and gross energy 4120 – 4301 kcal per kg. There were significant increases in crude fibre, ash, and gross energy contents but nitrogen free extract decreased as the levels of UUCSC increased in the diets.

4.2 Proximate Composition of Ingredients and Experimental Weaner Diets

The proximate compositions of the major ingredients and experimental diets fed to weaner pigs in experiment two is presented in Table 3.4. The determined analysis showed that the samples of undelinted undecorticated cottonseed cake (UUCSC) contained dry matter, 93.82; crude protein, 26.02; ether extract, 8.50;crude fibre, 13.15; ash, 6.51; nitrogen free extract, 39.72% and gross energy, 4160 kcal per kg. The crude

protein contents of maize, groundnut cake, maize offal and wheat offal were 8.80, 44.88, 11.20 and 16.10% respectively.

The chemical compositions of the diets (Table 3.4) showed the following ranges of dry matter, 91.60 – 93.00; crude protein, 18.01 – 18.50; ether extract, 7.42 – 7.95; crude fibre, 4.40 – 10.00; ash, 5.70 – 6.65; nitrogen free extract, 48.84 – 57.38% and gross energy, 4150 – 4301 kcal per kg. There were significant increases in crude fibre, ash, and gross energy contents as the levels of UUCSC increased in the diets.

4.3 Performance Characteristics of Growing-Finishing Pigs on UUCSC Diets (Experiment 1):

Table 4.1 shows the results of the performance characteristics of growing-finishing pigs fed graded levels of UUCSC in the first trial. There were no significant differences ($P>0.05$) in terms of feed intake across dietary treatments. Feed intake increased as the level of undelinted undecorticated cottonseed cake increased in the diets,although the increases were not significantly different. Pigs fed the 30% cottonseed cake had the highest numerical feedintake.

Final live weight showed no significant differences ($P>0.05$) between treatment means. Average dailyweight gain was similar across the treatments. Feed to gain ratio increased non-significantly with increase in the levels of UUCSC in the diets. The efficiency of feed utilization was best for the control diets (diet 1).

There were linear decreases ($P<0.01$) in terms of feed cost per kilogramme (Figure 4.1) as the level of cottonseed cake increased in the diets of the weanling pigs. Feed cost perkilogramme gain was least for pigs fed 30% cottonseed cake diets.There were no

Table 4.1: Performance characteristics of growing-finishing pigs fed diets containing graded levels of undelinted undecorticated cottonseed cake (UUCSC)

	Levels of UUCSC, %					Level of
Parameters	0	10	20	30	SEM	Significance
Initial weight, kg	16.35	16.41	16.40	16.36	0.03	NS
Final weight, kg	48.66	48.60	47.49	47.01	0.82	NS
Weight gain, kg	32.31	31.19	31.09	30.65	0.61	NS
Feed intake, kg	128.75	129.15	131.30	132.22	1.75	NS
ADFI, kg	2.04	2.05	2.08	2.10	0.02	NS
Average daily gain, kg	0.51	0.50	0.49	0.48	0.02	NS
Feed to gain ratio	4.00	4.10.	4.24	4.37	0.14	NS
Feed cost per kg, ₦	57.02[a]	55.46[b]	54.07[c]	52.60[d]	0.50	L**
Feed cost per kg gain ₦	111.81[a]	110.91[ab]	110.35[b]	109.58[b]	0.68	*

[abcd]: Means within the same row bearing different superscripts are significantly different (P<0.05)
*=(P<0.05)
L** =Significant linear effect, (P<0.01)
NS = not significant
SEM = standard error of means
ADFI=Average daily feed intake

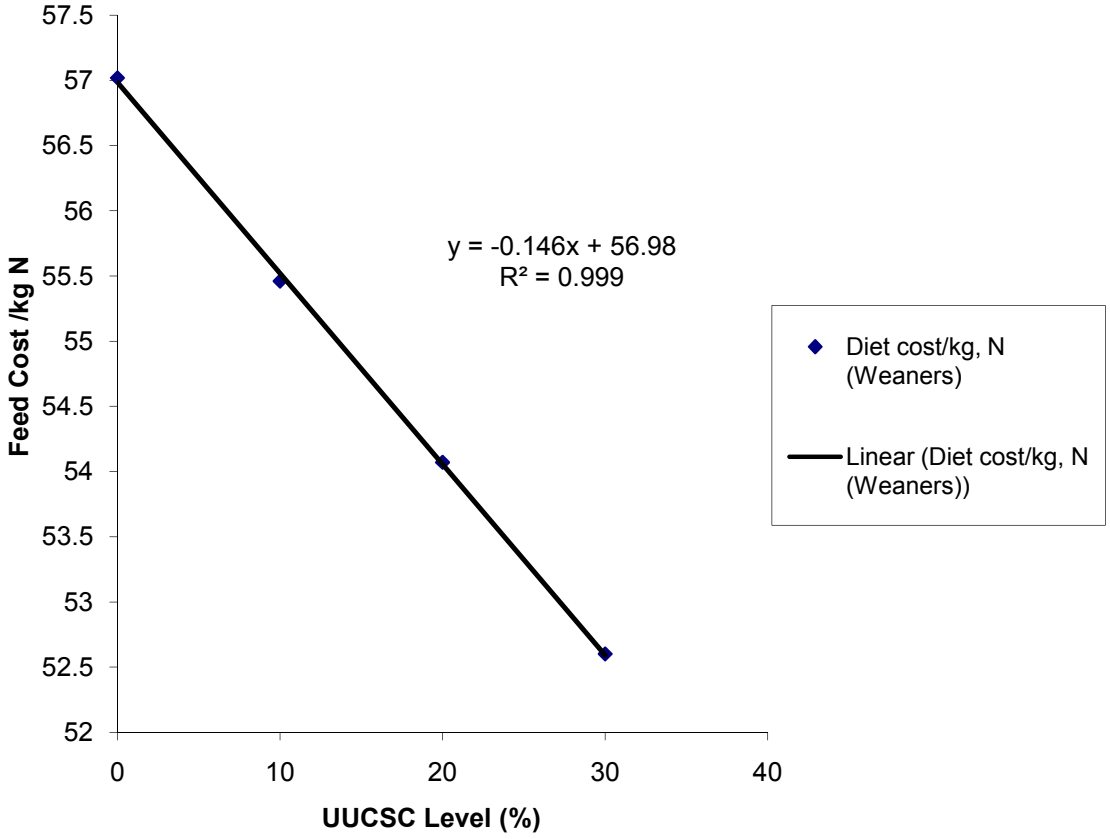


Figure 4.1: Feed Cost /kg,(N) for Weaners as Affected by UUCSC Levels

significant differences among the dietary treatments for pigs fed the 0 and 10% UUCSC diets in terms of feed cost per kilogramme gain. The weanling pigs fed 10, 20 and 30% UUCSC diets had similar values for feed cost per kilogramme gain.

4.4 Performance Characteristics of Weaner Pigs (Experiment 2):

The performance characteristics of weaner pigs fed diets containing graded levels of UUCSC were as presented in Table 4.2. Average daily feed intake was not significantly different ($P>0.05$) between dietary treatments. There were no significant differences in terms of weight gain across the dietary treatments. Feed to gain ratio increased non-significantly with increase in the levels of UUCSC in the diets. The efficiency of feed utilization was best for the control diets (diet 1).

There were linear decreases ($P<0.01$) in terms of feed cost per kilogramme as the level of cottonseed cake increased in the diets of the weaner pigs(Figure 4.1).Feed cost per kilogramme was least for pigs fed 30% cottonseed cake diets.There were no significant differences among the dietary treatments for pigs fed the 0, 10 and 20% UUCSC diets in terms of feed cost per kilogramme gain. The weanling pigs fed 0 10, and 20% UUCSC diets had similar values for feed cost per kilogramme gain and the control was significantly different from 30% UUCSC diet.

4.5 Performance Characteristics of Grower Pigs (Experiment 2):

The performance characteristics of grower pigs fed diets containing graded levels of UUCSC were as presented in Table 4.3. Average daily feed intake was not significantlydifferent ($P>0.05$) between dietary treatments. However, pigs fed cottonseed cake diet

Table 4.2: Performance characteristics of weaner pigs fed diets containing graded levels of undelinted undecorticated cottonseed cake (UUCSC)

Parameters	Levels of UUCSC, %				SEM	Level of Significance
	0	10	20	30		
Initial weight, kg	12.72	12.73	12.75	12.76	0.02	NS
Final weight, kg	21.90	20.35	20.53	20.40	2.27	NS
Weight gain, kg	9.18	7.60	7.78	7.62	2.26	NS
Feed intake, kg	27.16	26.97	26.63	27.91	2.36	NS
ADFI, kg	0.65	0.64	0.63	0.66	8.52	NS
Average daily gain, kg	0.22	0.18	0.19	0.18	0.12	NS
Feed to gain ratio, kg	2.78	3.37	3.38	3.58	0.22	NS
Feed cost per kg, ₦	57.02^{a}	55.46^{b}	54.07^{c}	52.60^{d}	0.50	L**
Feed cost per kg gain ₦	87.52^{a}	85.85^{ab}	84.48^{ab}	82.57^{bc}	2.10	*

a,b,c,d: Means within the same row bearing different superscripts are significantly different P<0.5
* = (P<0.05)
NS = non-significant difference
L** = Significant linear effect, (P<0.01)
SEM = standard error of means
ADFI=Average daily feed intake

required slightly more feed per unit gain in weight. There were no significant differences in terms of weight gain across the dietary treatments. Feed to gain ratio increased non-significantly with increase in the levels of UUCSC in the diets. The efficiency of feed utilization was best for the control diets (diet 1).

There were a linear decreases ($P<0.01$) in feed cost per kilogramme as the level of cottonseed cake increased in the diets of the grower pigs (Figure 4.2). The pigs fed 0, 10 and 20% UUCSC diets had similar feed cost per kilogramme gain values. Also those fed 10, 20 and 30% UUCSC diets had similar feed cost per kilogramme gain values. Feed cost per kilogramme and feed cost per kilogramme gain were least for pigs fed 30% cottonseed cake diets.

4.6 Performance Characteristics of Finisher Pigs (Experiment 2):

The performance characteristics of finisher pigs fed diets containing the graded levels of UUCSC were as presented in Table 4.4. Average daily feed intake was similar across dietary treatments. Feed intake increased as the level of cottonseed cake increased in the diets of the pigs, though the increases were not significantly different among the treatments.

Final weight showed no significant differences between treatments means. The pigs fed the 0 and 10% cottonseed cake diets had higher final weights compared with those fed 20and 30% cottonseed cake diets. Average daily weight gain was similar across the dietary treatments. The finisher pigs fed the control and 10% cottonseed diets gained more

weight compared with those fed 20 and 30% cottonseed cake diets.The efficiency of feed conversion decreased as the levels of cottonseed cake increased in the diets.

Table 4.3: Performance characteristics of grower pigs fed diets containing graded levels of undelinted undecorticated cottonseed cake (UUCSC)

	Levels of UUCSC, %					
Parameters	0	10	20	30	SEM	Level of Significance
Initial weight, kg	21.90	20.35	20.53	20.40	2.27	NS
Final weight, kg	34.10	34.29	34.50	35.77	1.02	NS
Weight gain, kg	13.63	13.50	13.71	14.78	0.76	NS
Feed intake, kg	46.35	46.62	48.67	51.72	4.43	NS
ADFI, kg	1.02	1.11	1.17	1.24	0.09	NS
Average daily gain, kg	0.31	0.32	0.33	0.35	0.02	NS
Feed to gain ratio, kg	3.29	3.34	3.50	3.53	0.24	NS
Feed cost per kg, ₦	57.01[a]	54.61[b]	51.90[c]	49.20[d]	0.50	L**
Feed cost/ kg gain, ₦	183.93[a]	173.31[ab]	163.85[ab]	150.28[bc]	11.38	**

[abcd]:Means within the same row bearing different superscripts are significantly different (P<0.01)
L** = Significant linear effect, (P<0.01)
NS = non-significant difference
SEM = standard error of means
ADFI=Average daily feed intake

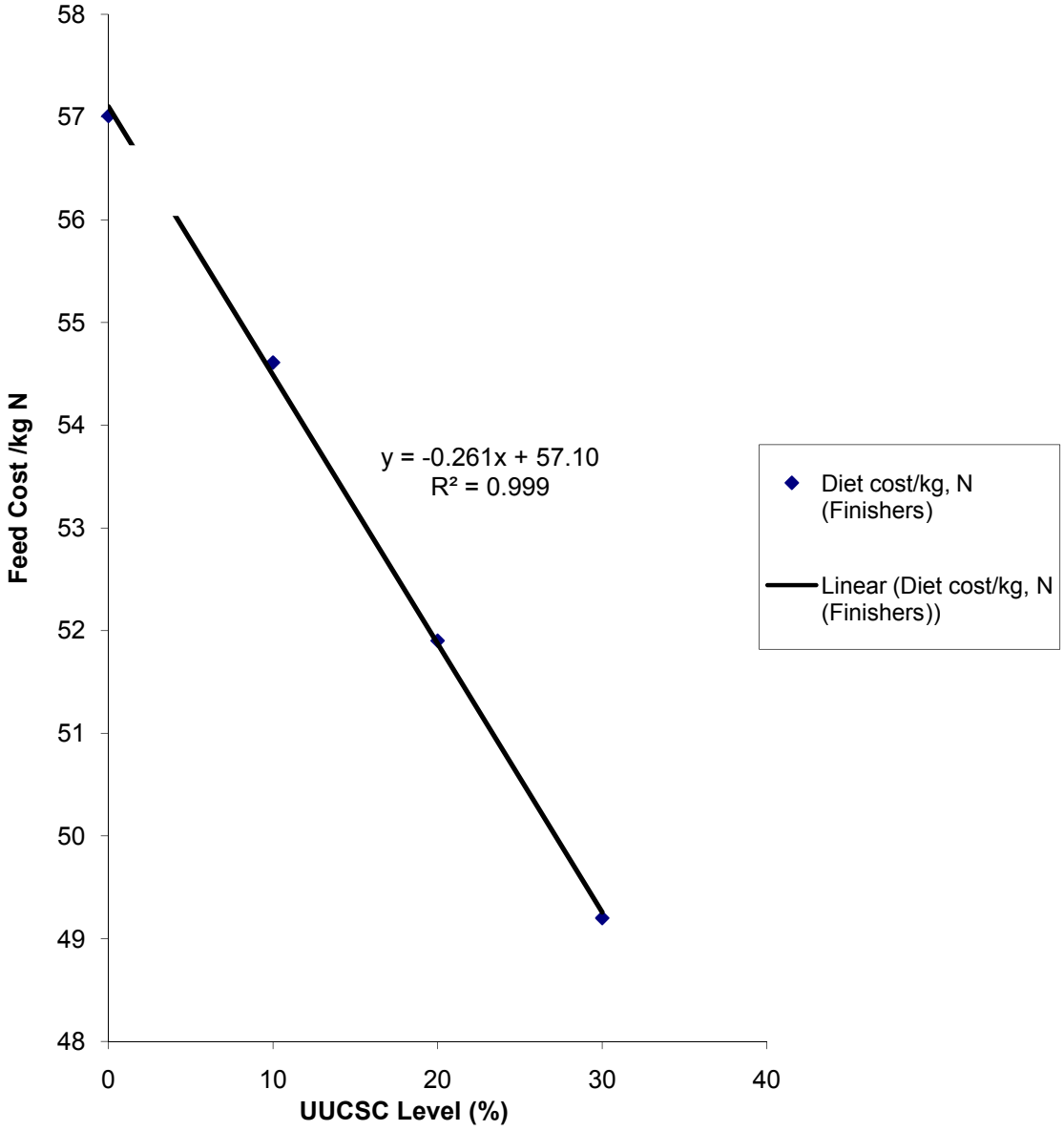


Figure 4.2: Feed Cost /kg,(N) for Finishers as Affected by UUCSC Levels

Table 4.4: Performance characteristics of finisher pigs fed diets containing graded

levels of undelinted undecorticated cottonseed cake (UUCSC)

Parameters	Levels of UUCSC, % 0	10	20	Level of 30	SEM	Significance
Initial weight, kg	34.10	34.29	34.50	35.77	1.02	NS
Final weight, kg	53.60	53.80	53.12	52.24	1.77	NS
Weight gain, kg	18.93	19.13	18.52	17.58	0.78	NS
Feed intake, kg	64.98	66.90	68.55	67.72	3.71	NS
ADFI, kg	1.51	1.58	1.60	1.61	0.90	NS
Average daily gain, kg	0.45	0.45	0.44	0.42	0.04	NS
Feed to gain ratio, kg	3.36	3.48	3.68	3.86	0.20	NS
Feed cost per kg, ₦	57.01[a]	54.61[b]	51.90[c]	49.20[d]	0.05	L**
Feed cost/ kg gain,₦	126.70[a]	121.35[ab]	117.95[b]	117.14[b]	4.24	**

[abcd] Means within the same row bearing different superscripts are significantly different (P<0.01),
** = (P<0.01).
L** = Significant linear effect, (P<0.01)
NS = not significant
SEM = standard error of means
ADFI=Average daily feed intake

Feed cost per kilogramme decreased linearly($P<0.01$) with increase in cottonseed cake inclusion in the diets of the growing-finishing pigs (Figure 4.2 above). Feed cost per kilogramme was least for animals fed 30% cottonseed cake diets. Feed cost per kilogramme gain significantly higher ($P<0.01$) for pigs fed the control diet compared with those on 30%cottonseed cake diet. However, feed cost per kilogramme gain was similar for pigs fed 10, 20 and 30% cottonseed cake diets.

4.7 Haematological Measurements (Experiment 2)

The haematological effects on the pigs fed undelinted undecorticated cottonseed cake (UUCSC) diets at the end of the finisher pig study are presented in Table 4.5. All the haematological indicies examined were similar across dietary treatments. Packed cell volume (PCV) showed no significant differences between the dietary treatments.However, the PCV decreased with increase in the level of UUCSC fed. Haemoglobin followed the same trend as the PCV with the 30% cottonseed cake diet having the lowest value. The white blood cell (WBC) count showed no significant differences between the dietary treatments.

Pigs fed the 20 and 30% UUCSC diets generally had slightly higher white blood cell count compared to those fed 0, and 10% cottonseed cake diets. Lymphocytes and neutrophils did not show any significant differences among the treatment means. There were slight decreases in the values of both measurements as the level of cottonseed cake increased in the diets. Eosinophils showed the same trend as the lymphocytes. Results obtained from the basophils and monocytes did not show any significant differences between the treatment means.

Table 4.5: Haematological measurements of gilts fed graded levels of undelinted undecorticated cottonseed cake (UUCSC)

Measurements	Levels of UUCSC, %				SEM	Level of Significance
	0	10	20	30		
Packed cell volume, %	41.67	41.33	41.00	40.67	0.41	NS
Haemoglobin, g/100ml	12.50	11.55	11.55	11.52	0.30	NS
WBC, $10^3/mm^3$	14.54	14.56	15.33	15.33	0.51	NS
LDC, %						
Lymphocytes	47.40	47.00	46.83	46.67	0.41	NS
Neutrophils	41.00	40.67	41.33	41.33	0.58	NS
Eosinophils	2.00	2.00	1.83	1.83	0.12	NS
Basophils	1.00	1.00	1.00	1.00	0.00	NS
Monocytes	1.17	1.00	1.07	1.17	0.12	NS

NS = Not significan
SEM = Standard error of means
WBC = White blood cells
LDC = Leucocyte differential counts

4.8 Carcass Analysis

The results of the carcass analysis of the finisher pigs fed 0, 10, 20 and 30% dietary levels of undelinted undecorticated cottonseed cake in their diets are presented in Table 4.6. There were significant differences ($P<0.05$) among the dietary treatments in terms of slaughter weight of the pigs. The slaughter weight of pigs fed 30% UUCSC diet was significantly higher ($P<0.05$) than those fed 0, 10, and 20% UUCSC diets. Pigs fed the control diet had significantly higher ($P<0.05$) slaughter weight compared with those fed 10 and 20% UUCSC diets while those fed 10 and 20% UUCSC diets were similarThe warm carcass weights of the pigs followed the same trend as the slaughter weights. Dressing percentage was not significantly affected by the dietary treatments.

The percentages of the ham, shoulder and loin were not significantly affected by the levels of cottonseed cake in the diets of the pigs. There was a linear reduction ($P<0.05$) in loin-eye area as the level of inclusion of cottonseed cake increased in the diets of the female pigs (Figure 4.3). The female pigs fed the 30% UUCSC diet the least value for loin eye area. Back-fat thickness also increased linearly ($P<0.01$) as the level of cottonseed cake increased in the diets of the gilts (Figure 4.4). The gilts on 30% cottonseed cake diet the highest back fat thickness.

4.9 Organ Weights and Gut Dimensions

The results of the effect of feeding diets containing undelinted undecorticated cottonseed cake on soft organ yields and gastro-intestinal dimensions are shown in Table 4.7. The liver yield decreased linearly ($P<0.05$) as the level of UUCSC increased across dietary

Table 4.6: Effect of diets containing undelinted undecorticated cottonseed cake (UUCSC) oncarcass characteristics of gilts.

	Levels of UUCSC, %					
Measurements	0	10	20	30	SEM	Levels of significance
Slaughter weight, kg	72.90[b]	64.93[c]	64.40[c]	81.90[a]	2.12	*
Warm carcass weight, kg	50.10[b]	44.99[c]	44.00[c]	56.67[a]	0.84	*
Dressing %	68.72	69.29	68.32	69.19	1.05	NS
Ham, %	24.22	23.09	23.06	25.01	1.65	NS
Shoulder, %	46.42	46.30	46.86	45.10	0.82	NS
Loin, %	12.76	12.47	12.91	13.30	1.04	NS
Loin eye area, cm^2	25.10[a]	23.27[b]	23.23[b]	23.00[b]	1.29	*
Backfat thickness, cm	2.30[b]	2.32[b]	2.37[b]	2.50[a]	0.32	L**

[a,b,c] :Means within the same row bearing different superscripts are significantly different ($P < 0.05$) , ($P<0.01$)
* = $P < 0.05$, ** = $P<0.01$
L**= Significant, $P<0.01$
NS = Not significant
SEM = standard error of means.

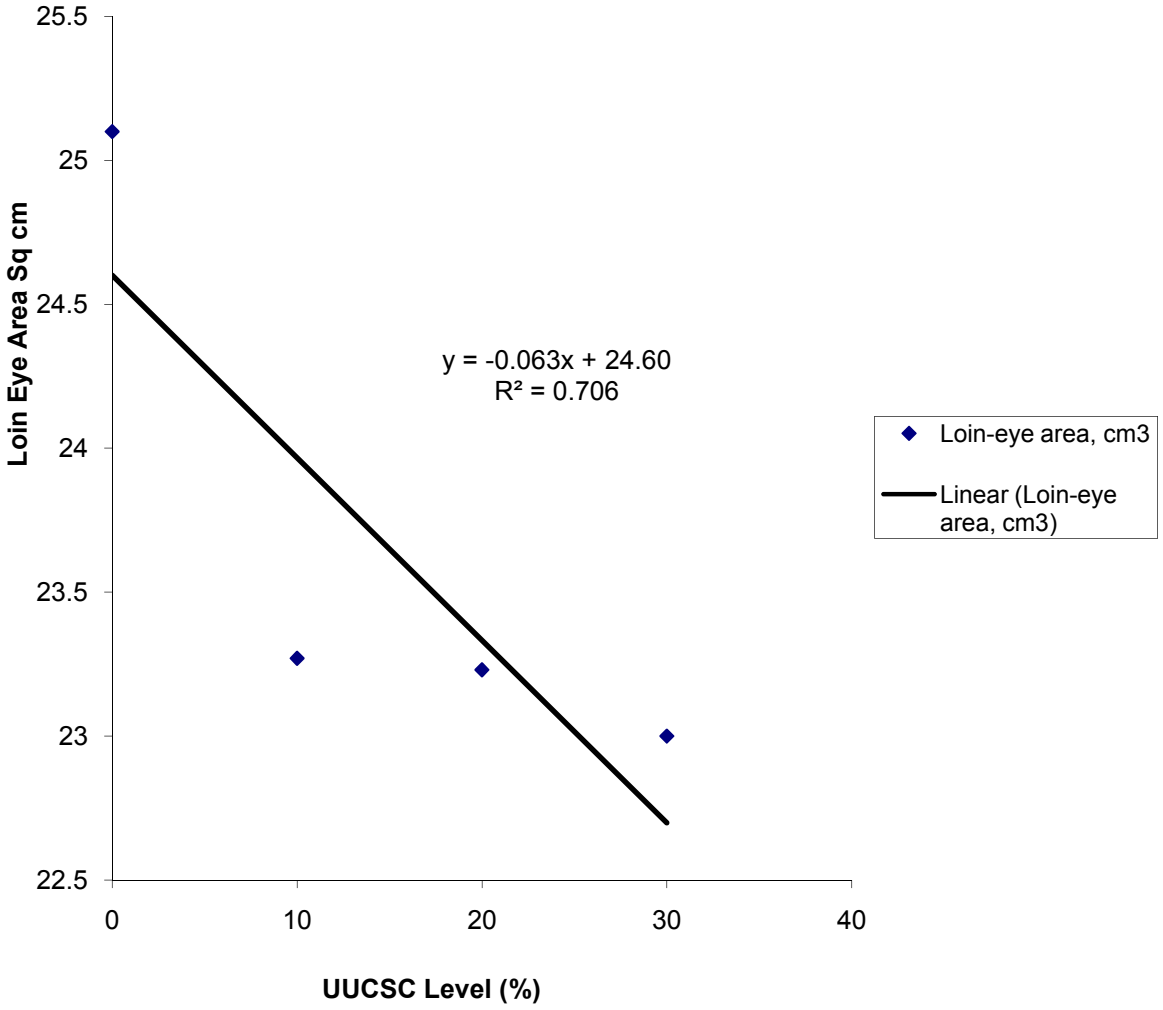


Figure 4.3: Lion Eye Area as Affected by UUCSC Levels

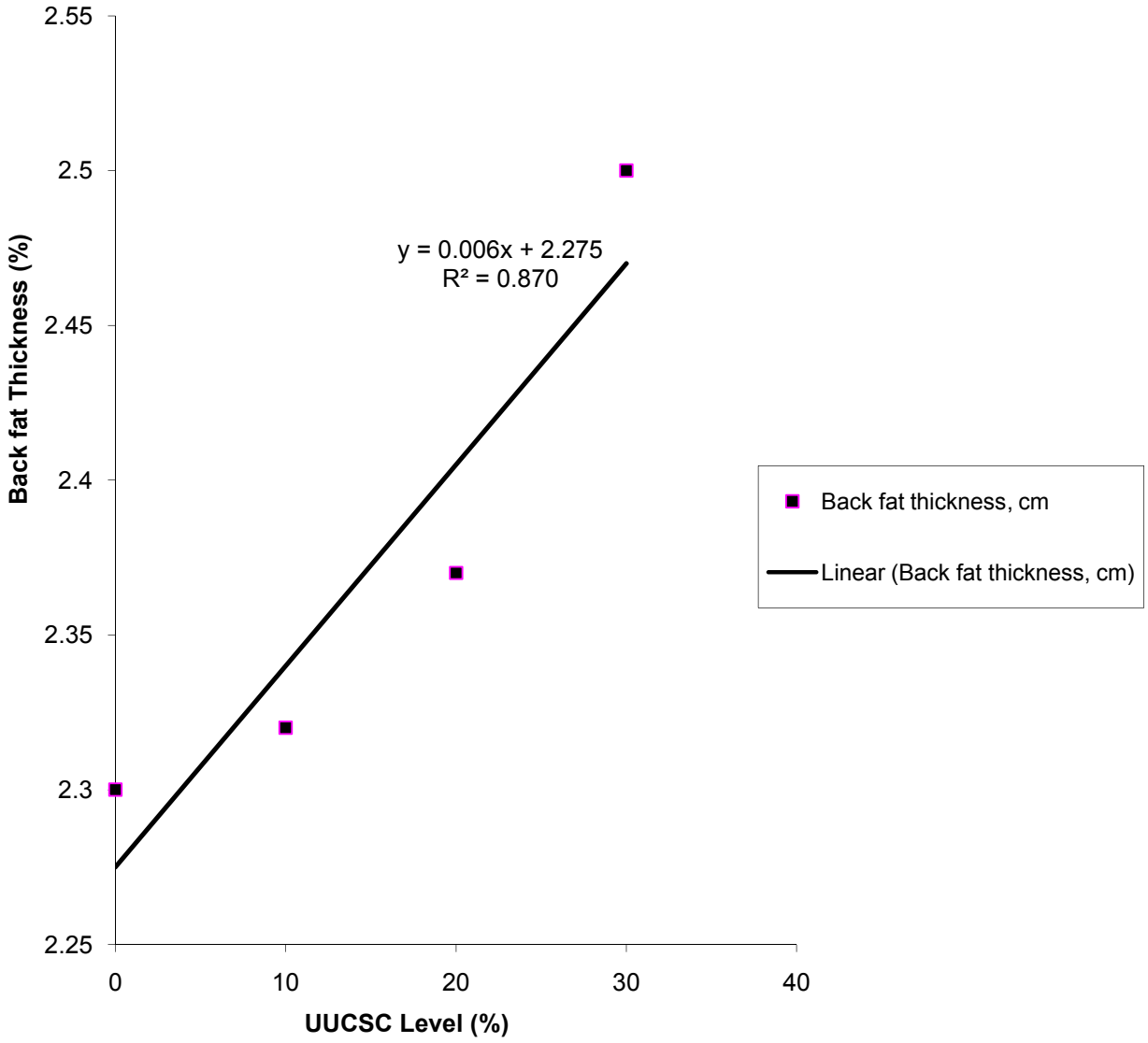


Figure 4.4: Back fat thickness as Affected by UUCSC Levels

treatments (Figure 4.5). The liver yield of the pigs fed 30% cottonseed cake was significantly lower ($P<0.05$) compared to the pigs on any of the other diets. There were no significant differences among the pigs fed 0, 10 and 20% UUCSC diets in terms of liver yield. Percent lung yield was similar across dietary treatments. The pigs fed the 30% diets had the least lung yield.

There was no significant difference between dietary treatments for % heart. Gilts fed the 30% UUCSC diet had the least heart yield value of 0.3%. Kidney yield decreased linearly ($P<0.01$) as the level of cottonseed cake increased in the diets of the pigs (Figure 4.6). The kidney yield of the gilts fed the 30% diet had significantly lower ($P<0.01$) kidney yield than the gilts fed any of the diets containing 0, 10 and 20% UUCSC. Spleen yield decreased linearly ($P<0.05$) as the level of cottonseed cake increased in the diets of the pigs (Figure 4.7). The values of spleen yield for pigs fed 0, 10 and 20% UUCSC diets were not significantly different from each other but were significantly higher ($P<0.05$) than for pigs fed 30% level of inclusion of UUCSC.

Empty stomach yield increased linearly ($P<0.05$) as the level of cottonseed cake increased across the dietary treatments (Figure 4.8). The gilts fed the control diet had significantly lower ($P<0.05$) empty stomach yield compared with the gilts on 10, 20 and 30% UUCSC diets. There were no significant differences between the treatment means of the lengths of the small and large intestines. The lengths of the guts (137.00, 138.10, 138.33 and 140.00cm for small intestine and 41.10, 41.10, 41.30 and 41.60cm for large intestine) increased non-significantly as the level of UUCSC inclusion increased in the diets. The gilts fed the 30% cottonseed cake diets had the longest guts compared to gilts on other

Table 4.7: Effect of diets containing undelinted undecorticated cottonseed cake (UUCSC) on organ yields and gut dimensions of gilts

Measurements	Levels of UUCSC, %				SEM	Level of significance
	0	10	20	30		
Liver, %	0.23[a]	0.24[a]	0.22[a]	0.17[b]	0.02	*
Lungs, %	0.74	0.74	0.70	0.69	0.03	NS
Heart, %	0.40	0.40	0.39	0.39	0.01	NS
Kidneys, %	0.27[a]	0.26[a]	0.23[a]	0.20[b]	0.01	**
Spleen, %	0.18[a]	0.18[a]	0.17[a]	0.15[b]	0.01	**
Empty Stomach, %	0.77[b]	0.87[a]	0.88[a]	0.88[a]	0.04	*
Small Intestine, cm	137.00	138.10	138.33	140.00	4.43	NS
Large Intestine, cm	41.10	41.10	41.30	41.60	0.51	NS

a, b: Means within the same row bearing different superscripts are significantly different ($P < 0.05$), ($P < 0.01$)
* = $P < 0.05$, ($P < 0.01$)
NS = Not significant
SEM =Standard error of means.

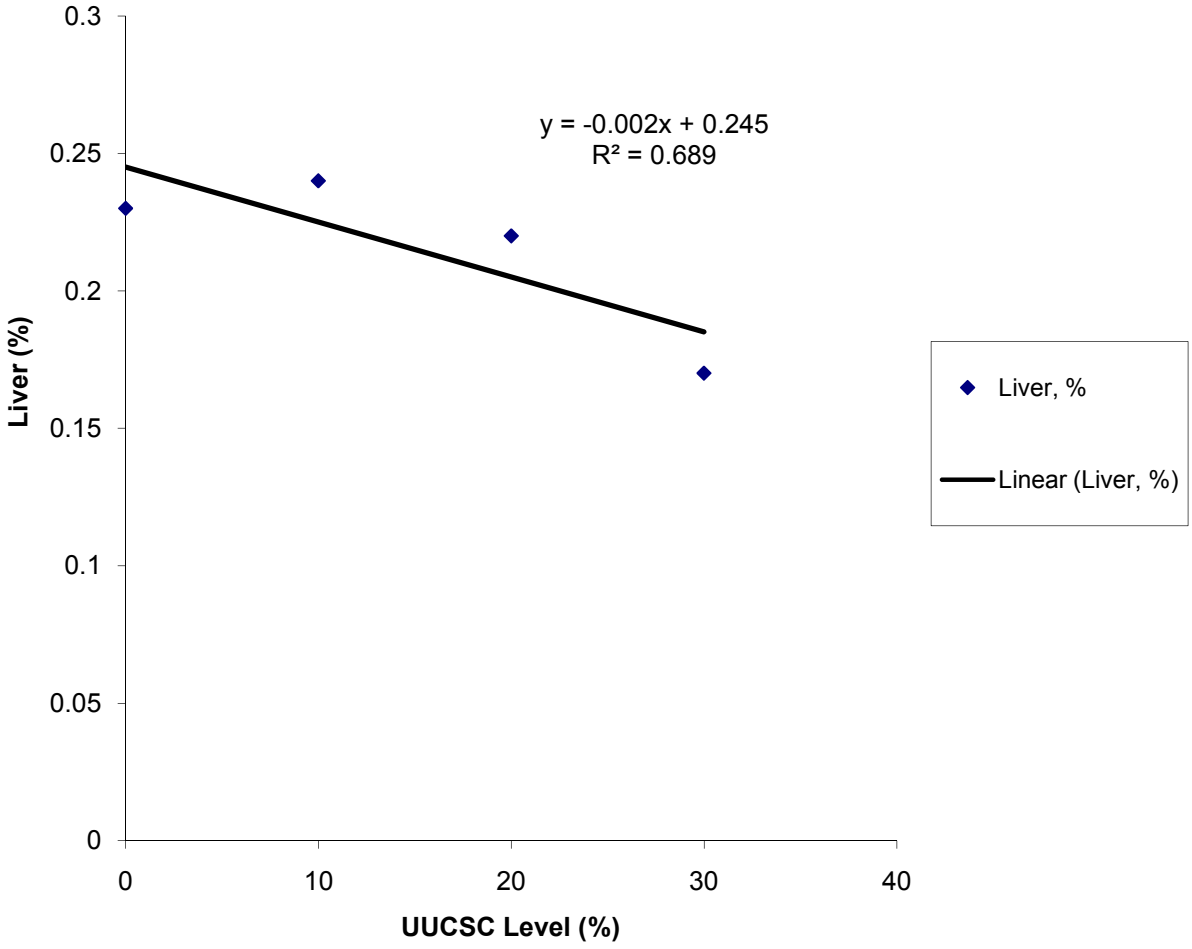


Figure 4.5: Liver %, as Affected by UUCSC Levels

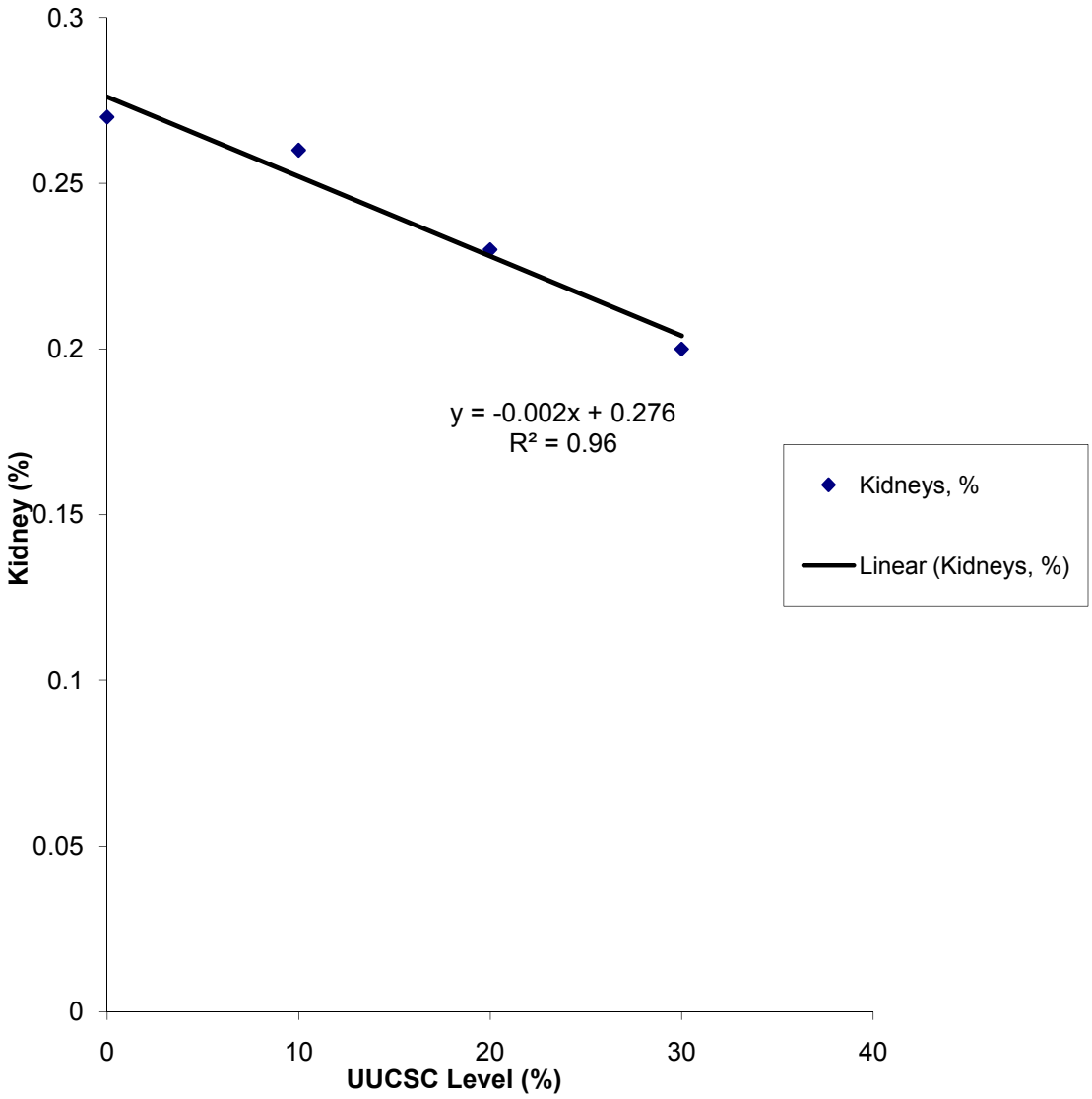


Figure 4.6: Kidney %, as Affected by UUCSC Levels

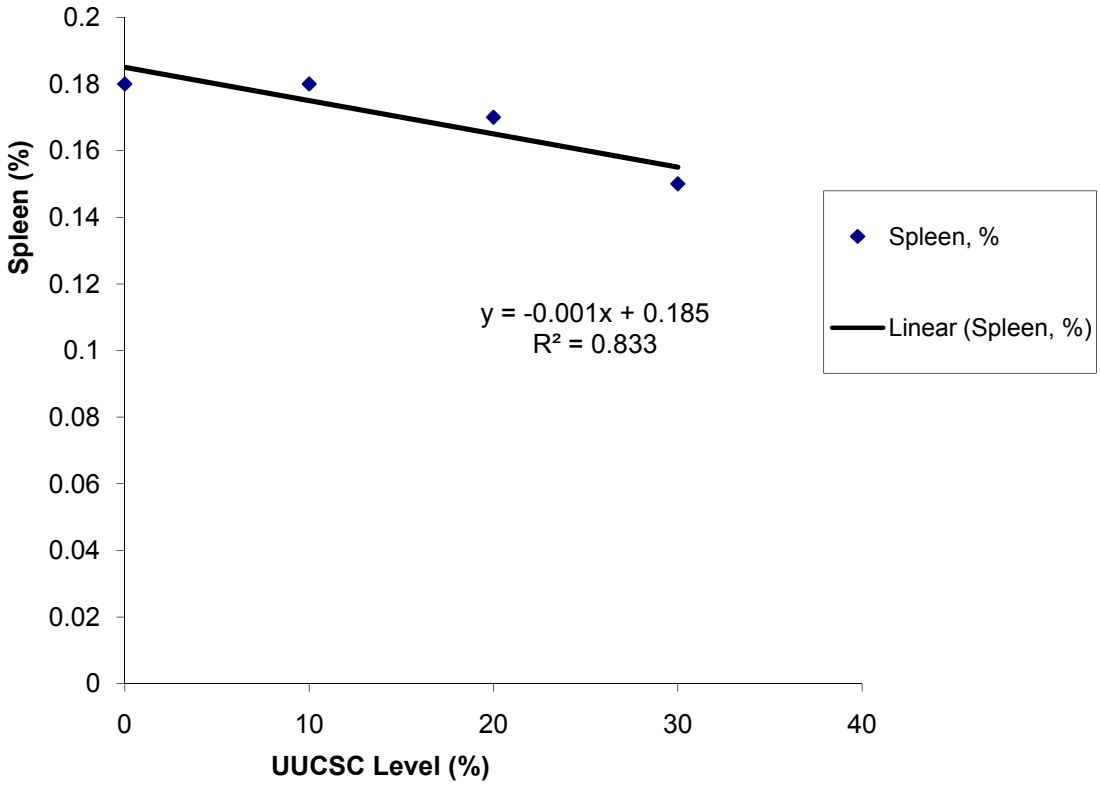


Figure 4.7: Spleen %, as Affected by UUCSC Levels

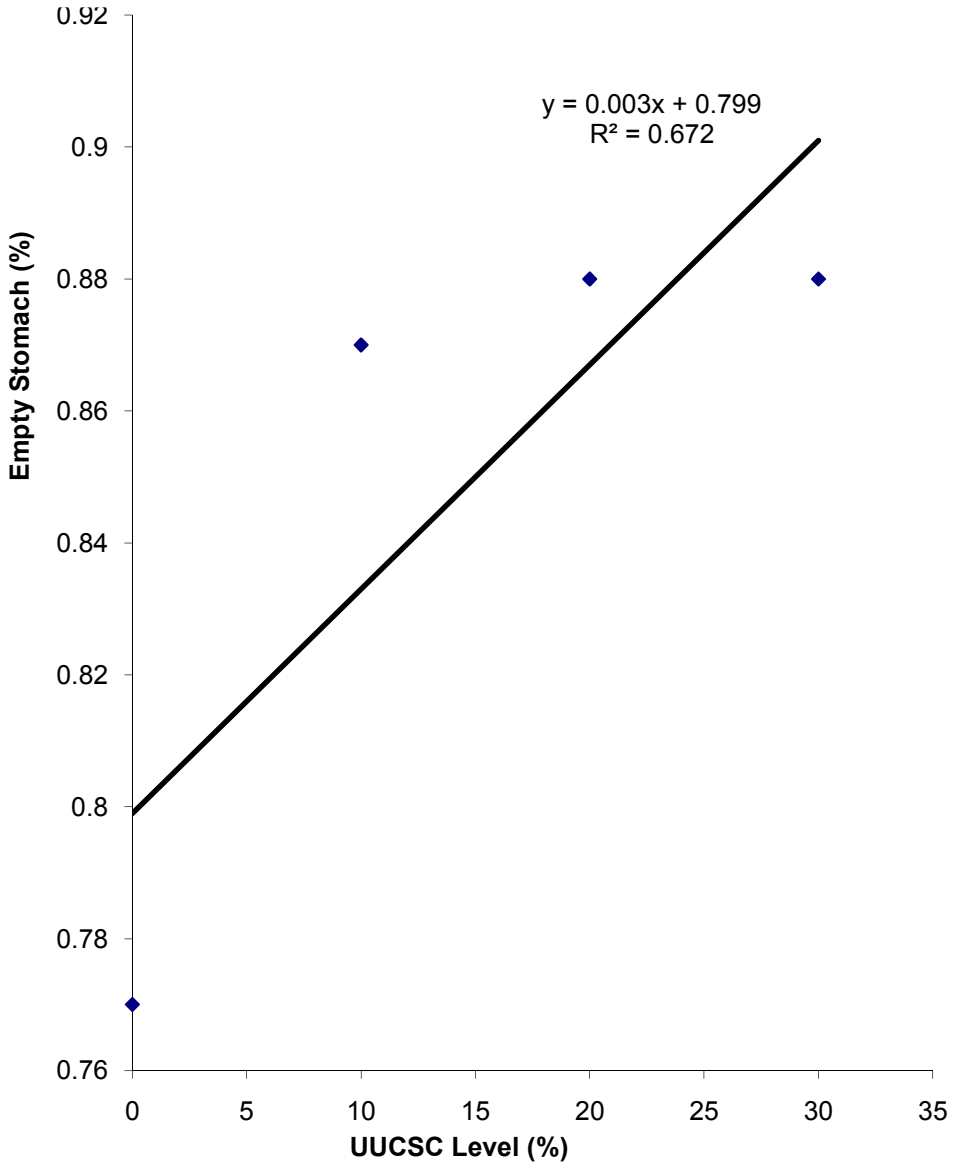


Figure 4.8: Empty Stomach %, as Affected by UUCSC Levels

gilts fed the 30% cottonseed cake diets had the longest guts compared to gilts on other dietary treatments.

4.10 Histopathological Study

The results of the histopathological examination of the selected visceral organs (liver, kidney, heart, lung, spleen, lymph node and ovary) of the gilts fed graded levels of UUCSC diets showed that the organs of gilts fed 30% UUCSC were severely affected by UUCSC. They showed visible lesions. The liver showed hepatic degeneration and necrosis while the kidney, heart, spleen and ovary showed lesions. Gilts on other diets were free from all lesions.

4.11 Reproductive Study

The reproductive data of the female pigs fed diets containing UUCSC from the weaner phase to the first parity are presented in Table 4.8. The ages of the weaner pigs at the start of the trial were similar across the dietary treatments and ranged from 122.67 to 124.33 days. There were no significant differences between dietary treatments in terms of age at puberty or first heat. These values ranged from 190.67 to 196.00 days with pigs fed 30% having the highest. Gestation lengths showed no significant differences among treatment means. Results obtained did not show any significant difference among the treatment means in terms of number of stillbirths, piglets born alive and litter size of the sows.

Mortality of the piglets before weaning, number of piglets weaned and age at weaning were similar across dietary treatment means. Average weaning weight showed no significant differences between the dietary treatments. It ranged from 8.33 to 9.80 kg.

Table 4.8: Effect of diets containing undelinted undecorticated cottonseed cake (UUCSC) on reproductive performance of female pigs.

	Levels of UUCSC, %					Levels of
Parameters0	10	20	30	SEM	Significance	
Age at start of trial, days	123.33	122.67	124.33	123.67	0.95	NS
Age at puberty, days	193.33	190.67	192.00	196.00	2.89	NS
Gestation length, days	113.67	114.00	114.00	113.33	0.47	NS
No of stillbirths	1.00	1.00	1.00	1.00	0.00	NS
No born alive	7.00	8.00	8.00	7.67	0.83	NS
Litter size	8.00	9.00	9.00	8.67	1.07	NS
Average litter weight, kg.	1.03	0.97	0.97	1.10	0.41	NS
Mortality before weaning	0.33	0.33	0.67	0.00	0.29	NS
No weaned	6.67	7.67	8.00	7.67	0.82	NS
Age at weaning, days	42.00	42.00	42.00	42.00	0.00	NS
Average weaning weight, kg	9.80	8.83	8.73	8.33	1.21	NS

NS = Not significant
SEM = Standard error of means.

4.12 Digestibility Trial(Experiment 3)

4.12.1 Proximate Composition of the Major Feed Ingredients and Weaner Experimental Diets

The proximate compositions of the major ingredients and experimental diets fed to weaner pigs in experiment two are presented in Table 3.8. The determined analysis showed that the samples ofundelinted undecorticated cottonseed cake (UUSC) contained dry matter, 93.82; crude protein, 26.02; ether extract, 8.50; crude fibre, 13.15; ash, 6.51; nitrogen free extract, 39.72% and gross energy, 4160 kcal per kg. The crude protein contents of maize, groundnut cake, maize offal and wheat offal were 8.80, 44.88, 11.20 and 16.10% respectively.

The chemical compositions of the diets (Table 3.8) showed that the following ranges of dry matter, 91.60 – 93.00; crude protein, 18.01 – 18.50; ether extract, 7.42 – 7.95; crude fibre, 4.40 – 10.00; ash, 5.70 – 6.75; nitrogen free extract, 48.84 – 57.38% and gross energy, 4120 – 4301 kcal per kg. There were significant increases in crude fibre, ash, and gross energy contents but nitrogen free extract decreased as the level of UUCSC increased in the diets.

4.12.2 Performance Characteristics of Weaner Pigs (Experiment 3)

The performance characteristics of young pigs fed diets containing UUCSC during the two periods of the trial are presented in Table 4.9. Average daily feed intake was not significantly differentbetween dietary treatments. However, pigs fed cottonseed cake dietsrequired slightly more feed per unit gain in weight. The weight gain of the pigs decreased linearly ($P<0.05$) as the levels of cottonseed cake increased in the diets.

However, there were no significant differences between the 0 and 10% dietary treatments and between the

Table 4.9: Performance characteristics of weaner pigs fed graded levels of undelinted undecorticated cottonseed cake (UUCSC)

	Levels of UUCSC in diets, %					
Period	0	10	20	30	SEM	Level of Significance
Average daily feed intake, g						
I	676.19	666.67	692.86	680.95	26.17	NS
II	1528.57	1523.81	1504.76	1542.95	46.57	NS
Average	1102.40	1095.20	1180.00	1112.40	191.12	NS
Average daily gain, g						
I	495.19[a]	480.95[ab]	476.14[b]	461.90[c]	6.80	*
II	504.76	500.00	495.24	485.71	8.91	NS
Average	499.98[a]	490.48[ab]	485.69[b]	473.81[c]	6.73	*
Feed to gain ratio						
I	1.37	1.37	1.48	1.51	0.08	NS
II	3.02	3.03	3.04	3.12	0.11	NS
Average	2.19	2.20	2.28	2.30	0.37	NS

a, b, c: Means within the same row bearing different superscripts are significantly different ($P<0.05$)

* = $P<0.05$.

NS = Not siginificant

SEM = Standard error of means

10 and 20% dietary level. Pigs fed the 30% UUCSC diet had the least ($P<0.05$) growth rate. The feed feed to gain ratios were similar across the dietary treatments.

4.12.3 Nutrient Intake

The nutrient intake of the various nutrients by weaner pigs fed graded levels of UUCSC is presented in Table 4.10. The daily intake of dry matter did not show any significant differences between treatment means. Nitrogen intake was similar across the dietary treatments. Ether extract intake was not significantly affected by dietary treatments. As would be expected, daily crude fibre intake increased significantly ($P<0.01$) as the level of cottonseed cake increased in the diets. There was a significant linear ($P<0.01$) increase in crude fibre intake as the level of cottonseed cake increased in the diets. Nitrogen free extract intake did not show any significant difference across dietary treatments.

4.12.4 Feacal Nutrient Output

The feacal outputs of the various nutrients by young pigs were as presented in Table 4.11. There were significant differences ($P<0.01$) among treatments in terms of daily dry mater output. The young pigs fed 30% diet had the highest ($P<0.01$) dry matter output while the pigs fed the control diets (diet 1) had the least value. The result of nitrogen output showed that pigs on diets with 20% and 30% UUCSC had significantly higher ($P<0.05$) nitrogen output compared to those fed 0 and 10% cottonseed cake.

There were no significant differences among dietary treatments in terms of faecal etherextract output. Crude fibre output increased linearly ($P<0.01$) as the level of UUCSC increased in the diets. There were however no significant differences between 10% and

Table 4.10: Nutrient intake of diets containing undelinted undecorticated cottonseed cake (UUCSC) fed to weaner pigs.

Levels of UUCSC in diets, %						
Measurements0	10	20	30	SEM	Levels of Significance	
Average nitrogen intake, g/pig/day	32.53	32.27	32.14	32.67	0.24	NS
Average ether extract intake, g/pig/day	85.25	87.21	88.78	92.76	15.36	NS
Average crude fibre intake, g/pig/day	44.57[a]	72.59[a]	91.38[b]	111.14[b]	14.39	L**
Average NFE intake, g/pig/day	500.80	500.50	477.50	466.70	84 .11	NS

a, b, c: Means within the same row bearing different superscripts differ significantly (P<0.01).
L** = Significant linear,(P<0.01)
NS = Not significant
SEM = Standard error of means
NFE = Nitrogen free extract

Table 4.11: Faecal nutrient output of diets containing undelinted undecorticated cottonseed cake (UUCSC) fed to weaner pigs.

Levels of UUCSC in diets, %						
Measurements0	10	20	30	SEM	Level of Significance	
Average dry matter output, g/pig/day	183.14^{c}	199.95^{b}	212.23^{b}	257.00^{a}	20.60	**
Average Nitrogen output, g/pig/day	3.27^{b}	3.75^{b}	4.18^{a}	5.39^{a}	0.52	*
Average ether extract output, g/pig/day	15.31^{b}	17.77^{ab}	19.02^{ab}	21.61^{a}	2.26	*
Average crude fibre output, g/pig/day	10.05^{c}	17.60^{b}	23.46^{b}	30.66^{a}	3.04	L**
Average NFE output, g/pig/day	67.11^{b}	70.67^{b}	78.38^{a}	78.13^{a}	3.88	*

a, b, c, d: Means within the same row bearing different superscripts differ significantly (P<0.05),(P<0.01)
* = (P<0.05), ** = (P<0.01)
NS = Not significant
L** = Significant linear, (P<0.01)
NFE = Nitrogen free extract
SEM = Standard error of means

20% diets in terms of crude fibre output. In terms of faecal nitrogen free extract output, the weaner pigs fed 20 and 30% UUCSC diets had significantly higher ($P<0.05$) output compared with the pigs fed 0 and 10% cottonseed cake diets.

4.12.5 Apparent Nutrient Digestibility Coefficients.

The results of the effect of feeding diets containing undelinted undecorticated cottonseed cake on apparent digestibility of dry matter, crude protein, ether extract, crude fiber and nitrogen free extract by weaner pigs are presented in Table 4.12. Apparent average dry matter intake by the weaner pigs was similar across the dietary treatments.

Apparent dry matter digestibility decreased significantly across the dietary treatments. There were no significant differences between the pigs fed 0 to 10% and 10 to 20% cottonseed cake diets in terms of the dry matter digestibility. The weaner pigs fed the 30% UUCSC diets had the least dry matter digestibility and this was significantly lower ($p<0.01$) than that of other dietary treatments.

Apparent crude protein digestibility decreased linearly ($p<0.01$) as the level of cottonseed cake inclusion increased in the diets. Apparent ether extract digestibility followed the same trend as the crude protein digestibility. As the level of UUCSC increased, ether extract digestibility significantly decreased ($p<0.01$) across the dietary treatments. There were significant differences among the dietary treatments in terms of crude fiber digestibility. The pigs fed the control diet had higher ($p<0.01$) apparent crude fibre digestibility compared with those fed 20 and 30% cottonseed cake diets. The pigs fed 10% UUCSC diets also had higher apparent crude fiber digestibility than the pigs fed 30% UUCSC diets.

Table 4.12: Apparent nutrient digestibility coefficients of diets containing undelinted undecorticated cottonseed cake (UUCSC) fed to weanerpigs.

Levels of UUCSC in diets, %						
Parameters	0	10	20	30	SEM	Levels of Significance
Average dry matter intake, g/pig/day	1012.40	1008.30	1007.60	1015.80	4.74	NS
Average dry matter digestibility, %	81.91[a]	80.17[ab]	78.91[b]	74.70[c]	0.80	**
Apparent crude protein digestibility, %	92.70[a]	91.21[b]	86.21[c]	81.98[d]	0.44	L**
Apparent ether extract digestibility, %	81.44[a]	79.69[b]	78.44[c]	75.66[d]	0.52	L**
Apparent crude fibre digestibility, %	77.44[a]	75.75[ab]	74.33[bc]	72.48[c]	1.34	**
Apparent NFE digestibility, %	86.66	85.88	85.68	83.26	1 .82	NS

a, b, c, d: Means within the same row bearing different superscripts differ significantly($P<0.01$)
**($P<0.01$)
L** = Significant linear, ($P<0.01$)
NS = Not significant
NFE = Nitrogen free extract
SEM = Standard error of mean

There were no significant differences in apparent nitrogen free extract across the dietary treatments.

4.12.6 Nitrogen Balance

The effects of feeding diets containing undelinted undecorticated cottonseed cake on the nitrogen intake, apparent nitrogen excreted and retention by weaner pigs are shown in Table 4.13. There were no significant differences among the pigs fed 0, 10, 20 and 30% undelinted undecorticated cottonseed cake in terms of average daily nitrogen intake. The pigs fed 30% cottonseed cake had significantly higher ($P<0.05$) faecal nitrogen excreted (5.39g per day) when compared to the weaner pigs fed any of the dietary treatments. There were no significant differences among the pigs fed 0, 10 and 20% UUCSC diets in terms of faecal nitrogen excreted. The weaner pigs fed 30% UUCSC diet had significantly higher ($P<0.05$) urinary nitrogen excreted when compared to the pigs fed any of the other dietary treatments. The values of the feacal nitrogen excreted across dietary treatments were generally higher than the values of the faecal nitrogen excreted across dietary treatments. The pigs fed 30% UUCSC diets had significantly higher ($P<0.01$) total nitrogen excreted than those pigs on 0, 10 and 20% cottonseed cake.

Nitrogen retention decreased as the level of cottonseed cake increased in the diets. Weaner pigs fed the control diet had significantly ($P<0.01$) higher nitrogen retention compared with those fed 10, 20 and30% cottonseed cake diets. There were no significant differences among the pigs fed 10, 20 and 30% UUCSC diets. Apparent nitrogen loss increased as the level of cottonseed cake increased in the diets of the pigs. The pigs fed 0, 10 and 20%

UUCSC had similar apparent nitrogen loss but these (31.94, 35.30 and 35.30%) were significantly lower ($P<0.01$) than for the pigs fed 30% UUCSC diet. Apparent nitrogen retained was significantly higher ($P<0.01$) for pigs fed the control diet (68.06%) compared with those of pigs fed 10, 20 and 30% UUCSC diets. The pigs fed 30% UUCSC diets had the least value (58.03%) of apparent nitrogen retention.

Table 4.13: The effect of feeding diets containing undelinted undecorticated cottonseed cake (UUCSC) on nitrogen balance by weaner pigs

Levels of UUCSC in diets, %						
Parameters	0	10	20	30	SEM	Levels of Significance
Feacal nitrogen excretion, g/pig/day	3.27[b]	3.75[b]	4.18[b]	5.39[a]	0.52	*
Urinary nitrogen excretion, g/pig/day	7.12[b]	7.64[b]	8.12[b]	8.32[a]	0.54	*
Total nitrogen excretion, g/pig/day	10.39[b]	11.38[b]	12.30[b]	13.71[a]	1.22	**
Average daily nitrogen retained, g/pig/day	22.14[a]	20.88[b]	19.84[b]	18.96[b]	1.24	**
Apparent daily nitrogen loss, %	31.94[b]	35.30[b]	38.27[b]	41.97[a]	3.70	**
Apparent daily nitrogen retention, %	68.06[a]	64.70[b]	61.73[b]	58.03[b]	3.60	**

a b: Means within the same row bearing different superscripts differ significantly (P<0.05), (P<0.01)
* = P<0.05; ** = P<0.01
NS = Not significant
SEM = Standard error of means

CHAPTER FIVE

5.0 DISCUSSION

5.1 Performance Characteristics of Weaner, Grower and Finisher Pigs

Average daily feed intake of all classes of pigs in this study did not show any significant differences across the dietary treatments. The pigs fed the 30% cottonseed cake diets ate more of the feed in order to meet their energy requirement. Frank *et al.* (1984) observed that the relationship between voluntary feed intake and energy content of a diet is that pigs eat more of low energy diet than the high energy diet in an attempt to satisfy their energy requirements. Hence, in this trial the pigs fed the 30% UUCSC diet consumed slightly more of this diet compared with the 0, 10 and 20% diets. The results obtained in this trial agree with the findings of earlier workers (Ikurior and Fetuga, 1985, 1988 and Balogun *etal*., 1990). But the results obtained by Fombad and Bryant, (2004) were contrary to the findings of the present study. They observed that feed intake decreased as the level of cottonseed cake increased in the diets of swine.

In the digestibility trial of this study, the significant linear decrease ($P< 0.05$) in the growth rate of the weanling pigs as the levels of cottonseed cake increased in the diets is in agreement with the findings of Kenneley and Aherne, (1980) and Frank *et al,*. (1984). They observed that young pigs fed high fibre diets had significantly lower average daily gain compared to the control animals.

For the adult female pigs (growers and finishers), the non-significant decrease in average daily gain observed as the level of cottonseed cake increased in the diets agrees with the studies carried out by Ikurior and Fetuga, (1988) and Balogun *et al.,* (1990) who showed that there were no significant differences in weight gain of pigs as the levels of cottonseed cake increased in their diets of pigs. This might be due to the increased crude fibre content

of diets as the levels of cottonseed cake increased in the diets. Kenneley and Aherne (1980) observed that pigs fed high fibre diets had lower average daily gain compared to the control animals. The non-significant decline in growth rates obtained in this study is in contrast with those reported by Clawson and Smith, (1966) and Rincon *et al*.,(1978).

The feed to gain ratio was not significantly affected by the dietary treatments. However, the slight linear decrease in feed efficiency as the level of cottonseed cake increased in the diets would appear to suggest that the cottonseed cake diets were less efficiently utilized than the control diets. It has been observed that feed conversion ratio in swine is inversely related to increase feed intake level because higher feed intake allows for increased body (Blair *et al,* 1969) and body fat deposition requires more energy than protein (muscle) for the same unit increase in body weight (Hammond *et al,* 1971). The performance characteristics reported in the present study tend to agree with the findings of these authors cited above.

The linear decreases ($P<0.01$) in feed cost per kilogramme of diet as level of cottonseed cake increased in the diets of the pigs in this trial showed that cottonseed cake diets are much cheaper compared to the control diet. As at the time this study was conducted, the prices of groundnut cake and cottonseed cake were seventy thousand and forty thousand naira per ton respectively. Hence the price differential between the groundnut cake and cottonseed cake is responsible for the significant linear decreases ($P<0.01$) in feed cost per kilogramme of the diet as the level of UUCSC increased in the diets. Thus the diet containing 30% cottonseed cake replacement was the least cost diet. Feed cost per unit gain decreased linearly ($P<0.05$) as the levels of cottonseed cake increased in the diets. The results obtained in the present study agree with the findings of Fombad and Bryant, (2004) who observed that inclusion of cottonseed cake in the diets of pigs was cost effective. The

results obtained in this study showed that cottonseed cake diets are more cost saving when compared with the control diet.

In summary, the results of this trial suggests that the feeding of diets containing up to 10% of undelinted undecorticated cottonseed cake would not adversely affect the performance, nutrient digestibility and perhaps its utilization by weanling pigs. Inclusion of up to 30%undelinted undecorticated cottonseed cake in the diets of grower and finisher pigs would notadversely affect their performance

5.2 Haematological Measurements

The purpose of investigating blood composition is to have a way of distinguishing normal states from a state of stress in an animal (Kelly, 1979). Such stress factors can be inadequate nutrition, poor management, environmental or physical stress. According toVeulterinora (1991), the function of the blood is to transport hormones, metabolites such as thermo-regulators and general homeostasis and diets have been reported to have significant influence on haematological variables.

The haematological measurements - packed cell volume (PCV), haemoglobin(Hb) and white blood cells, WBC) were similar across dietary treatments. The values of the PCV (40.67 – 41.67%) reported for the pigs in this study were within the normal range(38 – 43%) reported by Mitruka and Rawnsely (1977) for pigs in normal physiological state. Generally, the results indicate the good health status of the pigs as low PCV values are taken to indicate anaemia. The results obtained for heamoglobin (Hb) followed the same pattern with that of PCV. This shows that the cottonseed cake based diets are nutritionally adequate to meet the protein needs of the pigs since decreased Hb values in animals indicate low protein intake, parasite infection or liver damage (Lindsay, 1977). This result also suggests that the blood of the pigs has an appreciable oxygen carrying capacity which

indicates that the nutrient transport by the blood was not impaired by the levels of cottonseed cake fed in this study. This study agrees with the works of Church *et al.* (1984) who observed that PCV and Hb are correlated with the nutritional status of an animal which is directly related to the nutritional balance of the diet fed to the animal.

The non-significant values of leucocytes recorded across the dietary treatments are indications that the pigs have the ability to fight disease invasion. The leucocytes differential counts (Lymphocytes, neutrophils, eosinophils, basophils and monocytes) followed the same trend as the white blood cells. These values were within the range recorded for pigs in stable physiological conditions by Mitruka and Rawnsley (1977). The values recorded for lymphocytes, neutrophils and monocytes suggest the ability of pigs to resist diseaseconditions. Lymphocyte value is an indication of viral or bacterial infection while high neutrophil and monocyte values are indications of parasitic infections and injuries to body tissues (Church *et al.,* 1984). The reports on studies of gossypol toxicity in animals by some workers indicated significant decreases in PCV and Hb concentrations while the wbc concentration increased significantly (Rogers *et al.,* 2002, Kerr, 1989 and Neser *et al.,* 1988).

The haematological measurements were not affected by the levels of cottonseed cake fed in the diets. This is an indication of the immunity status of the pigs in normal physiological conditions.

In summary,the inclusion of up to 30% undelinted undecorticated cottonseed cake in the diets of female pigs will not adversely affect the physiological state of the animals.

5.3Carcass Analysis

The significant differences ($P<0.05$) observed in the slaughter and carcass weights among the dietary treatment were not similar to those obtained for growth rate. This might be due

to the increased crude fibre content of the diets as the level of cottonseed cake increased in the diets. This is in line with the findings of Kenneley and Aherne (1980) who showed that pigs fed high fibre diets had lower average growth rate compared to those fed the control diet.The results obtained in this study in terms of dressing % and percent ham, shoulder and loin are similar to those reported by Moura and Laverenti (1979) and Ikurior and Fetuga (1985).

Loin eye area is a measure of the meatiness or leanness of the carcass of an animal. The significant linear decrease ($P<0.05$) in loin-eye area is an indication of reduced meatiness of the pigs as the level of UUCSC increased in the diets of the female pigs. In this study, the value of the loin eye area for the control diet (25.10cm^2) was significantly higher ($p<0.05$) than for the average value for 10-30% UUCSC diets (23.17cm^2). Thus the inclusion of UUCSC in the diets of the female pigs reduced the meatiness of the carcass by 7.7%. Ikurior and Fetuga (1985), however, observed that the percentage of lean meat (meatiness), bone and head of pigs were not significantly affected by diets containing cottonseed cake. The results obtained in this study do not agree with this observation.

Back fat thickness is a measure of the fattiness of the carcass of the pig. The significant linear increase ($P<0.05$) in back fat thickness of the pigs as the level of UUCSC increased in the diets is an indication of the increased fattiness of those pigs on UUCSC diets. The value of the back fat thickness for the 30% diet (2.50cm) was significantly higher ($P<0.05$) than for the average value of 0 -20% UUCSC diets (2.33cm). Hence, the inclusion of 30% UUCSC in the diets of female pigs increased the fattiness of the carcass by 6.8%. Ikurior and Fatuga (1985) showed that the percentage fat increased linearly ($P<0.05$) as the level of cottonseed cake increased in the diets fed to pigs. The results of the present study agree with this observation.

In summary, the inclusion of up to 30% undelinted undecorticated cottonseed cake in the diets of female pigs had no adverse effect on percent ham, shoulder and loin. However, the meatiness and fattiness of the female pigs were significantly reduced and increased respectively with increasing level of UUCSC in the diets of the pigs.

5.4Organ Yields, Gut Dimensions and Histopathology of visceral Organs

The significant decrease ($p<0.05$) in the liver, kidney and spleen yields of the gilts fed the 30% UUCSC diets compared with those pigs fed 0, 10 and 20% might be related to gossypol effect on those organs (Smith, 1957). In several studies on the pathology of gossypol poisoning in the pigs, Buitrago *et al*.(1970) and Ikurior and Fetuga (1985) reported that there were severe congestions of the liver, kidney, spleen and lungs of pigs and concluded that there was an inverse relationship between free gossypol and liver weight in pigs.

Although the relatively low levels of free gossypol might be contained in the glandular type of cottonseed cake in the test diets in the present study, it is possible that some toxic gossypol effects could have begun to be manifested in the livers, kidneys and spleens of the pigs which were fed the diets containing the highest level (30%) of UUCSC.

Since gossypol poisoning also affects pig spleen, the lower average spleen weight obtained for pigs fed the 30% cottonseed cake diet may be associated with the dietary free gossypol. The fact that only the percent liver, kidney and spleen yields, among the organs studied, appeared to have been affected in the present study would seem to be consistent with the findings of Buitrago *etal.,* (1970) and Ikurior and Fetuga, (1985) that gossypol is released from tissues and deposited in the liver and spleen, from where slow depletion occurs. In the present study, the mean values for percent liver, kidney and spleen for 0-20% which were not significantly different from each other but weresignificantly higher than that of

30% level of inclusion of UUCSC. The values for 30% UUCSC diet amounted to reductions of 26.09, 20.00 and 16.67% in the percent yields of the liver, kidney and spleen respectively in female pigs.

The significantly heavier ($P<0.05$) empty stomachs of the pigs fed the cottonseed cake diets compared to those on the control diet and the linear increases ($P>0.05$) in the lengths of the small and large intestines as the levels of cottonseed cake increased in the diets in this study, might be due to the increased level of dietary fibre in the diets. This observation agrees with the findings of Pond *et al.* (1981) who observed an increased gut dimensions as the levels of crude fibre increased in the diets of pigs. This suggests an adaptation mechanism by pigs in an attempt to accommodate more ofthe large quantities of bulky feedstuffs in their diets. In the present study, the average value of empty stomach yield for 10-30 % cottonseed cake level of inclusion (0.88%) was significantly higher than for the value of the control diet (0.77%). This suggests an increase of 11.36% in the gut dimensions of the female pigs fed the diets containing UUCSC.

The histopathological examination results of the organs of the pigs fed 30% UUCSC could probably be attributed to the presence of gossypol (a toxic substance) in the UUCSC fed to the animals. This was manifested at the highest level (30%) of UUCSC. It is obvious that when diets contain contaminants, the effect always results in histopathological damage to the body organs such as liver, kidney, heart, spleen, ovary and nodes. (Ewuola *et al.,*2009; Odetola *etal*., 2010).

In summary, the liver, kidney, spleen and empty stomach yields of the female pigs were significantly reduced when fed 30% UUCSC but the lung and the heart yields and lengths of the guts were not affected by the levels UUCSC fed to the pigs.Inclusion of up to 20% UUCSC in the diets of female pigs will not adversely affect the pathology of their organs.

5.5Reproductive Performance of Gilts

The gilts in this study were not affected significantly (P > 0.05) by the levels of cottonseed cake inclusion in the diets in terms of age at first heat. Age at first heat (190.67-196 days) obtained in this study is in agreement with the findings of several workers who recorded a range of 150-210 days (Hunter, 1980; Eusebio, 1990; Devendra and Fuller, 1989; Holness 2005). The gilts fed the 30% cottonseed cake diet had the longest (p>0.05) ages at first heat compared with gilts fed 0,10 and 20% cottonseed cake diets. Cottonseed cake appeared to have lengthened age at puberty though not to a significant effect.Lin-yun *et al.* (1984) observed delayed oestrus with increasing levels of gossypol in the diets fed to gilts. They indicated that gossypol appeared to disrupt the ovarian and hormonal activities in the cycling female pigs.

The gestation lengths (113.33 – 114 days) recorded in this trial for the gilts fed graded levels of cottonseed cake fell within the range of 111-117 days observed by Devendra and Fuller (1979) and Holness (2005). The finding of this trial is, however, not in agreement with view of Randel *et al.* (1992) who observed that the gestation lengths of gilts were delayed as the levels of cottonseed cake increased in their diets.

The stillbirths and litter size of the gilts showed no significant differences (P> 0.05) across the dietary treatments. This is an indication that the levels of cottonseed cake fed to the gilts did not adversely affect the number of piglets born. This is not in agreement with the findings of Abou-Donia (1976);Eisele (1986);Randel *et al.* (1992) and Rogers *et al.* (2005). These workers observed that the gossypol in cottonseed cake seemed to disrupt oestrous cycle, pregnancy and early embryo development in females. This, they said was as a result of the anti-fertility effect of gossypol.Lin-yun *et al.* (1984) observed that stillbirths increased as the levels of cottonseed cake increased in the diets of gilts and sows.

At these levels (0-30%) of inclusion of cottonseed cake in the diets of nursing sows, mortality before weaning, piglets weaned and weaning weights of piglets were not adversely affected. There were no clear cut trends in these measurements across dietary treatments. The findings of this study are contrary to the observations made by Lin-yun *et al*. (1984) and Randel *et al.*(1992). These workers recorded high piglet mortality before weaning.

The results of this study indicate thatcottonseed cake appeared to have lengthened age at puberty though not significant.The other reproductive parameters of gilts fed up to 30% undelinted undecorticated cottonseed cake diet were not adversely affected.

5.6Digestibility Trial

5.6.1Apparent Nutrient Digestibility

The similar dry matter intake of pigs across dietary treatments could be a reflection of similar feed intake of the pigs (Table 4.9 and 4.10). This view is supported by Ikurior and Fetuga (1985) and Fombad and Bryant (2004) who reported similar feed and dry matter intake by pigs fed cottonseed cake based diets.The observed significant decrease in dry matter digestibility across dietary treatments (Table 4.12) might be due to the increase in the dietary fibre as the levels of UUCSC increased in the diets of the weaner pigs. Frank *et al*. (1984), Yaakugh *et al.* (1988) and Bawa (2003) have earlier shown that as cell wall increased, apparent digestibility of organic nutrients also decreased.

The significant linear depression in crude protein digestibility observed across dietary treatments as the levels of the UUCSC increased, might be due to the corresponding increases in the levels of dietary fibre in the diets of the pigs. The average nitrogen loss also increased progressively from control to 30% UUCSC diets.Kuan *et al.* (1983), Frank

etal. (1984) andDegen *et al.* (2007) also reported linear decreases in the apparent crude protein and energy digestibility coefficients with increased fibre levels in the diets of pigs (4.40% in the control to !0.0% in thr diet containing 30% UUCSC. In this trial, the increased fibre content of the diets was observed to depress the digestibility of these nutrients.

The significant reductions in the apparent crude fibre and ether extract digestibility might be as a result of the dietary increases in the fibre content of the diets as UUCSC increased in the diets (Table 4.10). The observation made in this study is in agreement with the findings of Pollman *et al*. (1979) andCunha (1997) who noted linear decreases in the apparent nutrient digestibilities of ether extract and crude fibre as fibre increased in the diets of gravid swine. Other workers (Gargallo and Zimmerman, 1980 and Frank *et al.,*1984) also reported significant linear reductions in crude fibre digestibility which they said might be due to similar intake of dry matter across the dietary treatments. This observation was made by Ikurior and Fetuga (1985) and Fombad and Bryant (2004).

The observations made in this study are in agreement with the findings of Cunha (1997) in terms of ether extract, nitrogen free extract and crude fibre digestibility coefficients. Cunha (1997) observed that the cellulose and lignin represent most of the fibre in swine feeds and both have low digestibility coefficients for the pig. In this study, it is assumed that the increased proportion of the fibre components depressed crude fibre digestibility of the UUCSC diets. Other workers, Gargallo and Zimmerman, (1980), Frank *et al.,*(1984) and Low, 1985) have also reported significant linear decreases in crude fibre digestibility with increased concentration of dietary fibre.

5.6.2 Nitrogen balance

The observed insignificant differences across the dietary treatments in terms of nitrogen intake might be due to non-significant differences in feed intake and dry matter intake among the dietary treatments (Tables 4.9 and 4.10). Frank *et al.* (1984) observed that differences in nitrogen intake by growing pigs were largely due to differences in daily dry matter intake.

These workers also indicated that the relationship between voluntary feed intake and energy content of a diet is that pigs eat more of low energy diet than the high energy diet in an attempt to satisfy their energy requirements. Hence, in this trial the weanling pigs fed the 30% UUCSC diet consumed slightly more of this diet and thus the slightly higher nitrogen intake.

Faecal nitrogen is a product of nitrogenous substances that escape digestive activities along the gastrointestinal tract. The more these nitrogenous substances escape from the activities of the digestive enzymes, the higher the faecal nitrogen. In this study, fecal nitrogen increased gradually from 3.27 and 3.75 g per pig per day. in the control and diet with 10% UUCSC respectively to 4.18 and 5.39 g per pig per day in the 20 and 30%UUCSC diets respectively. the control diet up to 20% UUCSC diet but the 30% UUCSC diet was significantly the highest. The high levels of dietary crude fibre in the diets of the growing pigs have resulted in increased metabolic faecal nitrogen (Low, 1985 and Morgan and Whittemore, 1988). Hence, the significant increase in faecall nitrogen output of the 30% UUCSC diet. Malmlof and Hakansson (1984) reported that the fermentation of fibre in the caecum of the pig is affected by a proliferation of bacteria which retain nitrogen during their growth and are passed out in faeces resulting in faecal nitrogen loss.

The significantly higher apparent nitrogen retention by weaner pigs on the control diet (22.14g/pig/day)compared with those fed the UUCSC (19.89g/pig/day being the average of diets with 10-30% UUCSC) might bedue to the quality and the availability of amino acids of the diet. Just (1980), Frank *et al*. (1984) and Morgan and Whittemore (1988) have earlier linked nitrogen retention of a diet to its crude fibre content. These workers observed that nitrogen retention and protein digestibility declined with increasing levels of dietary fibre. In the present study, the apparent nitrogen retention was significantly affected by the levels of cottonseed cake fed to the pigs and hence the significantly better performance in terms of weight gain on the control diet compared to the 20 and 30% UUCSC diets.

In summary, the results of this trial suggest that the feeding of diets containingundelinted undecorticated cottonseed cake to weanling pigs depressed the digestibilities of most nutrients (dry matter, crude protein, ether extract and crude fibre) and this must have been responsible for the poor growth rates of the pigs at the 20 and 30% levels of inclusion of undelinted undecorticated cottonseed cake compared with other levels of feeding.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

The effects of feeding diets of undelinted undecorticated cottonseed cake on the growth, carcass, haematology,reproductive performance, nutrient digestibility and nitrogen balance of various classes of female pigs was evaluated in three different studies. This work was undertaken in order to find cheaper alternative protein source for compounding least cost rations for swine. It has been observed that the major protein sources (groundnut cake and soya bean cake) in the monogastric nutrition are very expensive and hence reduce the profit margin in the industry. The effect of cottonseed cake diets on the blood and reproductive parameters was investigated. Studies have shown that the gossypol in the cottonseed cake negatively affects the performance of pigs.

In each of the first and second studies, twenty four weaner pigs were randomly assigned to pens based on initial weight groups. There were three replications of the four treatments in randomized block design trials. At the end of the second study, twelve gilts were selected and slaughtered for carcass analysis while the remaining twelve were used for the reproductive study. The haematology of the pigs was also carried out. In the third trial, the digestibilities of nutrients in the cottonseed cake diets by young pigs were investigated. Twelve young pigs were randomly allotted to metabolic crates based on their initial weight groups. There were three replications of the four treatments in a randomized block design trial. The study consisted of 28-day trial of two adjustment and two collection periods of total urine and faeces. Statistical analyses of the data collected in the three studies were carried out.

The performance characteristics of all classes of pigs in the first and second studies were similar across the dietary treatments. Feed cost per kilogramme and feed cost per kilogramme gain decreased significantly as the level of cottonseed cake increased in the diets. The feeding of UUCSC diets did not affect all the haematological measurements (PCV, Hb, WBC and leucocyte counts) of the female pigs. The carcass quality of the pigs was not grossly affected by the level of UUCSC in the diets of the pigs. Stomach and organ weights (liver, kidney and spleen) were significantly affected while the gut lengths were similar across the dietary treatments. The reproductive measurements of the gilts were not affected by the levels of cottonseed cake fed to the animals. In the digestibility study, the apparent digestibility coefficients were significantly reduced as the level of cottonseed cake increased in the diets.

In conclusion, the feeding of up to 20 and 30% UUCSC in the diets ofweanling and adult female pigs respectively didnot adversely affect their growth performance. The inclusion of up to 30% UUCSC in diets of female pigs did not have adverse effect on their haematologicalindices and reproductive performance. The inclusion of 30% UUCSCin the diets of female pigs significantly reduced and increased the meatiness and fattiness of the carcasses of the female pigs respectively. Notwithstanding that the feeding of diets containing UUCSC in diets of young pigs reduced the digestibility of the nutrients; it is, however, cost effective to include cottonseed cake in the diets of all classes of pigs.

It is therefore recommended that:

1. Undelinted undecorticated cottonseed cake can be fed at up to 20% to weanlingpigs and up to 30% dietary level to adult female pigs without adversely affecting their performance and physiological state.

2. Undelinted undecorticated cottonseed cake can be fed at up to 30% level in the diets of all classes of female pigs without affecting their reproductive performance.

3. Undelinted undecorticated cottonseed cake should be fed only up to 20% in order to obtain good carcass quality.

4. For least cost rations, undelinted undecorticated cottonseed cake should be used to supplement the major protein sources in swine diets.

5. Further studies should be carried out to determine the possibility of incorporating higher levels of undelinted undecorticated cottonseed cake in swine diets.

6. Further studies should be carried out to ascertain the level of gossypol in the undelinted undecorticated cottonseed cake and in the diets containing cottonseed cake samples so that conclusive statements can be made on the effects of undelinted undecorticated cottonseed cake diets for swine.

6.1 CONTRIBUTION TO KNOWLEDGE

1. Inclusion of UUCSC in the diets of female pigs decreases the meatiness and increases the fattiness of the carcass by 7.7% and 6.8% respectively.

2. The % liver, kidney and spleen are significantly reduced when UUCSC is fed to female pigs

3. The % empty stomach of the female pigs is significantly increased by 11.4% when fed diets containing 30% UUCSC as compared with the lower levels of inclusion.

4. Inclusion of UUCSC in the diets of female pigs appears to lengthen the age to puberty.

5. Feed cost per kilogramme and feed cost per kilogramme gain are significantly reduced as the level of inclusion of UUCSC increased in the diets.

6.1 REFERENCES

Abou-Donia, M. B. (1976). Physiological effects and metabolism of gossypol.*Residue Review* 61:126

Abou-Donia, M. B. (1989). *In:* P. R. Cheeke (Ed.) Toxicants of Plant Origin. Volume IV: Phenolics. CRC Press, Boca Raton, Florida. Pp. 1-22.

Abou-Donia, M.B. and Lyman, C.M. (1971). Metabolic fate of gossypol: The mechanism of ^{14}C gossypol in laying hens. *Toxicology and Applied Pharmacology*17:4473-4486.

Abou-Donia, M.B.and Dieckett, J.W. (1975). Metabolic fate of gossypol: The metabolism of ^{14}C gossypol in swine. *Toxicology and Applied Pharmacology* 31:32-46.

Adams, R.,Geissman, T.A. and Edwards, J.D. (1960). Gossypol: A pigment of Cottonseed.*Chemistry Review*60:555.

Adebambo, O. A. (1982). Evolution of the genetic potential of Nigerian indigenous pigs. *In*: Proceedings of World Conference on Genetics as Applied to Livestock.Production. Madrid. Spain. Pp. 543-553.

Adeyemo, G.O., and Longe, O.G. (2007). Effects of graded levels of cottonseed cakeon Performance, haematological and carcass characteristics of broilers fed from day-old to 8 weeks of age. *Journal of Biotechnology* 6(8):1064-1071.

Aduku, A. O. (1992). *In:* Practical Livestock Feed Production in the Tropics. Asekome and Company Publishers, Zaria, Nigeria.

Albrecht, J.E., Clawson, A .J. and Smith, A. J. (1972). Rate of depletion and route of elimination of intravenously injected gossypol in swine. *Journal of Animal Science* 35 (5): 941-946.

Anderson, L.L., (1995). Pigs.*In:* Reproduction in Farm Animals. Hafez, Editor. 5th edition.Lea &Febier. Philadelphia, U.S.A. pp 275-287.

AOAC, (1995).Association of Official Analytical Chemists.*Official Methods of Analysis.*17th edition.AOAC, Washington, DC.

Ariel, A. (1998). Whole cottonseed in dairy cattle feeding: A review. *Animal Feed Science and Technology* 72: 1-2, 97-110.

Arshami, J. and Ruttle, J. L. (1988).Effects of diets containing gossypol on spermatogenic tissues of young bulls.*Theriogenology* 30:507-512.

Balogun, T.F., Aduku, A.O., Dim, N.I. and Olorunju, S.A.S. (1990). Undecorticated cottonseed meal as a substitute for soybean meal in diets of weaner and growing finishing pigs. *Animal Feed Science Technology* 30:3-4, 193-201.

Bawa, G.S. (2003). Effects of cooking time on the levels of antinutritional factors and the nutritive value of dolichos lablab (*Lablab purpureus* CV. Rongai) seeds for pigs. *Ph.D. Dissertation* submitted Department of Animal Science, Ahmadu Bello University, Zaria.

Baustad, B.M. (1974). Cottonseed meal in the feeding of growing pigs.*East African Agricultural and Forestry Journal* 40:1, 96-102

Bender, H.S., Saunders G.K. and Misra, H.P. (1988).A histopathological study of the effects of gossypol on female rat.*Contraception* 38:585.

Benjamin, M.M. (1978). *In:*Outline of Veterinary Pathology. The Iowa State University Press.ISBN 0-81338.

Bernardi, L.C. and Goldblatt, L.A. (1969).Gossypol.*In*: Liener, I.E. (Ed). Toxic Constituents of plant Foodstuffs. Academic Press, New York, pp. 158-266.

Bernard, J. K. (1999). Performance of lactating dairy cows fed whole cottonseed coated with cornstarch. *Journal of Dairy Science* 82:1305-1309.

Blair, R., Dent, J.B., English, P.R. and Raeburn, J.R. (1969). Protein, lysine and feed intake level on pig growth and feed effects. *Journal of Agricultural Science Cambridge* 72:379-388.

Boatner, C.H. (1948). *In:* Cotton products: Their Chemistry and Chemical Technology. Chapter 6. Hailey, A.E. (Ed). Willey Interscience Press. New York.

Brahma, J.E., Jarquin, R., Bressani, R., Gonzalez, M. and Elias, L.G. (1967).Effect of gossypol on iron-binding capacity of serum in swine.*Journal of Nutrition* 93:241-248.

Bressani, R., Elias, L.G., Zaghi, S., Mosorich, L. and Viteri, F. (1964). The protein quality of cottonseed protein concentrate prepared by two different processes.*Journal of Agricultural Food Chemistry* 14:493-496.

Bressani, R., Braham, J.E., Elias, L.G and Jarquin, R. (1966). Effect of mineral salts upon the performance of swine, chicks and rats fed gossypol, pigment glands and cottonseed meal. *In:* Altschul, A. M., Clawson, A.J., Ullrey, D. and Hill, F.W. (Eds.). *In:*Proceedings of conference on inactivation of gossypol with mineral salts. New Orleans, U.S.A. pp.76-99.

Buitrago, A.J, Clawson, A.J and Smith F.H (1970). Effects of dietary iron on gossypol accumulation in and elimination from the porcine liver *Journal of Animal Science* 31: 554-558.

Cabell, C.A. and Stevenson, J.W. (1966). Studies on the effect of orally administered iron salts upon the performance of swine and rats fed gossypol. *In:* Altschul, A.M., Clawson, A.J., Ullrey, D. and Hill, F.W. (Eds.) *In*: Proceedings of conference on inactivation of gossypol with mineral salts. New Orleans, U.S.A. Pp. 100 – 103.

Calhoun, M.C., Kuhlmann, S.W. and Baldwin, B.C. (1995). Cotton feed products : Composition, gossypol availability and toxicity.*In:* Eastridge, M.L. (Ed.) 2nd Natural Feed Alternative Symposium. St. Louis, MO, USA. Pp. 125-133.

Calhoun, M. C., Huston, J.E. and Calk, C. B. (1991). Effects of gossypol on digestive and metabolic function of domestic livestock. *Journal of Animal Science*99 (supplementary.):534-538.

Carter, F. L., Castelo, A. E. Foamton, V. L. and Terr, T. (1977). Chemical composition studies of seeds of the genus gossypium. *Phytochemistry*5: 1103-1112.

Chandler, P. (1992). Whole cottonseed has economic feeding value for dairy cattle. *Feedstuffs* 64:53, 10-15.

Chase Jr., C.C., Bastidas, P., Ruttle, J.L, Long, C.R. and Randel, R.D. (1989). Reproductive development and function of Brahma bulls fed diets containing gossypol. *Journal of Animal Science*67(suppl.):368 (Abstr.).

Chase Jr., C.C., Bastidas, P., Ruttle, J.L, Long, C.R. and Randel, R.D. (1994). Growth and Reproductive development in bulls fed diets containing gossypol. *Journal of Animal Science* 72:445-452.

Choyce, M.A. (1968). A review of Cotton Production in Nigeria.*Samaru Agricultural Newsletter* 10(3): 44-57.

Church, D.C and Pond W.G (1992).*In:*Basic Animal Nutrition and Feeding. 3rd edition.John Willey and Sons. New York.

Church, J.P., Jude, J.T., Young, C.W., Kabey, J.L. and Kim,W.W. (1984). Relationship among diet constituents and specific serum clinical components of subjects eating self selected diets.*American Journal of Clinical Nutrition* 40: 1338-1344.

Clawson, A. J., Smith, F. H., Osborne, J. C. and Barrick, E. R. (1961).Effect of protein source, autoclaving and lysine supplementation on gossypol toxicity.*Journal of Animal Science* 20:547-552.

Clawson, A. J. and Smith, F. H. (1966).Effect of dietary iron on gossypol toxicity and on residues of gossypol on porcine liver.*Journal of Nutrition* 89 : 307-310

Clawson, A. J., Gomez, G., Flores, Z. and Buitrago, J. (1975). Unextracted cottonseed indiets for monogastric animals. 2. The effect of boiling and oven versus sundrying following pretreatment with ferrous solution. *Journal of Animal Science* 40:648-654.

Cole, E.H. (1986). *In:* Veterinary Clinical Pathology. Saunders. Philadelphia, USA.

Cunha, T.I. (1997). *In:* Swine Feeding and Nutrition. 6th edition. Academic Press, New York. Pp. 161-182.

CTA.,Spore 132. (2007). Technical Centre for Agriculture and Rural Co-operation.Pigs: Assets under treat. Centre for Agricultural and Cooperation, Wageningen, Netherlands. *http://www.cta.int*

Dacie, J.V and Lewis, S.M. (1991).*In:*Practical Haematology 7th edition. ELBS, Church Hill, Livingstone, London.

Dafwang,I.I., Adebambo,O.A. and Adesehinwa, A.O.K. (2010).Status of Pig Production in Nigeria: An overview Of Current Practices, Problems and Prospects. *In:* Proceedings of the First Nigerian International Pig Summit.Adesehinwa, A.O.K., Akinfala, E.O, Omole, A.J. and Makanjuola, B.A. (Editors). Held at Institute of Agricultural Research & Training, Moore Plantation, Ibadan, Oyo State, Nigeria.

Danke, R.J. and Tillman, A.D. (1965).Effect of free gossypol and supplemental dietary iron on blood constituents of rats.*Journal of Nutrition* 87:493-494.

Degen,,L., Halas,V. andBabinszky, L. (2007). Effect of dietary fibre on protein and fat digestibilityand its consequence on diet formulation for growing and fattening pigs: A Review. *Acta Agricultural Scand Section A,* 57: 1-9.

Devendra, C. and Fuller, M.F. (1989).Pig Production in the Tropics. *In*: Oxford Tropical Handbooks. 4th edition.Oxford University Press, Oxford. UK. Pp. 126-135.

Duncan, D.P (1955). Multiple Range and Multiple F-Tests.*Biometics*11:1-42.

Dziuk, P.J.(1977). Reproduction in Pigs. *In*: Cole, H.H. and Cupps, P.T. (Eds.). Reproduction in Domestic Animals. Academic Press, New York. Pp.455-474.

Eisele,G.R. (1986). A perspective on gossypol ingestion in swine.*Veterinary and Human Toxicology* 28 (2): 118—122.

Eusebio, J.A. (1990).Pig Production in the Tropics. *In:* Intermediate Tropical Agriculture Series.3rdedition. Longman Group Limited. Longman House, Essex. UK. Pp. 96-101.

Ewuola, E.O. (2009).Organ traits and histopathology of rabbits fed various levels of dietary fumonisin B.1.*Journal of Animal Physiology and Animal Nutriton* 93: 726-731

FAO.(2002). Food and Agriculture Organisation.Global Pig Numbers – World Hog Population.*http://www.pigsite.com/articles/7*

Faulkner, R.C. (1974). Cotton in Nigeria: Research towards increased production.*Samaru Research Bulletin* 219.

Fombad, R.B. and Bryant, M.J. (2004).An evaluation of the use of cottonseed cake in the diet of growing pigs.*Tropical Animal Health and Production* 36 (3): 295-305.

Framptom, V.L., Pons Jr., W.A. and Kerr, T. (1960).A comparison of chemical properties of seeds of gossypium species.*Ecology and Botany* 14:197-199.

Frank, G.R. Aherne, F.X. and Jensen, A.N. (1984). The relationship between the performance and dietary digestibility by swine fed different levels of dietary fibre. Canadian *Journal of Animal Science* 64:196 (Abstract).

Frywell, P.A. (1969*). In:*The natural history of cotton tribe. Texas A. and M University Press, College Station.New York & London.

Gallup, W.D. (1928). Value of iron salts in counteracting the toxic effects of gossypol.*Journal of Biological Chemistry* 77:437-439.

Gallup, W.D. and Reider, R. (1934). Calcium salts in the detoxification of gossypol. *In*: Proceeding of Oklahoma Academy of Science 14:74-75.

Gargallo, J. and Zimmerman, D.R. (1980). Effect of dietary cellulose and neomycin on function of the caecum of pigs.*Journal of Animal Science* 51:121-126.

Geotch, A. L. and Owens, F.M. (1985).The effects of commercial processing method of cottonseed meal on site and extent of digestion in cattle.*Journal of Animal Science* 60:803-808.

Gu, Y. and Anderson, N.O. (1985). Effect of gossypol on the oestrous cycle and ovarian weight in rat.*Contraception* 32:491-495.

Hafez, E.S.E. (1995). FunctionalAnatomy of Female Reproduction.*In:* Reproduction in Farm Animals. Hafez, Editor. 5th edition.Lea &Febier. Philadelphia, U.S.A. pp 24-26.

Hale, F. and Lyman, C. M. (1957). Effect of protein level in the ration on gossypol tolerance in growing-fattening pigs.*Journal of Animal Science* 16:364-368.

Hale, F., Lyman, C.M. and Smith, H. A. (1958). Use of cottonseed meal in swine rations.*Texas Agricultural Experiment Station.Bulletin* 898.

Hammond, J. Jr., Masson, I.L and Robinson, T.J. (1971). *In:* Hammond's Farm Animals. 4th edition. Edwards Arnolds (Publishers) Ltd., London. Pp 21-25.

Hollon, B.F., Waugh, R.K. and Wise, G.H. (1958). Cottonseed meal as the primary protein supplement in concentrate feeds for young calves. *Journal of Dairy Science* 41:286-291.

Holness, D.H. (2005). Pigs.*In:* Coste, R. and Smith, A.J. (Editors). The Tropical Agriculturist. Macmillan Publishers Ltd., London. Pp. 1-6.

Hunter, R.H.F. (1980).*In*: Physiology and Technology of Reproduction in Female Domestic Animals.Academic Press.London &NewYork. Pp 1-44.

Ikurior, S.A. and Fetuga, B. L. (1984).Some anti-nutritional components in Nigerian cottonseed and cottonseed meals.*Nigerian Journal of Animal Production* 11(2):110-11

Ikurior, S.A. and Fetuga, B.L.A. (1985).The replacement value of Nigerian cottonseed meal for groundnut cake in diets for weaner-grower pigs. *Nigerian Journal of Animal Production*12(2): 13-19.

Ikurior, S.A. and Fetuga, B.L.A. (1988).Equi-protein substitution of cottonseed meal for groundnut cake in diets for weaner-grower pigs.*Journal of Science of Food and Agriculture* 44(1):1-8.

Jain, N.C. (1986).*In*: Schams Veterinary Haematology. 4th edition..Lea and Fibiger, Philadelphia.

Jarquin, R., Bressani, R., Elias, L.G. and Brahma, J.E. (1966).Effect of cooking and iron supplementation on gossypol toxicity in swine.*Journal of Agricultural Food Chemistry* 14: 275-277.

Jegede, J.O., Tegbe, T.S.B., Aduku, A.O. and Olorunju, S.A.S. (1994).The effect of feeding palm kernel meal on performance and carcass characteristics of pigs. *Nigerian Journal of Animal Production* 21:88-95.

Jimenez, D.A., Chandler, J.E., Adkinson, R.W., Nipper, W.A., Braham, A and Saxton A. M. (1989).Effect of feeding gossypol in cottonseed meal on growth, semen quality and spermatogenesis of yearly Holstein bulls.*Journal of Dairy Science* 72:1866 – 1875.

Jones, L.A. (1981). Nutritional values for cottonseed meal. *Feedstuffs* 53:19-28.

Jones, L.A. (1988). Gossypol toxicosis.*Journal of American Veterinary Association* 193: 292-94.

Jones, L.A. and Smith, F.H. (1977).Effect of bound gossypol and amino acid supplementation of glandless cottonseed meal on growth of weanling rats. *Journal* of *Animal Science* 44: 401-409.

Just, A. (1980).Factors influencing energy losses during metabolism of faecal losses in pigs.*In:*31st Annual Meeting of EAAP. Munch, pp 5-10.

Kelly, W.R., (1979). *In:*Veterinary Clinical Diagnosis. 2nd edition. Bailhere Tindall, London.

Kenneley, J.J. and Aherne, F.X. (1980). The effect of fibre addition to diets formulated to contain different levels of energy and protein on growth and carcass quality of swine. Canadian *Journal of Animal Science* 60: 385-393.

Kerr, L.A. (1989). Gossypol toxicosis in cattle.*Compendium.On Continuing Education for Practicing Veterinarians* 11:1139-1144.

Knabe, D.A., Tanksely Jr., T.D. and Hesby, J. H. (1979).Effect of lysine, crude fiber and free gossypol in cottonseed meal on performance of growing pigs.*Journal of Animal Science* 49(1):134-142.

Kornegay, E.T., Clawson, A.J., Smith, F.H. and Barrick, E.R. (1961). Influence of Protein Source on toxicity of gossypol in swine rations. *Journal of Animal Science* 20:597-504.

Kowell, J. (1968). Some physical properties of soils at Samaru, Zaria, Nigeria: Storage of water and its use by crops. Part 1: physical status of soil. *Nigerian Agricultural Journal* 5: 13-20.

Kuan, K.K, Stanogias,G.and Dunkin, A.C.(1983).The effect of cell-wall material from incerne leaf meal on apparent digestibility, rate of passage and gut characteristics in pigs. *Animal Production* 30:201-209.

Lamb, G.M. (1981). *In:* Manual of Veterinary Laboratory Rabbit Techniques, Ciba-Geigy, Kenya.

Lamidi, O.S. (2006). The use of some non-conventional protein sources for fattening cattle. Unpublished, *Ph.D. Dissertation.*Ahmadu Bello University, Zaria. Nigeria.

La Rue, D.C., Knabe, D.A and Tanksley Jr., T.D. (1985). Commercially processed glandless cottonseed meal for starter, grower and finisher swine.*Journal of Animal Science* 60(2): 495 – 502.

Lindsay, D.B (1977). The effect of feeding patterns and sampling on blood parameters.*Occasional publications: No.1 British Society of Animal Production*. Editor, D. Lister. Pp. 99-120.

Lindsey, T.O., Hawkins, G.E. and Guthrie, L.D. (1980). Physiological response of lactating cows to gossypol cottonseed meal rations. *Journal of Dairy Science* 63:562-573.

Lin, Y.C., Fukaya, T., Rikihisa, Y. and Walton, A. (1985). Gossypol in female fertility control: Ovum implantation and early pregnancy inhibited in rats. *Life Science* 37:39.

Lin, Y.C., Rikihisa, Graham, P. and Knight, J. (1986). Serum testosterone changes and residual gossypol content in reproductive and endocrine organs of male pigs fed a ration containing 450 parts per million gossypol. *Journal of Endocrinology* 7:13-21.

Lin-yun, Q.,Shu-haun, Z.,Gia-xiang, W. and Xin-min. (1984). Effect of cottonseed meal on reproductive performance in boars and sows.*Acta Veterinary et Zootech. Sinica* 15 (3): 157-162.

Lipstein, B and Bornstein, S. (1964). Studies with acidulated cottonseed oil soap stock: 2 Attempts to reduce its gossypol contents. *Poultry Science* 43: 694 – 701.

Liu, B.S. (1957). A tentative idea of the use of cooking cottonseed oil for fertility control. Shanghai *Journal of Clinical Medicine* 6:43-50.

Liu, G.Z. and Segal, S.J. (1985).Introduction and history of gossypol.*In:* Segal, S. J. (Ed.). Gossypol, a potential contraceptive for men.Plenum Press. New York. Pp.1-7.

Love, R.J., Peacock, A.J. and Evan, G. (1990). Premature farrowings caused by feeding cottonseed meal. *Australian Veterinary Journal* 67(6):223-226.

Low, A.G. (1985). The role of dietary fibre in digestion absorption and metabolism. *In:*Proceeding of the 3rd International Seminar on Digestive Physiology in the Pig. Report No 250 Copenhagen, Denmark.

Lyman, C.M. and Midmeri, C. (1966).Mode of action and sites of concentration and metabolic fate of gossypol with mineral salts.*National Cottonseed Products Association, Memphis,* Tennessee, pp.43-53.

Malmlof, K and Hakansson, J. (1984).The effect of dietary fibre level on the deurnl pattern of urinary nitrogen excretion in swine.*Swedeen. Journal of Agricultural Research* 14: 53-57.

Martinez, W.H., Framptom, V.L. and Cabell, L.C. (1961).Effect of gossypol and rafinose on the lysine content and nutritive quality in meal from glandless cottonseed.*Journal of Agricultural Food Chemistry*15:427 – 432.

Morgan, S. E. (1989). Gossypol as toxicant in livestock.*Veterinary Clinic of North America Food and Animal Practice* 5(2): 251 – 263.

Morgan, C.A. and Whittemore, C.T. (1988).Dietary fibre and nitrogen excretion and retention by pigs.(Short communication).*AnimalFeed Science Technology* 19: 185-189.

Moura, M.P. and Lavorenti, A. (1979).Effect of increasing amounts of cottonseed meal on performance and carcass characteristics of growing and finishing pigs. *Bulletin de Industria Animal* 36(1): 23 – 38.

Mujahid, A., Abdullah, M., Barque, A. R. and Gilani, A. H. (2000).Nutritional value of cottonseeds and its derived products. I. Physical fraction and proximate composition. *Asian-Australasian Journal of Animal Science* 13(3): 348 – 355.

NCPA.(1999). National Cottonseed Products Association.Cottonseed and its products.CSIP, 10th (edition) NCPA, Cordova, TN. USA.*http://www.cottonseed.com*

NCPA (2002). National cottonseed Products Association. Cottonseed feed product Guide. NCPA, Cordova, TN, USA.*http://www.cottonseed.com/publications.*

Neser, J. A., Grimbeek, P. J., Langford, M. J. and Nel, P. N. (1988).Gossypol poisoning in pigs.*Journal of South African Veterinary Association* 59(2):104 – 110.

Nigerian Metrological Agency, (2007).Weather Forecasting Station, Makurdi, Benue State.

Nikokyris, P., Kandylis, K., Deliginnis, K. and Liamiadis, D. (1991). Effects of gossypol content of cottonseed cake on blood constituents in growing fattening lambs. *Journal of Animal Science* 74: 4305-4313.

Niswender, T.M., Nett, M. and Akbar, AM. (1995). The hormones of reproduction. *In:* Reproduction in Farm Animals. Hafez, Editor. 5th edition.Lea &Febier.Philadelphia, U.S.A. pp57-81.

NRC.(1990). National Research Council. United States-Canadian Tables of feed composition (6th edition). National Academy Press, Washington D.C. USA.

NRC.(1998). National Research Council.Nutrient Requirements of Swine.(10th edition).National Academy Press Washington D.C. USA.

Nwokolo, E. N., Bragg, D.B. and Saben, H.S. (1977). A nutritive evaluation of palm kernel in poultry rations. *Tropical Science* 19:147 – 154.

Nzekwe, H. N. and Olomu, J.M. (1984).Cottonseed meal as a substitute for groundnut meal in the rations of laying chickens and growing turkeys.*Journal of Animal Production Research* 4:57 – 71.

Odetola, O.M.., Ewuola, E.O, Raji, A.M and Olumide, M.D. (2010). Serum biochemistry and organ histopathology of rabbits fed graded levels of whole kenaf (Hibiscus canabinus) seed meal. *In*: Proceedings of the 15th Annual conference of Animal Science Association of Nigeria. University of Uyo, Nigeria. Ifut ,O.J., Inyang, U.A., Akpan, I.P and Ebeso, I.E. (Editors)

Ogundipe, S.O., Olurunju, S.A.S. and Sekoni, A.A. (1990). Utilization of undecordicated undelinted cottonseed cake in poultry rations. 2: Experiment with laying hens. *In:* Proceedings of the 15th Annual Conference of the Nigerian Society for Animal Production, Ogun State University, Ago Iwoye, Nigeria.

Ogunfowora, O., Olayemi, J. K., Fetuga, B.L. and Amogu, U. (1980).An evaluation of the state of development and economics of pig production in Nigeria.*Report to Federal Livestock Department,* Lagos. Nigeria.

Onwudike, O.C. (1986). Palm kernel as a feed for poultry. *Animal Feed Science Technology* 16:179-202.

Osuhor, C.U. (2007). Utilization of cottonseed and poultry litter rations by Yankasa sheep fed a basal diet of maize stover.Unpublished,*Ph.D Dissertation*, Department of Animal Science, Ahmadu Bello University, Zaria.

Oyenuga, V.A. (1968).*In:*Nigerian foods and feeding-stuffs. (3rd edition).University of Ibadan Press, Ibadan, Nigeria.

Pathiraja, N., Rekwot, P.I., Oyedipe, E.O., Alhasan, W.S. and Dawuda, P.M. (1986).Studies on the pig production systems in Southern Zaria. *In:* Proceedings of the 11th Annual Conference of the Nigerian Society for Animal Production. Ahmadu Bello University, Zaria, Nigeria. 1986. Pp. 133-138.

Phelps, R.A., Shenstone, F.S., Kemmer, A.R. and Evans, R.J. (1965). A review of cyclopropenoid compounds: Biological effects of some derivatives. *Poultry Science* 44: 358-394.

Pollman, D.S, Danielson, D.M and Peo Jr. E.R (1979).Value of high fibre diets for gravid swine.*Journal of Animal Science* 48:1385-1393.

Pond, W.G., Yen, J.T., Linvall,R.N.and Hill,D. (1981).Dietary alfalfa meal for genetically obese and lean growing pigs: Effect on body weight gain and on carcass and gastrointestinal tract measurements and blood metabolites. *Journal of Animal Science* 51: 367-373.

Pondey, S. N and Thejapa, N. (1975). Study on relationship between oil, protein and gossypol in cottonseed kernels. *Journal of American Oil Chemistry Society* 52:312.

Pons, W.A., Hoffpauir, C. L. and Hopper, T. H. (1953).Gossypol in cottonseed; Influence of variety of cottonseed and environment.*Journal of Agricultural Food Chemistry* 1:1115-1118.

Pons, W.A. and Hoffpauir, C.L. (1957). Determination of free and total gossypol in mixed feeds containing cottonseed meal. *Journalof Association AgriculturalChemistry* 4:1068-1069.

Ramirex, V. D. (1973).Endocrinology of Puberty.*In:* Handbook of Physiology and Edocrinology II. Pp.1-28.

Randel, R.D., Chase Jr., C.C. and Wyse, S.J. (1990).Effect of gossypol on reproduction in domestic livestock.*Journal of Animal Science* 68(supplementary): 405 – 415.

Randel, R.D., Chase Jr., C.C. and Wyse, S.J. (1991).Potential infertility agent for males.*Annual Review of Pathology and Toxicology* 24:329 – 360.

Randel, R.D., Chase Jr., C.C. and Wyse, S.J. (1992).Effects of gossypol and cottonseed products on reproduction of mammals.*Journal of Animal Science*70:1628 – 1638.

Ranjhan, S.K. (1990*). In:*Animal Nutrition in Tropics. Vikas Publishing House, New Delhi, India. Pp. 387-428.

Reiser, R. and Fu, H.C. (1992).The mechanism of gossypol detoxification by ruminant animals.*Journal of Nutrition* 76:215-216.

Rekwot, P.I. (1999). Influence of biostimulation on onset of puberty and postpartum ovarian function in Bunaji and Friesian X Bunaji cattle.Unpublished,*PhD Dissertation*.Ahmadu Bello University, Zaria.

RIM. (1992). Federal Department of Livestock and Pest Control Services,*Nigerian Livestock Resources*Volume II: National Synthesis by Resource Inventory and Management Ltd. (RIM).

Rincon, R., Smith, F.H. and Clawson, A. J. (1978).Detoxification of gossypol in raw cottonseed and the use of raw cottonseed meats as replacement for soybean meal in diets for growing-finishing pigs.*Journal of Animal Science* 47(4):865 – 873.

Rogers, P.A.M., Hanaghan, T.P. and Wheeler, (1975).Gossypol poisoning in young calves.*Iris Veterinary Journal* 29: 9-13.

Rogers, G. M., Poore, M. H. and Paschal, J.C. (2002).Feeding cottonseed products to cattle.*Journal of Veterinary Clinic and Food Animal Practice* 18: 267 – 294.

Rutknowski, A. (1971). The feed value of rape seed meal.*Journal of American Oil Chemistry Society* 48: 863-868.

S.A.S., (2000).Statistical Analysis System Institute Inc. *Users' Guide Statistic Version* 6.03. Carry, North Carolina, USA.

Schroff, C., KaltenbachC.C., Graber, J.N. andNiswender, G.D.(1971).Maintenance of corporal luteain hypophysectomized ewe.*Journal of Animal Science* 33: 268-271.

Sewell, W.E. (1943). Detoxification of cottonseed meal for hogs.*Alabama Polytechnic Institute of Agriculture Experimental Station Bulletin* 259.

Skutches, C. L., Herman, D.L. and Smith, F. H. (1974). The effect of intravenous gossypol injection on iron utilization in swine. *Journal of Nutrition* 103:851-853.

Smalley, S.A. and Bicknell, E. J. (1982).Gossypol toxicity in dairy cattle.*Compendium on Continuing Education for Practicing Veterinarians* 4:378-382.

Smirnova, M. I. (1934). Inter- and intra-specific variations in gossypol.*Priklad Botany, Genetics and Selection* 159 (11): 227 – 236.

Smith, H. A. (1957). The Pathology of gossypol poisoning.*American Journal of Pathololog*y 33:52-355.

Smith, I.M. (1959). The blood picture of normal zebu in Uganda. British Veterinary *Journal of Pathololog*y33 : 353-356.

Smith, F. H. (1965). Determination of free and bound gossypol in swine tissues.*American Chemical Society* 42:155 – 147.

Smith, F.H. and Clawson, A. J. (1966).The effects of mineral elements on the toxicity of gossypol and its accumulation in the organs of swine.*In:* Altshul, A. M., Clawson, A. J., Ullrey, D. and Hill, F.H. (Editors). Proceedings of conference on inactivation of gossypol with mineral salts.New Orleans, USA. 4-5 April, 1966.

Spruill, D.G., Hays, V.W. and Cromwell, G.L. (1971). Effects of dietary protein and iron on reproduction and iron related blood constituents in swine. *Journal of AnimalScience* 33:376-383.

Tanksley Jr., T.D. (1990). *In:*Cottonseed meal: Non-traditional feed sources for use in swine Production. Thacker, P.A. and Kirkwood, R. N (Editors). Butterworth, Stoneham, M.A. USA.

Thibault, C.and Levasseur, M.C. (1995). Reproductive Life Cycle.. *In:* Reproduction in Farm Animals. Hafez, Editor. 5th edition.Lea &Febier. Philadelphia, U.S.A. pp 82-100.

Veulterinora, M. (1991).Nutrition and Erythropoiesis.*In*: C.R.C. Handbook of Nutritional Requirements in Functional Context. M. Rechcigi (editor). Boca Ratio, CRC. Press, Pp. 65-74.

Wikipedia, (2010).*Wikipedia –Gossypol: htt;//en.wikipedia.org*

Withers, W.A. and Carruth, F.E. (1917). Iron as an antidote to cottonseed meal injury. *Journal of Biological Chemistry* 32:245-248.

Withers, W.A. and Carruth, F.E. (1915). Gossypol – a toxic substance in cottonseed meal. A preliminary note. *Science* 41:324-326

.

Wu, Y.M. Chapel, S.C. Flickinger, G. L. (1981). Effects of gossypol on pituitary ovarian endocrine function, ovulation and fertility in female hamsters.*Contraception*. 24:259-264.

Yaakugh, I.D.I., Tegbe, T.S.B., Olorunju, S.A,S., Aduku, A.O. and Njoku, P.C. (1988) The digestibility of nutrients by young pigs fed diets in which brewers' dried grains (BDG) replaced maize. *Nigerian Journal of Animal Production* 15: 49-55.