# INFLUENCE OF CASTRATION METHODS ON THE PERFORMANCE AND MEAT QUALITY OF WEANER RABBITS

**BY**

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**MTech/SAAT/2018/7929**

**DEPARTMENT OF ANIMAL PRODUCTION**
**FEDERAL UNIVERSITY OF TECHNOLOGY**
**MINNA**

**AUGUST, 2023**

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**A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGERIA, IN PARTIAL FULFILMENTOF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OFTECHNOLOGY IN ANIMAL PRODUCTION**

**AUGUST, 2023**

## DECLARATION

I hereby declare that this thesis titled "**Influence of castration methods on the performance and meat quality of weaner rabbits**" is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from other sources (published or unpublished) has been duly acknowledged.

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## CERTIFICATION

This thesis titled **"Influence of castration methods on the performance and meat quality of weaner rabbits**" by WAMBAI, Saidu Ismaila (MTech/SAAT/2018/7929) meets the regulations governing the award of the degree of Master of Technology of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

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## DEDICATION

This project work is dedicated to Almighty ALLAH. It is also dedicated to my late father, Alh. Ismaila Wambai Doma (Galadiman Yelwa- Ediya).

## ACKNOWLEDGEMENTS

All praises and adoration be to Almighty Allah, who guided me towards the path of achieving this goal. My salutation goes to the noblest Prophet and Servant of Allah, Muhammad (Peace be upon Him) who was sent as a mercy to mankind. I will like to thank the Head of the Department of Animal Production in the person of Prof. D. N. Tsado for his kindness and support. I am indeed very grateful to my Supervisors, Prof. D. N. Tsado and Dr. (Mrs.) K. E. Akande for their patience, resilience and guidance in ensuring the success of this study. I am extending my profound gratitude to Prof. T. Z. Adama, Dr. A.A. Malik, Dr. A. Usman and all the academic and non-academic staff, technicians and my colleagues in the Department of Animal Production, Federal University of Technology, Minna, for their contribution towards the success of this study.

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## ABSTRACT

A 12-week-study was conducted to evaluate the influence of castration methods on the performance and meat quality of weaner rabbits. A total of 24 rabbits were used in this experiment. The rabbits were allotted into three (3) treatments, with each treatment having four (4) replicates; with two (2) rabbits per replicate. Treatment one (1) were intact males (control group), treatment two (2) were Unilateral castrates and treatment three (3) were bilateral castrates. The rabbits were served the same diets (concentrates and cowpea haulms). The data collected on growth performance, carcass characteristics, apparent digestibility coefficient and meat quality were processed and subjected to statistical analysis using SPSS version 23 (2021). Result of growth performance revealed no significant ($p>0.05$) difference in initial body weight (IBW), final body weight (FBW), average feed intake (AFI), protein intake (PI) and protein efficiency ratio (PER), but showed higher significant ($p<0.05$) difference in total body weight gain (TBWG) and energy efficiency ratio (EER) in favor of bilateral castrates. The result of carcass characteristics showed no significant ($p>0.05$) difference in all the measured parts except in the head and penis. Apparent digestibility coefficient values indicated that intact males (non castrates) had higher significant ($p<0.05$) values above the remaining treatment groups in crude protein (CP), crude fibre (CF), and dry matter (DM) digestibility. Bilateral castrates has significant ($p<0.05$) values in Ash digestibility. In NFE value, intact males and bilateral castrates showed statistical ($p<0.05$) similarities but showed significantly ($p<0.05$) higher values above unilateral castrates. Meat quality result showed no significant ($p>0.05$) difference among the treatment groups in cooking loss and cooking yield. The pH values of non-castrates and bilateral castrates are statistically the same, but bilateral castrates differs significantly ($p<0.05$) from the unilateral castrates. Bilateral castrates showed higher significant ($p<0.05$) values in water holding capacity over the control group. It can be concluded that bilateral castration of male rabbits produced significantly higher weight gain and average body weight gain as well as better feed conversion ratio and energy efficiency ratio.

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# CHAPTER ONE

# 1.0 INTRODUCTION

## 1.1 Background to the Study

Nigeria is a populous and sundry country with the high prevalence of nutritional deficiency varying widely across it borders owing to high cost and inadequate supply of animal protein (Adekunmi *et al*., 2017). As at 2019, Nigeria per capita daily protein intake (45.4 g) was lower than both the Food and Agriculture Organization (FAO) recommended minimum per capita daily protein intake (53.8 g) and the global daily intake (64 g), indicating that the country is faced with protein deficiency. The increasing demand for animal protein necessitates the need to intensify livestock production. The average estimated crude protein requirement of an adult is between 65 – 85 g per person per day and 35 g of the crude protein requirement should come from animal source (Adetunji and Adepoju, 2011). Increased rabbit production is a fast means of meeting the animal protein requirements of the Nigerian populace (Iyeghe-Erakpotobor *et al.,* 2002). The domestic rabbit (*Oryctolagus cuniculus*) production had been on the increase in Nigeria (Megan *et al*., 2015; Dikko *et al*., 2011). The production of rabbit is sustainable because the feeding does not compete with that of man as much. Rabbit grows as fast as the modern day broiler chicken and utilize feed protein more efficiently. Rabbits have relatively short gestation interval of 30 to 31 days, producing 4 – 5 litters per year and consisting of 6 – 8 kitten on the average (Biobaku and Oguntona, 1997).

Feed accounts for about 70 % of the total cost of production in livestock and it's a major threat to the expansion of the sector in Nigeria, (Ojebiyi and Saliu, 2014). Hence, efforts are being made by animal scientists and nutritionists to replace the costly conventional feed ingredients with locally-available and cheaper alternatives. For instance, cowpea, a legume crop, contains adequate amounts of protein, essential amino acids, dietary fibre

and essential minerals and vitamins when compared to the other common legumes (Bhat and Karim, 2009). Ayanwale *et al.* (2001), Adeniji and Jimoh (2007) and Tabinda and Butt (2012) used *Colocasia esculentum*, rumen content and chicken intestine to feed rabbits, pullet chicks and fish fry, and the results showed feed conversion ratio, weight gain and carcass characteristics were sustained, with no detrimental effects on the animal's performance.

Castration in rabbit involves cutting blood supply to the testes either by crushing the blood vessels or elevating temperature of the testes (Dikko *et al*., 2011; Frandson and Spurgeon, 1992). Castration in rabbits have produce better meat quality; and the castrates grow faster than intact males (Saheed *et al*., 2020). According to Devendra and Mcleroy (1988), castrated rabbits have no sex life thus, have higher feed intake and feed conversion ratio. Furthermore, Jehl *et al.* (2000) reported that castrated males had higher carcass adiposity than intact males. Castrated rabbits had higher feed intake and better feed conversion ratio compared to intact males at day 99 – 141 (Jehl *et al*., 2000). Hence, castration in rabbits can be used to improve the performance in terms of better feed conversion and body weight gain of mixed rabbits breed. Saheed *et al.* (2020) reported significant ($p<0.05$) differences between castrates and non-castrate's weaner rabbits fed forage and concentrates, in total weight gain (TWG), castrates showed significant superiority (304.33) over non castrates (204.33). In average weight gain (AWG), castrates showed significant superiority (38.04) over non castrates (25.54). The average feed intake of the study reported by Saheed *et al.* (2020) showed no significant ($p>0.05$) difference among the castrates and non castrates. These authors also reported that castrates had significantly higher values in all growth parameters and concluded that castrates had better meat quality and grew faster than the non-castrates.

## 1.2 Statement of the Research Problem

The demand for animal protein in Nigeria is still high and rabbit have the potentials to fill some gaps. The assessment of the effects of unilateral castration of rabbits on growth performance, nutrient digestibility and carcass characteristics have not been fully established.

Literature shows that most of the research work carried out on rabbit castration has been done bilaterally. Saheed *et al.* (2020) recorded significant performance of rabbits castrated bilaterally over non-castrates in final and total body weight gain. However, there is limited literature showing effect of unilateral castration on rabbit's performance, hence the need for this work.

Most of the researches done on rabbit's castration were done bilaterally. So, this study aimed at investigating the influence of unilateral method of castration on rabbit's performance, carcass characteristics, apparent nutrient digestibility and meat quality of mixed rabbit breeds.

## 1.3 Justification for the Study

Castration has some effects on growth performance and meat characteristics of most animals (Lirette *et al.,* 1984; Desmoulin *et al*., 1990; Bonneau *et al*., 1996). Also, Georgiev *et al.* (2011) reported neutering induces weight gain in male rabbits. The feed conversion ratio investigated by Jehl *et al.* (2000) revealed significantly higher feed conversion efficiency in castrates above intact males between 36 -75 days of age. Saheed *et al.* (2020) recorded significance performance of rabbits castrated bilaterally over non castrates in final and total body weight gain.

Most of the research done on rabbit's castration were done bilaterally. So, this study aimed at investigating the influence of castrations of on rabbit's performance, carcass characteristics, apparent nutrient digestibility and meat quality of mixed rabbit breeds.

### 1.4 Aim and Objectives of the Study

The study aimed to investigate and compare the influence of unilateral and bilateral methods of castration on the performance of the mixed breeds of weaner rabbits.

The objectives of this study were to:

i. determine the growth performance and apparent nutrient digestibility of unilateral and bilateral castrates and non-castrates weaner rabbits;
ii. assess the effect of castration methods on the carcass characteristics of weaner rabbits; and
iii. evaluate the influence of unilateral and bilateral castration methods on meat quality of castrates and non-castrates weaner rabbits.

# CHAPTER TWO

# 2.0 LITERATURE REVIEW

## 2.1 Scientific Classification of Rabbit

Rabbits, also known as bunnies or bunny rabbits, are small mammals in the family *Leporidae* (which also contains the hares) of the order Lagomorpha (which also contains the pikas). *Oryctolagus cuniculus* includes the European rabbit species and its descendants, the world's 305 breeds of domestic rabbit (FAO, 2018). *Sylvilagus* includes 13 wild rabbit species, among them the seven types of cottontail. The European rabbit, which has been introduced on every continent except Antarctica, is familiar throughout the world as a wild prey animal and as a domesticated form of livestock and pet. With its widespread effect on ecologies and cultures, the rabbit is, in many areas of the world, a part of daily life as food, clothing, a companion, and a source of artistic inspiration. Although once considered rodents, lagomorphs like rabbits have been discovered to have diverged separately and earlier than their rodent cousins and have a number of traits rodents lack, like two extra incisors.

## 2.2 Breeds of Rabbit

The United States Department for Agriculture (USDA) has classified rabbits according to size, weight and type of pelt. Small rabbits weigh about 1.4 – 2 kg at maturity, medium breeds 4 – 5.4 kg, and large breeds 6.4 – 7.3 kg (USDA, 1972). Based on this classification, two most popular breeds for meat production include the New Zealand white and the Californian. These breeds are most popular because they combine white fur and good growth characteristics. The New Zealand rabbits are slightly larger than the Californian, 4 – 5.9 kg and 3.6 – 4.5 kg respectively. The New Zealand rabbit has a completely white, red or black body, whereas the Californian is white with coloured nose, ears and feet. The two most popular rabbits for fur production are the Rex and the

American Chinchilla. The Rex is slightly smaller than the American Chinchilla, 3.2 kg versus 4.5 kg respectively (USDA, 1972). At present there are many breeds of rabbit being used for both meat and skin production in developing countries. For example in Brazil there are the New Zealand White, Californian, Chinchilla, Palomino, Hollander, Rex, Dalmation, Flemish Giant, New Zealand Red, Barboleta, Champaigne, d'Argent; in Ecuador there are the New Zealand White, Blue Viennese, Silver German and Angora. In Malawi there are the New Zealand White, Californian, Angora, Rex; in Nepal there are the Californian Hybrids, while in Ghana there are the Thuringa, Blue Viennese, Flemish Giant, Checkered Giant, Lop, Californian, Alaska, and the Yellow Silver (USDA, 1972).

In Nigeria, the commonest breeds include the New Zealand White, Californian, Angora, Rex amongst others (Aduku and Olukosi, 1990). All of these breeds of domestic rabbits are descendants of the European wild rabbit, *Oryctolagus cuniculus* (Aduku and olukosi, 1990). Although many of these are breeding successfully in various countries, the most popular breeds are the New Zealand White and the Californian rabbits. These two breeds are also the most popular in commercial rabbit industries in the developed countries. The various production traits such as fertility, growth and feed conversion rates when considered, under commercial conditions, New Zealand White and Californian rabbits are amongst the better breeds available for meat production (Bombeke *et al*., 1975).

### 2.3 Status of Rabbit Industry in Nigeria

Rabbit production in Nigeria could be described, at best, as rudimentary, developing or emerging when compared with France, Hungary, China, United States, etc. This is evident from the small rabbit keeping population in which gender bias and sociological status of rabbit keepers, weak inventory of rabbit keeping infrastructure, low consumption rate of rabbit meat, absence of organized or thriving market for rabbit meat products, and

lack of governmental and institutional support, limit the expansion of rabbit production. Employing the above for parametric assessment of meat animal production and consumption in Nigeria: it falls sixth rate after beef; fish; mutton; goat-meat (chevon) and bush meat or game animals.

The above notwithstanding, rabbit production is witnessing a burgeoning public interest due to several reasons amongst which economic initiatives to source for alternative meat types and animal protein ranked highest. Further encouragement is obtained from institutional and governmental promotion of rabbit keeping. There is also increasing public awareness of rabbit meat nutritional characteristics: high protein; low sodium, fat and cholesterol levels, which compared favourably with the local bush-meat. Hobbyist rabbit keeping is also gaining popularity amongst residents of highbrow settlement in Nigeria (Onifade *et al.*, 1999).

## 2.4 Housing Management of Rabbits

Rabbit keeping in Nigeria is both intensive and semi-intensive, though some scattered cases of free-rein (free range) backyard rearing were recorded. Rabbits are frequently housed in cages of varying dimensions that are usually smaller than the conventional spatial requirements. This is particularly evident in urban and densely populated areas where a representative cage measurements for a pair of rabbits are 48 x 36 x 44 cm for the length, width and height unlike the cages in the institution that measured 60 x 60 x 50 cm, respectively (Onifade *et al.*, 1999). Spatial allowance tends to be bigger in the rural areas where space is non-limiting, and there are local materials for making the houses. In the rural areas, houses/hutches are made from planks, woods or wood barks or bamboo. Houses built with mud having cemented or non-cemented floors are also common. Institutional or research centre's keep rabbits in cages made of iron, steel or wood. Adaptation of abandoned layer cages into rabbit housing cages were also observed. Local

people use wooden cages because of cheaper cost although they are less durable. Most local rabbit houses do not have deep litter floor, the left-over straws from green leaves fed are kept on the floor for 2-3 days after which they are swept out, and there is continuous replacement. Expectedly, rabbits reared on the floors are dirtier than those kept in cages; the incidence of disease may be greater in rabbits reared on the floors because the rabbits are in contact with their excreta. Depending on the location of housing, the cages may be separately erected on bamboo or wooden legs raised platforms. Roofs are made of grasses or palm fronds, planks, broken asbestos or at best used corrugated iron sheets. Houses constructed with bamboo or planks provide sufficient ventilation, but the construction exposed the rabbits to cold during the wet season and the long harmattan period of northern cold winds in West African countries (Onifade *et al.,* 1999).

### 2.5 Feeds and Feeding of Rabbits

Like housing, feeds and feeding of rabbit in Nigeria remain traditional and rudimentary. Feeds are served in feeding troughs made of wooden or earthen material, iron, metal, half-split bamboo, and cans or tins of beverages. The use of metal fabrications as utensils is usually placed on the floor; thereby wastage is minimized. Feeds are frequently and carefully sprinkled with little amount of water to cause some stickiness to reduce dustiness and wastage. Feeds are usually unpelleted except commercially prepared diets. Diets of rabbits in Nigeria are primarily forages, grasses and legumes. Indeed in most rural, peri-urban and sub-urban areas, rabbits are fed solely on vegetables- green leaves. In Nigeria, it is a common belief that rabbits cannot be raised without green leaves as supplementation. Onwudike (1995) made the observation that Nigerian rabbit keepers believed that the access of rabbit to green feeds allows for better rate of growth when compared with rabbits which do not have access to green feeds. Various leaves are fed,

however, edible vegetables (for humans) are seldom fed except when overgrown or when the parts are not consumed (e.g. carrot leaves or stems of green vegetables). Pasture cultivation for rabbit feeding is non-existent despite the sole dependence on green plants. Thus, feed security becomes critical during the dry season particularly in the Northern Nigeria. This is because many of the green feeds traditionally fed to rabbits are annuals that are not high yielding. Thus, it is not uncommon for rabbits to lose weight at this period, and breeding is also somewhat affected. Most smallholder farmers are not aware of the superior nutritional value of leguminous tropical plants such as *Pueraria, Stylosanthes, Centrosema*. The rabbit keepers are, however, mindful of some toxic weeds that are frequently determined using goat (West African Dwarf) as indicator. Forages such as *Panicum maximum* (Guinea grass), *Tridax procumbens*, potato leaves, cassava leaves and haulms, *Talinum triangulare*, though less nutritive are commonly fed to rabbits by local people. Feeding of the leaves of multipurpose leguminous trees like *Leucaena leucocephala, Gliricidia sepium, Acacia albicans* and the lesser known types are carried out mostly in research institutes.

### 2.6 Health Management of Rabbits

Rabbits in Nigeria do not suffer from any peculiar diseases. Frequent attack of skin disease (mange) is common and this is treated locally using sulphur ointment, rubbing of a mixture of used engine oil and salt or kerosene or at best ivermectin upon veterinary consultation. There is an increasing awareness to seek veterinary attention, but most farmers do not attend or have poor access to veterinary clinics. Cases of coccidia infection are also rampant, but the farmers apparently do not understand the symptoms. Some rabbit keepers do put the animals on unprescribed medication of terramycin (oxytetracycline) or in combination with aspirin (acetasalicylic acid). Some green leaves as *Aspilia africana* locally called ‘yunyun’ and pawpaw (*Carica papaya*) leaves are fed to rabbits for their

medicinal properties against diarrhoea. We could not ascertain fully during the survey the extent of morbidity of rabbits, and the implications on their productivity in Nigeria. However, it was estimated that the overall mortality between birth and marketing (irrespective of the categories) was between 30-40% being highest in the young ones is common in Nigeria.

### 2.7 Marketing and Consumption of Rabbit in Nigeria

Certainly, markets for rabbit meat exist in Nigeria. However, there is no organized or festival-targeted marketing and sales of rabbit in Nigeria. This is unlike beef cattle, sheep, goats, and broiler or spent laying chickens. The reason could be the subsistence level of rabbit production. Nonetheless, the increasing popularity of rabbit among the populace is gradually expanding the market for rabbit meat. Rabbits in Nigeria are either marketed live or processed. The processing involves removal of the skin and the head before refrigeration. Otherwise, the slaughtered animal is singed and roasted on fire without cutting the head or tarsals. For such processing the chest and abdominal compartments are longitudinally incised while short sticks are used to expand the chest. The roasting is effectively completed within 24 hours of continuous exposure to fire (Ibrahim *et al*., 2017). Retail outlets are springing up in meat shops and supermarkets for which supply fryer rabbits, but smoked rabbits are sold best when disguised as game meat. Smoked rabbits are sold along roadsides of major highways especially in south western Nigeria. In Northern Nigeria where the rabbit population is the highest, they are seldom consumed because of the availability of other meats types (Lawal *et al*., 2017).

### 2.8 Strategies for Promoting Rabbit Production in Nigeria

Despite culinary preferences for other meat types, and the somewhat non-competitive production and market price of rabbit meat; rearing of rabbits offers a great potential towards attainment of family or household food security in terms of animal protein intake.

Therefore, every effort at promoting rabbit production is well deserved. Revitalisation of promotional efforts by government agencies like such as the Department of Rural Development, Family Support Programme and World Bank Assisted Agricultural Development Projects would greatly encourage rabbit keeping amongst the populace (Lawal *et al*., 2018). This should be backed up with an effective extension and accessible veterinary services. Formation of rabbit keeping and breeder association in the community; and rabbit keeping clubs at pre-tertiary institutions would profoundly sustain interest in rabbit keeping. Provision and accessibility of the co-operative rabbit keepers to soft loans represent an ideal incentive strategy. Realizing that feeding of rabbits especially during the dry season remains critical and the most costly aspect of their management; simple feed formulations based on local feedstuff's and appropriate combination of kitchen wastes need be taught to the rabbit keepers. Further awareness on the nutritional complementarity of local feedstuffs, grass and leguminous forages, kitchen wastes, foliar biomass of harvested crops as cowpea, groundnut, cassava, potato, edible vegetable stems, and agro-industrial by-products should be created. Supplementary feeding of permissible growth promoters, especially the non-antibiotic types and the inclusion of low-cost animal protein sources like blood meal, could significantly increase performance of rabbits. Marketing of rabbit meat and their products need to be promoted to sustain the economic initiatives of the producers. Pragmatic steps involve documenting highlights of the comparative meat types in print and in electronic media; organizing rabbit (agricultural) shows, serving rabbit meat at public banquets or dinners, hotels and restaurants as variety meat, and recommending rabbit meat because of its low-cholestrol properties for dietetic management of patients suffering from coronary (arteriosclerosis) disease, hypertension and other related ailments in the hospital. The use of the hides and skins of the rabbits in leather and ornament industries can create an additional source of

income to the producers. Adeola *et al.* (2013) stated that Governmental support for research on rabbit production in tertiary institutions especially the key aspects of sustainable and economic feeding, disease prevention and control, and improved breeding programmes would provide immense promotion for rabbit keeping in Nigeria.

## 2.9 Problems and Prospects of Rabbit Production in Nigeria

Rabbit farming in Nigeria, is faced with myriad of problems, which have resulted to a gross shortage of meat to meet up the population challenge in the country (Nworgu, 2007). The growth rate of the Nigerian agricultural sector is below the potentials of natural and human resourcesdue to high cost of agricultural inputs, poor funding of agriculture, inadequate functional infrastructural facilities, inconsistencies of government agricultural policies, inadequate private sector participation, poor mechanized farming and little or no adoption of some simple agricultural technologies developed by scientists (Nworgu, 2007). In Nigeria, consumption of animal protein remains low at about 6.0 - 8.4 g/ head/ day which are far below the 13.5g per day prescribed by the WHO (Egbunike, 1997).

Rabbit production is a veritable way of alleviating animal protein deficiency in Nigeria (Ajala and Balogun, 2004). The rabbit has immense potentials and good attributes which include high growth rate, high efficiency in converting forage to meat, short gestation period, and high prolificacy, relatively low cost of production, high nutritional quality of rabbit meat which includes low fat, sodium, and cholesterol levels. It also has a high protein level of about 20.8 % and its consumption is bereft of cultural and religious biases (Biobaku and Oguntona, 1997). The presence of caecal microbes enables the rabbit to digest large amounts of fibrous feed as most non ruminant species cannot (Taiwo *et al.*, 1999).

## 2.10 Benefits of Rabbit Meat to Health

Meat is a major source of proteins, essential amino-acids, B-complex vitamins, minerals, and other bioactive compounds Nistor *et al.* (2013). Recommended by nutritionists over other meats, rabbit meat is valued for its nutritional properties because is lean, rich in proteins of high biological value, low in cholesterol content and high in linolenic acid. In the research conducted by Nistor *et al.* (2013), meat samples, collected from rabbit, chicken, beef and pork, were subjected to chemical analysis for moisture, protein, fat, ash, calcium, phosphorus, sodium and cholesterol, to identify differences in nutrient content among these animal species. Rabbit meat was richer in calcium (21.4 mg/100 g) and phosphorus (347 mg/100 g) than other types of meat and lower in fat (9.2 g/100 g) and cholesterol (56.4 mg/100 g). Beef had the highest cholesterol content (114.5 mg/100 g), almost double than rabbit meat, while pork was rich in fat (28.2 g/100 g). Nistor *et al.* (2013) concluded that rabbit meat is healthier over other meats frequently used in human nutrition, high in protein and low in fat.

## 2.11 Nutrient Requirements of Rabbit

Information on specific nutrient requirements of rabbits can be obtained from the National Research Council publication on rabbit nutrition (NRC, 1977). Briefly, for major nutrients, the requirements for growth and lactation of the diet are crude protein, 17 %; digestible energy, 10.5 MJ; crude fibre, 10.9 %; calcium, 0.75 % and phosphorous, 0.5 %. On a practical basis, the nutritional requirements of the rabbit is met with quite simple diets. Because rabbits engage in coprophagy, their B vitamins requirement are satisfied by intestinal synthesis. Rabbit diets are traditionally high in lucerne, which is an excellent source of fat soluble vitamins and trace minerals. Thus, a simple mixture of grain or grain by-products, lucerne, a protein supplement, and a mineral supplement is satisfactory.

Recently there has been much interest in the role of fibre in rabbit nutrition. Fibre has an interesting role, in that while it is largely indigestible in the rabbit, it seems to be necessary for normal growth and prevention of enteritis. Cheeke and Patton (1978) and Pote *et al.* (1980) reported that the growth rate of weaning rabbit was significantly poorer on a high energy, low fibre diet, than when higher fibre levels were used. The incidence of enteritis was higher with low fibre diets.

### 2.11.1 Energy requirements of rabbit

Energy is derived from the synthesis of carbohydrates, protein and lipids (fats). Young growing rabbits in good health condition normally consume sufficient feed to meet their energy requirements (Parigi Bini and Xiccato, 1998). Aduku and Olukosi (1990) reported energy requirement of rabbits to range between 2390 kcals kg-1 to 2700 kcals kg-1 digestible energy, which can be obtained from the consumption of grains, fat, fibrous and non- fibrous feeds. Different estimates of DE requirements for maintenance (DEm) of growing rabbits have been identified (Lebas, 1989; Parigi Bini and Xiccato, 1998). This varies from 381 KJ day-1 kg-1 LW0.75 in New Zealand White rabbits (Partridge *et al.*, 1989), to 552 KJ DE day-1 Kg-1 LW0.75 in Giant Spanish growing rabbits (De Blas *et al.*, 1985). Partridge *et al.* (1989) recorded maximum average daily growth when the dietary DE concentration was between 11 and 11.5 MJKg-1 DM to 10 and 10.5 MJ Kg-1 as fed. An increase in the level of dietary energy intake also affected the composition of body gain and partition of energy retained as protein and fat (Partridge *et al.*, 1989).

### 2.11.2 Crude protein requirements of rabbit

Rabbits need diets that contain sufficient digestible protein to replace worn out tissues and synthesize new ones to ensure good production. Mateos and De Blas (1998) recommended crude protein range of 14.5 – 16.2 g for fattening rabbits and 15.4 – 16.2 g in mixed feed. However, Parigi Bini *et al.* (1991) and Xiccato *et al.* (1992)

recommended 11.4 – 13.9 g digestible protein (DP) for fattening rabbits.

Forage provides adequately cheap feed-stuff for livestock, especially rabbits with no significant reduction in production. The uses of leguminous residues as supplement in animal production have been described by several authors (Dematerova *et al.,* 1991; Manyuchi *et al.,* 1997; Savadogo *et al.,* 2000; Omoikhoje *et al.,* 2006; Iyeghe-Erakpotobor, 2007). Many leguminous forages have been reported to provide high quality low cost feed materials for ruminants and non-ruminants especially rabbits, however, the utilization of forage species by rabbits is higher for leafy and succulent woody species (Aduku *et al.,* 1986).

### 2.11.3 Vitamin and mineral requirements of rabbit

Requirements for minerals were recently analyzed by Mateos and De Blas (1998). Very little new information is available in this field. The work of Lebas *et al.* (1998) could be noticed demonstrating that the phosphorus requirement of growing rabbits may be satisfied with a feed containing only 0.3 % of raw phosphorus. In a previous work, the same team has demonstrated that 0.5 % of phosphorus is sufficient for the breeding does (Lebas and Jouglar, 1990). Requirements for vitamins were recently analyzed by Lebas (2000). The water-soluble vitaminsand vitamin K are normally synthesized by the rabbit's digestive flora and the amounts are sufficient. But in situation of high probability of digestive disorder *e.g*. just after weaning, a dietary supplementation may be advisable. In addition, a vitamin C supplementation (25 to 30 mg per rabbit and per day) can help the animal in stress situation (heat stress). This supplementation can be made by inclusion in pelleted feeds, but paying attention to the high susceptibility of vitamin C to high temperature; otherwise the supplementation could be done in the drinking water.

The vitamin A requirement is largely satisfied if the diet contains 10, 000 IU vitamin A per kg or 30 ppm of β-carotene. Additional distribution of vitamin A is without interest

for the growing rabbits and may be toxic for the fetus in the pregnant does. Recommendation for vitamin D supply is 800 to 1000 IU/ kg of diet. If the dietary concentration is greater than 2000 IU/ kg, abnormal calcification of soft tissues (aorta, kidneys) is generally observed within 4 to 8 weeks. Recommendation for vitamin E supply is 50 mg/ kg of complete feed. A diet that contains only 15 mg/ kg induced deficiency symptoms, (muscular dystrophy, sudden death,troubles of reproduction in both sexes). A massive introduction of vitamin E is not toxic (up to 1 %) but may improve to the rabbit meat conservation, by reduction of the speed of oxidation oflipids: inclusions of 200 to 300 ppm vitamin E are suitable. The information available on vitamins requirements is too scarce to propose recommendations for the different physiological stages (Lebas, 2000).

### 2.12 Nutritional Value of Rabbit Meat

Rabbit meat offers excellent dietary nutritional properties (Dalle Zotte, 2002; Hernández and Dalle Zotte, 2010) with protein contents as high as 22.4 % in the loin. The leanest cut of meat in the rabbit carcass is the loin, which contains an average lipid content of 1.8 g/ 100 g of meat, whereas the fattest is the foreleg, with an average lipid content of 8.8 g/ 100 g of meat. The quantitatively most important cut is the hind leg, with a moderate lipid content (an average of 3.4g/100 g) compared with most types of meat consumed today. Lipid content depends on the portion considered and productive factors, especially diet (Dalle Zotte, 2002). Rabbit meat has a moderately high energy value (from 603 kJ/ 100 g in loin meat to 899 kJ/ 100 g in foreleg meat) that essentially depends on its elevated protein content, which accounts for 80 % of its energy value. Together with its increased protein content, rabbit meat contains high levels of essential amino acids (EAA). Compared with other meats, rabbit meat is the richest in lysine (2.12 g/ 100 g), sulfur-containing amino acids (1.10 g/ 100 g), threonine (2.01 g/ 100 g), valine (1.19 g/ 100 g),

isoleucine (1.15 g/ 100 g), leucine (1.73 g/ 100 g), and phenylalanine (1.04 g/ 100 g). Increased and balanced content of EAA combined with easy digestibility give rabbit meat proteins their increased biological value. Furthermore, rabbit meat does not contain uric acid andalso has low purine content (Hernández and Dalle Zotte, 2010).

The variation of vitamin content in meats is greater than with other meat nutrients because of thestrong effect of the diet composition and the level of vitamin supplementation. The amount of vitamin E contained in rabbit meat may be increased by more than 50 %, for example, with the use of the right supplements (Castellini *et al.*, 1998). Vitamin E is involved in numerous physiological functions, is an essential nutrient for reproduction, and is a powerful anti-oxidant. The latter function of vitamin E makes it an essential nutrient for improvement of meat quality because it prevents the oxidation of the fatty acids and promotes the color desired in the meat. Meat is an important source of bioavailable vitamin B, with contents that vary from one speciesto another and even from one cut of meat to another in the same species, while cooking reducesthe original content (Lombardi-Boccia *et al.*, 2005). On average, the consumption of 100 g of rabbit meat provides around 8% of the riboflavin (vitamin $B_2$), 12 % of the pantothenic acid (vitamin $B_5$), 21 % of the pyridoxine (vitamin $B_6$), and 77 % of the niacin (vitamin $B_3$) required daily (Hernández and Dalle Zotte, 2010). The lack of vitamin $B_{12}$ created by the popularity of vegetarianism is a growing cause of concern in the most developed nations of the world. Meat from ruminants and rabbits are the richest sources of vitamin $B_{12}$, and the consumption of 100 gof rabbit meat provides three times the recommended daily intake (RDI) of vitamin $B_{12}$ (Dalle Zotte and Szendro, 2011).

### 2.13 The Choice of Concentrate and Forage Combination for Feeding Rabbits

Rabbits have the ability to thrive on forages which are abundant all year round (Aduku and Olukosi, 1990). According to Ojewola *et al.* (1999), rabbit perform better when fed

with mixture of forage and concentrate. A combination of concentrate diet and forage to achieve optimum performance is especially being sought after; to reduce cost of feeding, as well as the total cost of production for the small scale rabbit producers. Feeding rabbits solely on some forage species in the tropics has resulted in negative effect of weight loss (Adegbola *et al.,* 1985; Bamikole and Ezenwa, 1999).The use of compounded concentrate alone has not also given optimum results (Adegbola *et al.,* 1985; Bamikole and Ezenwa, 1999). However, there is paucity of information on the appropriate combination of forage to concentrate for optimum performance of rabbit because concentrate alone fed to rabbits do not give 100% performance. This experiment aim to evaluate the effect of varying combinations of forage to concentrate ratio and to determine the appropriate combination for optimum performance of rabbit.

### 2.14 Nutritional Attributes of Cowpea Haulms

Cowpea provides high quality forage, rich in protein (14 - 24 % DM). Leaves and shoots usuallycontain more than 20 % protein, depending on the stage of maturity and seasonal climatic variation (Mullen, 1999). Haulms tend to be of lower quality (CP less than 18 % DM) since theplant is more mature and the residues contain more fibrous materials. There are seasonal differences in the quality of haulms so that attention must be given to handling of haulms to minimize the amount of leaves lost during the wet season (Anele *et al.,* 2012). Indeed, protein content differs widely between leaves (22 % DM) and stems (8 % DM) (Mullen, 1999; Singh *et al.,* 2010). Cowpea pod husks are characterized by a high level of crude fibre (about 31 % DM)and a relatively low level of protein (12 - 13 %) (Oluokun, 2005).

As with many green-pasture crops, grazing cowpea may cause bloat in sheep or cattle. This may occur when hungry livestock have access to large quantity of cowpea haulms. However, the danger is far less than with alfalfa, and decreases as cowpea becomes more

mature (Mullen, 1999).

## 2.15 Anti-nutritional Factors of Cowpea

Cowpea is also valued for its useful ability to fix atmospheric nitrogen through its root nodules, and grow well in poor soils (Davis *et al*., 1991; Duke, 1981; Yost and Evans, 1988 and Singh *et al.*, 2003). However as a legume crop, the presence of antinutritional factors is a major limiting factor to the optimal food use of cowpea (Liener, 1975). Anti-nutritional factors (ANF) or antinutrients are plant's secondary metabolites which act to reduce food nutrient utilization (Soetan, 2008; Welch and Graham, 2004). However, Akande *et al.* (2010) noted that being an antinutrient is not an intrinsic property of a compound but depends on the metabolic processes of the ingesting animal. For instance, Trypsin inhibitors, which are ANFs for monogastric animals, do not exert any antinutrient effects in ruminants because they are degraded in the rumen. It has been suggested that the reason for formation of ANFs in plants may be a way of storing excess nutrients or a means of defense from destruction by insect pests and grazing animals (Harborne, 1989; Welch and Graham, 2004). The major ANFs in legumes include: protease inhibitors, lectins (phytohaemagglutinins), gossypol, goitrogens, antivitamins, phytates, saponins, estrogens, flatulence factors, chlorogenic acid, amylase inhibitors, allergens and lysinoalanine (Akande *et al*., 2010). Luckily, most ANFs are heat-libile. However, heat-stable ANFs (e.g., phytate and polyphenols) are not eliminated by simple soaking and heating, but through germination or fermentation (Sridhar and Seena, 2006).

## 2.16 Castration in Rabbits

Castration is a process of removing testicles or crushing of spermatic cord that subsequently leads to the atrophy of the testicle (Kesler, 1992). It could be done either as open or close castration. It also involves the removal or destruction of the testes, epididymis and a portion ofeach spermatic cord from a male domestic ruminant. In most

cases, non-breeding and breeding males not slaughtered at a young age should be castrated. Traditionally, farmers do not castrate animals and both males and females are allowed to roam together. The result is that inferior male's mate with females passing on undesirable traits and the young stock produced are not very productive, which can result in genetic defects, poor growth rate, and other problems.

Castration is also carried out to reduce goaty smell or tainted odour in the meat from slaughteredbucks. Castration of normal goat kids is one of the commonly performed routine surgical procedures in small ruminants in the tropic. Goat kids are castrated for management and production reasons. Castrated goat kids fed to slaughter age show changes in carcass weight, dressing percentage and tissue fat scores (Gyang, 1990).

## 2.17 Methods of Castration of Rabbits

There are several different methods of castration; however, they can be classified into three major groups: physical, chemical, and hormonal. These groups can be divided further by technique, but overall, castration is achieved by removing the testicles surgically, damaging them irreparably, or causing them to atrophy by stricture of the blood supply (Currah *et al*., 2009).

### 2.17.1 Physical methods

Physical castration methods that are frequently used are those that involve surgical removal of the testicles, application of a constricting elastic band (rubber ring) at the base of the scrotum, and bloodless castration by the use of external clamping with an appropriate device (i.e. Burdizzo clamp) (Stilwell *et al*., 2008). Combinations of physical methods can also be used, such as application of a Burdizzo clamp followed by rubber ring placement and surgical removal of scrotal tissue 9 days after application of a rubber ring (Becker *et al*., 2012).

### 2.17.2 Chemical methods

Chemical castration includes injection of sclerosing or toxic agents (e.g. 88% lactic acid) into the testicular parenchyma to cause irreparable damage and loss of function (Fordyce, 1989). Chemical castration requires additional procedural time and technical skill, and almost twice the healing time compared with surgical castration (Fordyce, 1989).

### 2.17.3 Hormonal methods

Hormonal castration (immunocastration) typically involves injection of immuncontraceptives to induce antibody production against gonadotropin releasing hormone (GnRH), resulting in decreased production of endogenous hormones. (Fisher *et al.,* 1996) Immunocastration has been shown to increase live weight, hot carcass weight, average daily gain, and dressing percentage following castration when compared with surgical methods. Although testosterone production is reduced for approximately 6 months after immunocastration, persistent mounting behaviour, consumer concerns and the need for repeat injections have made the technique less effective and desirable than traditional, physical methods (Stafford, 2007).

## 2.18 Potential Complications Associated with Rabbits Castration

### 2.18.1 Haemorrhage

Risk of haemorrhage is greater after surgical castration (Stafford, 2007). In a survey of New Zealand rabbit producers, surgical castration was associated with reportedly higher complications, including bleeding, swelling, infection, and death (Stafford *et al*., 2000).

### 2.18.2 Disease

Castration-associated immunosuppression may increase risks of local or systemic disease after the procedure. Surgical castration causes increased haptoglobin and decreased gamma-interferon production. Haptoglobin exerts a suppressive effect on lymphocyte function, and reduction of gamma-interferon results in suppression of the immune

system's cell-mediated immunity and response to antigens (Earley *et al.*, 2002; Fisher *et al*., 2001; Stafford *et al*., 2000; Fisher *et al*., 1997). Earley *et al.*, 2002; Fisher *et al.*, 1997) studies indicate that castration-associated leukocyte depression may be limited or eliminated by pre-surgical administration of a local anaesthetic and a systemic analgesic. Administration of ketoprofen, either alone or in combination with local administration of lidocaine decreased haptoglobin concentrations or prevented suppression of the gamma-interferon response; therefore, administration of ketoprofen reduced immunosuppression associated with surgical castration (Ballou *et al*., 2013). In contrast, administration of xylazine in combination with butorphanol had no effect on haptoglobin concentrations after surgical castration (Earley *et al*., 2002). Increased haptoglobin concentrations were not observed allowing elastrator band castration of 14-month-old bull calves.7 or ring castration of 6-month old bull calves when given flunixin meglumine in combination with local lidocaine use (Faulkner *et al*., 1992). 40 Necrotic tissue, such as ischemic scrotal tissues and testes after banding, is prone to infection with pathogens (Marti *et al*., 2010). Similarly, the wound associated with surgical castration is at risk of infection (Magrath and Magrath, 1954). Clostridial organisms, ubiquitous in soil, may enter the wound and result in local or systemic infection; clostridial vaccination prior to castration is recommended. Use of rubber rings in calves older than 6 months may be associated with increased risks of tetanus or other infection (La Fontaine, 2006).

### 2.18.3 Performance

Cattle may demonstrate reduced feed intake and average daily gain (ADG) for a period of time after castration. Many experiments failed to detect differences related to castration method (Fisher *et al.*, 1997; Chase *et al.*, 1995; Stafford *et al.*, 2005). Differences may be found in specific studies where band castration may produce either superior or inferior growth rates when compared with surgically castrated animal or controls (Fisher *et al.*,

2001; Berry *et al.,* 2001). Delaying castration conveys no benefit in terms of carcass weight and taste panels suggest that consumers prefer beef from cattle that are castrated at an early age (Fisher *et al.,* 2001; Heaton *et al.,* 2004). A recent study found that bulls castrated at a later age were 3% more likely to require treatment for bovine respiratory disease (BRD) than bulls that were castrated early (Heaton *et al.,* 2004).This can cause profit loss due to an increase in the number of days to market, decrease in hot carcass weight and potential carcass value (Massey *et al*., 2011). Castrating beef calves immediately after transport, however, may compound the stress experienced by the calves and lead to increased losses due to illness. Wagner (2007) observed that delayed castration is beneficial in bull calves that were at high risk of developing fever in the feedlot.

**2.18.4 Physiologic stress**

Castration is considered to be one of the most stressful experiences for livestock. Blood cortisol concentrations have been studied as indicators of physiologic stress in animals (Fisher *et al.,* 2001; Fell *et al*., 1986; Stafford *et al.,* 2002). Regardless of the means of castration, cortisol concentrations are increased following the procedure; however, onset, magnitude, and duration may vary with the procedure used. Surgical castration appears to produce the most substantial rise in plasma cortisol concentration (Stafford, 2007; Dinnis *et al.,* 1997; Molony *et al.,* 1995; Chase *et al.,* 1995; Stafford *et al.,* 2002). Application of the Burdizzo clamp may also be associated with a similar, rapid rise in cortisol concentration due to the barrage of afferent neural impulses during and after crushing of the spermatic cord and scrotal nerves (Fisher *et al.,* 1993; Earley *et al.,* 2002; Molony *et al.,* 1995; Stafford *et al.,* 2000; Stafford *et al.,* 2002). (Dinnis *et al.,* 1997; Molony *et al.,* 1995; Obritzhauser, 1998) observed that plasma cortisol concentrations increased immediately after surgical castration; animals that were banded had cortisol

increases of less initial intensity, but the concentrations were similar for both procedures on the second postoperative day. Salivary cortisol concentrations observed between 15 minutes and 2 hours after castration in 4- to 11- week-old calves undergoing surgery were much higher than those of calves castrated using rubber rings. Fell *et al.* (1986) and Stafford *et al.* (2002) observed similar overall cortisol responses for elastrator band, rubber ring, and surgical castration, but lower cortisol responses for castration using a Burdizzo clamp. Pieler *et al.* (2013) found that Burdizzo castration, surgical castration and partial scrotal resection do not cause significantly different levels of stress when the animal is administered xylazine and local anesthesia.

Placement of elastrator bands/rings without prior anesthesia produced a slightly lower cortisol increase than surgical castration Pieler *et al.* (2013). Immunocastration resulted in only transient increases in cortisol concentration, likely due to stress induced by handling and injection (Mellor *et al.*, 2002)

## 2.19 Anaesthesia and Analgesia

### 2.19.1 Local anaesthetics

Application of local anaesthesia prior to castration is mandated in some countries, and significantly reduces the cortisol response to castration. Administration of lidocaine into the testicular parenchyma and distal scrotum virtually abolished the cortisol response to castration when elastrator bands or rubber rings were used on 3-month-old calves (Dinnis *et al.*, 1997; Thuer *et al.*, 2007; Stafford *et al.*, 2002). Serum cortisol concentrations returned to baseline values within one hour of castration, and remained at those levels for the remainder of the 72-hour sampling period following lidocaine injection into the spermatic cords and scrotal neck (Stafford *et al.*, 2002). Local anesthesia had less effect on cortisol concentration when Burdizzo clamps were used, and a minimal effect with surgical castration (Thuer *et al.*, 2007). In several studies, local anesthesia with lidocaine

or bupivacaine significantly attenuated the increase in plasma cortisol concentration after Burdizzo clamp castration (Stafford *et al.,* 2002). Lidocaine administered locally with flunixin meglumine may also be an effective method of analgesia and of cortisol tempering. Lidocaine injected into the scrotal neck almost abolished the cortisol response to a combined clamp-ring castration approach in lambs, and injection into the spermatic cord reduced cortisol responses by 45% compared with animals castrated without local anesthesia (Webster *et al.,* 2013). Similar results were obtained when lidocaine was administered before rubber ring placement in lambs, but no beneficial effects were observed from administration of local anesthesia prior to castration using a Burdizzo clamp (Dinnis *et al.,* 1997). Suppression of the cortisol increase by local anesthetics is short-lived, and cortisol concentrations increase once the pharmacologic effects of the anesthetic agent have ceased. Administration of local anesthetic prior to surgical castration of 5.5-month-old calves resulted in improved ADG for the first week after surgery as compared with surgery alone, suggesting a longer duration of benefit (Fisher *et al.,* 1993; Earley *et al.,* 2002; Ting *et al.,* 2003).

### 2.19.2 Epidurals

Epidural anesthesia or local anesthesia (with lidocaine) prior to castration using a Burdizzo clamp did not significantly reduce the integrated (area under the curve) cortisol response in 13-monthold bull calves compared with use of the Burdizzo clamp alone. Although peak cortisol response was reduced approximately 30% by administration of an epidural, suppression was only observed for the one-hour duration of effect for the epidural (Ting *et al*., 2003). Xylazine epidurals combined with intravenous flunixin meglumine produced no significant differences in animal health or feedlot performance compared to animals that did not receive anesthesia/analgesia (Ting *et al.,* 2003).

### 2.19.3 Sedation

Intravenous xylazine, alone or with ketamine, has been shown to reduce behavioural indications of distress and serum cortisol concentrations immediately after castration. The addition of ketamine to more traditional chemical restraint formulas ("ketamine stun") can increase patient cooperation, and has been shown to lower stress response to both dehorning and castration in calves (Coetzee *et al*., 2010).

## 2.20 Performance of Rabbits

Ways to improve the quality of rabbit meat are limited. The most efficient is the age at slaughter, and therefore the degree of maturity of the meat. The increase of the slaughter age creates however new problems such as aggressive behaviours after the puberty, and males castration may be a solution. Besides this behavioural effect, castration has also some effects on growth performances and meat characteristics on most animals (Lirette *et al.,* 1984; Desmoulin *et al.,* 1990; Bonneau *et al.,* 1996). According to Devendra and Mcleroy (1988), castrated rabbit have no sex life and therefore have a higher feed intake level and feed conversion ratio. A research reported by Jehl *et al.* (2000), between 36-99 days of age, the intact males and castrates rabbits showed no significant differences in the feed conversion (FCR). But between 100-141 days of age, the castrates rabbits revealed higher feed conversion ratio (11.39) over non-castrates (15.28). Growth rate and feed intake were not significantly affected by sex before 14 weeks in the work of Jehl *et al.* (2000) with rabbits.

Zhang *et al.* (1996) in their research on rabbits, reported that after thirty days of the commencement of the research, the average body weight of the test group (castrates) exceeded that of the control group (non-castrates). When the experiment ended, the average body gain of the test group was 1288 g, while that of the control group was 1050 g. The difference was 238 g. By t-test, the average body gain between the two groups

were significantly different ($p<0.05$).

Saheed *et al.* (2020) reported significant ($p<0.05$) difference between castrates and non-castrate's weaner rabbits fed forage and concentrates, in total weight gain (TWG), castrates showed significant superiority (304.33) over non-castrates (204.33). In average weight gain (AWG), castrates showed significant superiority (38.04) over non castrates (25.54). The average feed intake of the study reported by Saheed *et al.* (2020) showed no significant ($p>0.05$) difference among the castrates and non-castrates. Saheed *et al.* (2020) also reported that castrates had significantly higher values in all growth parameters. Saheed *et al.* (2020) concluded that castrates have better meat quality and grow faster than the non-castrates.

### 2.21 Carcass Characteristics of Growing Rabbits

Rabbit meat is characterized by a high protein level, low fat and cholesterol contents and it is considered a healthful food product (Dalle Zotte, 2000). Carcass characteristics are affected by the mature body weight and the age of slaughter, hence selection for carcass traits in rabbits is an effective tool for improvement for meat type rabbits (Szendro *et al*., 2004). Animal's age or slaughter weight (Dalle Zotte, 2002) and sex (Cavani *et al.*, 2000) affect the carcass quality. Akınci *et al.* (1998) reported that carcass characteristics of New Zealand White and California rabbits were found to be significantly affected by age ($P<0.01$) but not affected by sex. Yalçın *et al.* (2006) also reported that female and male rabbits were not significantly different in the weights of fore legs, hind legs, ribs and loin. Likewise, Fayeye and Ayorinde (2008) reported that sex effect was not significant on carcass characteristics such as bled-weight,dress carcass weight, dressing percentage, carcass length, gastrointestinal tract, pelt, and external offal, and edible offal, adipose fat and primal cuts. However, Murshed *et al.* (2014) observed that slaughter and carcass weights were affected by sex and they reported that males were slightly lower than in

female rabbits.

### 2.22 Nutrient Digestibility in Rabbits

Feed accounts for about 70 % of the total cost of production in livestock and is a major threat to the expansion of the sector in Nigeria (Ojebiyi and Saliu, 2014). Research findings have shown that rabbits can do well on non-conventional feed ingredients. Ayanwale *et al.* (2001), Adeniji and Jimoh (2007) and Tabinda and Butt (2012) used *Colocasia esculentum*, rumen content and chicken intestine to feed rabbits, pullet chicks and fish fry respectively and the results showed that feed conversion ratio, weight gain and carcass characteristics were sustained, with no detrimental effects on the animals' performance. Cowpea, a legume crop, contains adequate amounts of protein, essential amino acids, dietary fibre and essential minerals and vitamins whencompared to the other common legumes (Bhat and Karim, 2009). Studies have shown that 20 % dietary inclusion of cowpea seed produced better performance with no reported negative effect on weaner rabbits (Matondi *et al.,* 2015). Cowpea milling waste is a by-product obtained from theindustrial processing of cowpea seed grains into cowpea flour used for the preparation of fried bean cakes (called “Akara” in Yoruba or “kosei” in Hausa) and “moin-moin”. They are readily used as feed for ruminants such as cattle, sheep and goats. However, there is paucity of cowpea milling waste as a non-conventional feedstuff for feeding weaner rabbits; hence this research study is aimed at determining the growth performance and nutrient digestibility of weaner rabbits fed diets containing varying levels of cowpea milling waste. Zhang *et al.* (1996) in their work on grower rabbits revealed that the feed efficiency of the test group (castrates) was 1:3.8, while that of the control group (non-castrates) was 1:4.7. Therefore, Zhang *et al.* (1996) concluded that early castration could make the male rabbits grow more rapidly and could improve the feed efficiency.

Saheed *et al.* (2020) reported better performance ($p<0.05$) of castrates (56.66) over non-castrates (40.83) in ash and nitrogen free extract in rabbits. In the research conducted by Dikko *et al.* (2011) which revealed significantly higher value (99.33) in non-castrates above castrates (unilateral, 98.89 and bilateral, 97.83) in ash content. Dikko *et al.* (2011) reported no significant difference among the treatment groups (castrates and non-castrates) in dry matter values. In crude protein, Dikko *et al.* (2011) revealed that bilateral castrates (96.02) is significantly lower than unilateral castrates (98.93) and intact males (98.38) weaner's rabbits. In crude fibre, Dikko *et al.* (2011) revealed that intact male's rabbits (99.11) is significantly higher over unilateral castrates (99.00) and bilateral castrates (97.32). In ash, intact male's rabbits (99.33) revealed significant higher value over unilateral castrates (98.89) and bilateral castrates (97.83). Saheed *et al.* (2020) revealed that apparent digestibility coefficient value shows that castrates is significantly higher in feed conversion ratio over non-castrates groups of weaner's rabbits.

### 2.23 PH of Meat

Fresh meat must have a pH value in the range of 5.5 to 6.2.1 During temporary storage, especially when it is not properly preserved, the fresh meat will turn rancid and have a pH value below 5.3 (Heinz and Hautzinger, 2007).

Rabbit meat is highly valued for its taste and nutritional and dietary qualities. The main traits that determine the quality of meat include colour, pH, tenderness, marbling, and flavor. These traits depend on many factors, among them breed, age, sex, feeding system, body weight before slaughter, and slaughtering methods Cavani *et al.* (2000). For a potential buyer, colour is one of the characteristics that determine his decision whether to buy meat or not. The most important pigments responsible for meat colour are myoglobin and haemoglobin. Meat changes its colour as a result of chemical reactions involving myoglobin, such as oxygenation, oxidation or the addition of a carbon monoxide

molecule, and reduction, which plays a central part in maintaining the colour of meat after slaughter Mancini and Hunt (2005). The acidity (pH) of meat, measured 45 minutes and 24 hours after slaughter, constitutes another important indicator of meat quality Bieniek *et al.* (2012). It is also an essential parameter taken into account when assessing the shelf life and technological usability of meat. The functional quality of meat is associated with its appearance, colour, and water absorption, whereas culinary quality is connected with taste, flavour, tenderness, and juiciness. Acidity is the one of the main factors inhibiting the development of bacterial microflora, which prevents spoilage. In rabbits, the acidity of aged meat (stored at least 24 hour), ranges between 5.6 and 5.85, indicating that rabbit meat has an inferior shelf life compared to the meat of other animal species. The acidity depends on many factors, among them the management system, extent of de-bleeding after slaughter, type of muscle, individual differences, and level of stress.

### 2.24 Water Holding Capacity of Meat

The ability of meat to retain its water when external force such as heating, pressing and grinding are applied. For consumers, poor water holding capacity in poultry meat products results in diminished visual appeal due to excess purge in package and inferior palatability traits related to juiciness and tenderness. For processors, improved water holding capacity in raw poultry meat leads to greater marinade pick-up and retention, better protein functionality and greater processing and cooking yield. In the research carried out by Lebas *et al.* (2000) which reported that castrates (rabbits) loss less water (2.89) at 20 weeks of age than non castrates (3.62).

### 2.25 Cooking Loss of Rabbits

Water in meat can be free, loosely bound or tightly bound. Free water is extracted from the meat by gravity, loosely bound using a force, and tightly bound by drying (Karan-Djurdjic and Peric, 1966). The ability of meat to retain its own water and to bind added

water is one of the most important technological properties of meat. The WHC of meat includes the ability of meat to retain its own water when applying force (pressing, centrifugation, chopping or warming), as well as to bind added water. Depending on the method applied and other factors (genotype, diet, rabbit age, part of the carcass, time post mortem etc.), WHC varies widely from 15.42% to 57.16% (Bivolarski *et al.*, 2011; Suradi and Yurmiaty, 2011). The losses during meat cooking depend on the same factors that affect WHC. Various procedures are applied to determine the cooking loss (boiling, roasting, different temperatures and duration of treatment), which varies from 30.22 to 39.15% (Hernández *et al.*, 1998; Dal Bosko *et al.*, 2001; Yalçın *et al.*, 2006; Omojola, 2007). The diversity of rabbit breeds offers the opportunity to increase the efficiency of meat production by commercial crossbreds.

# CHAPTER THREE

# 3.0 MATERIALS AND METHODS

## 3.1 Experimental Site

This study was conducted at the Teaching and Research Farm of the Department of Animal Production, School of Agriculture and Agricultural Technology, Federal University ofTechnology, Minna, Niger State. Minna is located between latitude $90^0$ 37′ North and longitude 6° 33′ East of the equator. Minna has a mean annual rainfall of 1,200 mm, with an average highest temperature in the month of March and lowest temperature in the month of August. The mean annual temperature is between 22 to 40$^o$C. Minna is located in the Southern Guinea Savannah vegetation belt of Nigeria and has two distinct seasons; wet season, from March to October; and dry season, from November to March (Weather Spark, 2019).

## 3.7 Data Collection

Data collected were from the feed intake, weight gain, carcass characteristics and apparent nutrient digestibility;

## 3.2 Experimental Diet and Source of Feed Ingredients

The ingredients used for the experiment as diets included maize (35.75), groundnut cake (24.85), maize offal (20.00), rice husk (15.00), bone meal (3.00), salt (0.40), methionine (0.25), lysine (0.25), and premix (0.50) (Table 3.1). All the ingredients including cowpea haulms were obtained from Kure ultramodern Market and other parts of Minna metropolis.

**Table 3.1: Percentage Composition of Experimental Diet (Concentrate) Fed to Castrates and Non-castrates Weaner Rabbits**

| **Ingredients** | **Composition (%)** |
|---|---|
| Maize | 35.75 |
| Groundnut cake | 24.85 |
| Maize offal | 20.00 |
| Rice husk | 15.00 |
| Bone meal | 3.00 |
| Salt | 0.40 |
| Lysine | 0.25 |
| Methionine | 0.25 |
| Premix | 0.50 |
| **Total** | **100** |
| **Calculated values** | |
| Crude protein | 18.07 |
| Crude fibre | 10.59 |
| Metabolizable energy (kcal/kg) | 2,612 |
| Calcium | 0.86 |
| Phosphorus | 0.49 |

### 3.3 Experimental Animals and Design

Twenty four (24) weaner rabbits of mixed breeds were sourced from Kwamba Farm, Suleja Local Government Area of Niger State with an average weight of 900 – 1000 g aged between 6 -7 weeks were used in this experiment. The rabbits were randomly assigned into three (3) treatments and four (4) replicates of two (2) rabbits per replicates. Treatments T1, T2 and T3 were made up of non-castrates, unilateral castrates and bilateral castrates respectively. The design used was a completely randomized design (CRD). All the rabbits were fed the same diet. Each replicate was served 100 g of basal concentrate diet and 40 g supplementary diets (cowpea haulms). Feeds were served twice in a day to make a total of 70 g (50 g concentrate and 20 g cowpea haulms) per rabbit per day. Concentrates were fed in the morning and cowpea haulms were fed in the evening, respectively. The experiment lasted for twelve (12) weeks.

**Table 3.2: Proximate Composition of the Experimental Diets Fed to Castrates and Non-Castrates Weaner Rabbits**

| Parameters | Concentrates (%) | Cowpea haulms (%) |
|---|---|---|
| Dry matter | 95.19 | 96.84 |
| Organic matter | 82.69 | 90.34 |
| Crude protein | 15.00 | 14.70 |
| Crude fibre | 6.40 | 33.00 |
| Ash content | 12.50 | 6.50 |
| Ether extract | 8.20 | 0.67 |
| Nitrogen free extract | 53.09 | 41.97 |

### 3.4 Castration Method and Procedure

Open castration method was adopted in this research. The rabbits were properly restrained and placed on dorso-lateral recumbency. The incision sites (scrotal sac) were disinfected using methylated spirit and shaved with the aid of sharp razor blade. The testes were pushed inward and circular incision was made at the ventral part of the scrotal sac. The testes were then pushed backward to expose the spermatic cord. The spermatic cords were ligated using chromic catgut. Finally, a sharp surgical C-section was made to remove the testes. After removing the testicles anti-tetanus and procaine were administered to the open wound. The wounds were healed after 6 days of the testicles removal.

### 3.5 Proximate Analyses of Concentrate and Cowpea Haulms

Feed samples were grinded in a hammer mill to pass a 1mm mesh sieve for proximate analysisaccording to the procedure described by (AOAC) 2005.

### 3.6 Management of Experimental Animals

The Rabbits were managed under intensive system of management. They were kept inside ventilated hutches of 4 x 4 (14cm square), with each hutch contain one feeder and one drinker. 100 g of concentrates and 40 g of supplemental cowpea haulms were supplied to them every day along with adequate and good drinking water.

#### 3.7.1 Feed intake

Average daily feed consumed per rabbit were calculated every day by subtracting feed left from the feed supplied and then divided by the number of rabbit per replicate.

$$\text{Feed intake (g)} = \frac{\text{Feed supplied (g)} - \text{Feed refused (g)}}{Number\ of\ rabbit\ per\ replicate} \qquad \textit{Eq. 3.1}$$

### 3.7.2 Body weight gain (g)

The initial weight of the experimental rabbits were taken and subtracted from the final body weight. The rabbits in each hutch were weighed together using laboratory sensitive weighing scale and the previous weight were subtracted from the current weight and divided by the number of rabbits in the replicate to determine the average weight gain per week. Body weight gain was obtained using the formula:

Body weight gain (g) = final weight – initial weight (g)

### 3.7.3 Average body weight gain (g)

The difference between the final body weight and the initial body weight is termed as body weight gain. The average of the body weight gain is the division of the general value obtained tothe number of the rabbits in the group. Average body weight gain was calculated as follows:

$$\text{Average body weight gain (g)} = \frac{Total\ body\ weight\ gain}{Number\ of\ animals\ in\ the\ group} \qquad Eq.\ 3.2$$

### 3.7.4 Average daily weight gain (g)

The summation of all the weight gain in a day per treatment or group is known as daily weightgain which is the positive difference between the current weight and the previous weight of theanimals. It is calculated as follows:

$$\text{Average body weight gain (g)} = \frac{Total\ body\ weight\ gain}{Number\ of\ animals\ in\ the\ group} \qquad Eq.\ 3.3$$

### 3.7.5 Feed conversion ratio (FCR)

The feed conversion ratio (FCR) was calculated as feed consumed divided by weight gain. That is, feed conversion ratio was calculated by dividing the feed consumed by the

weight gain.

$$\text{FCR} = \frac{Average\ feed\ intake\ per\ rabbit\ per\ week}{Body\ weight\ gained\ per\ rabbit\ per\ week} \qquad \textit{Eq. 3.4}$$

### 3.7.6 Protein intake

Protein intake was calculated from the proximate value of protein in feed. It was determined by feed intake multiply by the percentage crude protein divided by 100 as follows:

$$\text{Protein intake} = \frac{Feed\ \ intake\ X\ \%\ CP}{100} \qquad \textit{Eq. 3.5}$$

### 3.7.7 Protein efficiency ratio (PER)

Protein efficiency ratio was calculated as body weight gain divided by protein intake. It ismathematically demonstrated as follows:

$$\text{Protein efficiency ratio} = \frac{Body\ weight\ gain}{Protein\ intake} \qquad \textit{Eq. 3.6}$$

### 3.7.8 Energy efficiency ratio (EER)

Energy efficiency ratio was calculated as total body weight gain multiply by 100 divided by metabolizable energy, and it is mathematically expressed as follows:

$$\text{Energy efficiency ratio} = \frac{Total\ body\ weight\ gain\ X100}{Metabolizable\ energy} \qquad \textit{Eq. 3.7}$$

## 3.8 Evaluation of the Carcass Characteristics of Rabbit

At the end of the experiment, two rabbit from each replicate were randomly selected, tagged and their live weight taken. The selected rabbits were deprived of feed for 12 hours but were allowed access to water, after which they were slaughtered by cutting the jugular vein and carotid arteries at the neck region. Blood was allowed to drain for about five minutes, carcasses were hung for about 30 minutes to drain more blood

before evisceration. Slaughter weight, eviscerated weight, visceral organs weight (liver, lung. kidney, intestine, heart and spleen) and cut parts (hind limb, forelimb, lumber-sacral, cervico-thoracic) were used for carcass evaluation. Therefore, carcass weights were calculated as follows:

$$\text{Dressing \%} = \frac{Dressed\ carcass\ weight\ X100}{Live\ weight} \qquad Eq.\ 3.8$$

**3.9 Nutrient Digestibility Trial**

Nutrient digestibility trial was carried out at the end of the experiment. The rabbits were kept in metabolism hutches, 100 g of concentrates; 40 g of supplemented cowpea haulms of feed along with drinking water were served to rabbits and the rabbits were allowed seven (7) days acclimatization followed by seven (7) days of total faecal collection from each treatment. Total faeces released by each replicate were collected and immediately taken to the laboratory each day. The faeces were weighed (wet) and oven dried at $85^0$C until a constant weight was obtained. At the end of faecal collection, the total dried faeces for each treatment were bulked and 10 % were weighed and ground to a size that would pass through a 2 mm sieve for proximate analysis. The difference between the nutrient in feed consumed and the nutrient in voided faeces multiplied by 100 (%) gives the apparent nutrient digestibility coefficient of the feed. Dry matter, crude fibre, crude protein, ether extract, nitrogen free extract, and ash content of the faeces were determined using AOAC (2005) methods.

Apparent nutrients digestibility was determined using this formula:

$$\text{Apparent nutrients digestibility} = \frac{Nutrient\ in\ feed\ intake - Nutrient\ in\ faeces\ voided}{Nutrient\ in\ feed\ intake} \text{ x } 100$$

*Eq.3 9*

### 3.10 Chemical Analysis

The proximate composition of the samples of the diets and faeces were determined using the method of AOAC (2000). The parameters determined include: moisture, crude protein, crude fibre, ether extract, ash content and nitrogen free extract was obtained by difference.

### 3.11 Meat pH Determination

The pH values of samples collected from the hind limb muscles were measured (approx. 29 hours post mortem) in muscle homogenates (meat to redistilled water ratio of 1:1, m/v) with the use of a combination Polilyte Laboratory electrode and the 340i pH-meter with a TFK 325 temperature sensor (Daszkiewicz *et al.*, 2020).

### 3.12 Water Holding Capacity Determination

The external force used to drive out the water was the filter paper press method. Chromatography paper Whatman No. 40 was kept for 24 h in a dissociated 38 % sulfuric acid in advance that it complies with 60 % humidity and it helped to diffuse out the water freely through the paper (Kashif *et al*., 2014). Five grams of 24 hours aged meat was homogenized on a metal plate. Out of this, 300 mg meat which was measured right after preparation was put on the Whatman paper No. 40 and then was placed between two slides on which a 100 g weight was placed on the top slide for 5 min so as to exert downward force and to release water from the meat as per the method described by Abraham and Kumar (2010). The water released from the meat was wetting the paper and the boundary of that wetted area was demarcated using sharp pencil and was measured and reported in percentage of the ratio of the diameter of the meat to the diameter of the water wetted paper as per Mendiratta *et al.* (2008).

### 3.13 Cooking Loss and Cooking Yield Determination

Cooking loss was calculated as weight difference between fresh and cooked samples relative to the weight of fresh meat samples in percentage. Cooking loss and cooking yield were determined using the method of Pla *et al.* (1998)

$$\text{Cooking loss \%} = \frac{(W1-W2)}{W1} \text{ X } 100 \qquad \textit{Eq. 3.10}$$

$$\text{Cooking yield \%} = \frac{W2}{W1} \text{ X } 100 \qquad \textit{Eq. 3.11}$$

Where, W1= fresh sample weight

W2= cooked sample weight

### 3.14 Data Analysis

All the data collected were subjected to analysis of variance (ANOVA) according to Steel and Torrie (1980) using statistical package for social science (SPSS, 2021) version 23.0. Differences in means were separated using Duncan multiple range test.

# CHAPTER FOUR

# 4.0 RESULTS AND DISCUSSION

## 4.1 Results

### 4.1.1 Growth performance of castrates and non-castrates weaner rabbits

The results of the growth performance of castrate and non-castrate weaner rabbits fed concentrate and supplemented cowpea haulm diets is presented in Table 4.1. The results showed no significant ($p>0.05$) difference in initial body weight (IBW), final body weight (FBW), total feed intake (TFI), average feed intake (AFI) and protein intake (PI) among the treatment groups. However, in total body weight gain (TBWG), average daily gain (ADG), feed conversion ratio (FCR), protein efficiency ratio (PER) and energy efficiency ratio (EER) showed significant ($p<0.05$) difference among the treatment groups. The rabbits with bilateral castrates showed significantly ($p<0.05$) higher values over unilateral castrates (T2) and intact males (T1) in total body weight gain, average daily gain, feed conversion ratio, protein efficiency ratio and energy efficiency ratio. However, unilateral castrates (T2) and intact males (T1) showed statistical similarities among the treatment groups in the values mentioned above.

### 4.1.2 Carcass characteristics of castrates and non-castrates weaners rabbits

The results of carcass characteristics of castrate and non-castrate weaner rabbits fed concentrate and supplemented cowpea haulm diet is presented in Table 4.2. The results showed insignificant ($p>0.05$) difference among the treatment groups in all the parameters measured except in the values of penis and testicles. However, there was significant higher value of testicles of intact males (T1) when compared to unilateral castrates (T2) and bilateral castrates (T3).

**Table 4.1: Growth Performance of Castrates and Non-Castrates Weaner Rabbits**

| Parameters | T1 | T2 | T3 | SEM | P-value |
|---|---|---|---|---|---|
| Initial bodyweight (g) | 753.00 | 764.00 | 763.00 | 30.12 | 0.99 |
| Final body weight(g) | 1289.50 | 1300.75 | 1365.00 | 29.83 | 0.58 |
| Total body weight gain(g) | 527.50[b] | 536.75[b] | 601.50[a] | 13.67 | 0.03 |
| Total feed intake (g) | 469.42 | 452.38 | 425.44 | 12.72 | 0.40 |
| Average dailygain (g) | 7.53[b] | 7.67[b] | 8.61[a] | 0.19 | 0.03 |
| Average feed intake (g) | 52.57 | 50.65 | 48.06 | 1.33 | 0.42 |
| Feed conversion ratio | 6.99[b] | 6.62[b] | 5.59[a] | 0.24 | 0.02 |
| Protein intake | 9.47 | 9.12 | 8.65 | 0.24 | 0.24 |
| Protein efficiencyratio | 0.80[b] | 0.85[b] | 0.99[a] | 0.03 | 0.02 |
| Energy efficiency ratio | 19.46[b] | 19.80[b] | 22.19[a] | 0.50 | 0.03 |

[ab] means on the same row having different superscripts differs significantly (P<0.05) SEM=standard error of mean

KEY

T1=Control (intact male)
T2=Unilateral castrates
T3=Bilateral castrates

**Table 4.2: Carcass Characteristics of Castrates and Non-Castrates Weaners Rabbits**

| Parameters | T1 | T2 | T3 | SEM | P-value |
|---|---|---|---|---|---|
| Live weight (g) | 1.29 | 1.30 | 1.37 | 0.29 | 0.58 |
| Slaughter weight (g) | 1.26 | 1.16 | 1.24 | 0.36 | 0.51 |
| Dressed carcass weight (g) | 694.77 | 604.77 | 965.50 | 103.65 | 0.37 |
| Dressing % | 50.56 | 44.96 | 46.26 | 1.12 | 0.15 |
| Cervico-thoracic (%) | 11.37 | 9.93 | 9.97 | 0.53 | 0.48 |
| Lumber-sacral (%) | 14.68 | 13.55 | 13.14 | 0.41 | 0.31 |
| Hind limb (%) | 13.65 | 13.65 | 13.83 | 0.13 | 0.83 |
| Fore limb (%) | 9.27 | 9.79 | 9.81 | 0.21 | 0.52 |
| Head (%) | 9.92 | 10.50 | 9.88 | 0.13 | 0.09 |
| Tail (%) | 0.70 | 0.87 | 0.79 | 0.04 | 0.27 |

SEM=standard error of mean
T1= Control (intact males)
T2=Unilateral castrates
T3=Bilateral castrates

### 4.1.3 Visceral organs characteristics of castrates and non-castrates weaner rabbits

The visceral organs characteristics of castrates and non-castrates weaner rabbits is shown in Table 4.3. The result revealed no significant difference ($p>0.05$) in all the parameters. The result evaluated was statistically similar.

### 4.1.4 Apparent nutrient digestibility of castrates and non-castrates weaner rabbits

The results of apparent nutrient digestibility of castrates and non-castrates weaner rabbits fed concentrate and supplemented cowpea haulm diets is presented in Table 4.4. The results showed significant ($p<0.05$) difference in the values of crude protein (CP), crude fibre (CF), ash content, and nitrogen free extract (NFE) among the treatment groups. Intact males showed significant higher ($p<0.05$) values of crude protein (75.51) (CP) and crude fibre (86.13) (CF) digestibility over the other treatment groups. Similarly, the ash (68.59 and 67.49) content and nitrogen free extract (78.24 and 79.27) (NFE) digestibility values of castrates (unilateral and bilateral castrates respectively) were significantly higher when compared to the values of the control group (T1).

**Table 4.3: Visceral Organs Characteristics of Castrates and Non-Castrates Weaners Rabbits**

| Parameters | T1 | T2 | T3 | SEM | P-value |
|---|---|---|---|---|---|
| Fur (%) | 11.24 | 11.28 | 9.99 | 0.33 | 0.20 |
| Penis (%) | $0.04^{b}$ | $0.07^{b}$ | $0.16^{a}$ | 0.02 | 0.00 |
| Testicle (%) | $0.30^{a}$ | $0.13^{b}$ | $0.00^{c}$ | 0.04 | 0.00 |
| Liver (%) | 3.64 | 3.49 | 4.19 | 0.18 | 0.29 |
| Lung (%) | 0.87 | 0.84 | 0.84 | 0.35 | 0.94 |
| Kidney (%) | 0.96 | 1.03 | 1.05 | 0.43 | 0.76 |
| Spleen (%) | 0.07 | 0.06 | 0.05 | 0.01 | 0.71 |
| Intestine (%) | 21.88 | 23.62 | 24.32 | 0.96 | 0.61 |
| Heart (%) | 0.30 | 0.27 | 0.29 | 0.01 | 0.50 |

$^{abc}$ means on the same row having different superscripts differs significantly($P<0.05$),
SEM=standard error of mean
T1= Control (intact males)
T2=Unilateral castrates
T3=Bilateral castrates

**Table 4.4: Apparent Nutrient Digestibility of Castrates and Non-Castrates Weaner Rabbits**

| Parameters | T1 | T2 | T3 | SEM | P-value |
|---|---|---|---|---|---|
| Dry matter | 77.64 | 75.46 | 75.55 | 0.52 | 0.12 |
| Crude protein | 75.51[a] | 74.56[b] | 72.24[c] | 0.62 | 0.00 |
| Crude fibre | 86.13[a] | 76.83[b] | 77.49[b] | 1.89 | 0.00 |
| Ash | 62.03[b] | 68.59[a] | 67.49[a] | 1.29 | 0.00 |
| Ether extract | 36.82 | 45.32 | 48.46 | 2.49 | 0.10 |
| Nitrogen free extract | 76.35[b] | 78.24[a] | 79.27[a] | 0.55 | 0.01 |

[abc] means on the same row having different superscripts differs significantly($P<0.05$),
SEM=standard error of mean,
T1= Control (intact males)
T2=Unilateral castrates
T3= Bilateral castrates

### 4.1.5 Meat quality parameters of castrates and non-castrates weaner rabbits

The results of meat quality parameters of castrates and non-castrates weaner rabbits fed concentrate and supplemented cowpea haulms diets is shown in Table 4.5. The results showed that pH, cooking loss and cooking yield had no significant ($p>0.05$) difference among the treatment groups, but water holding capacity did. However, Bilateral castrates (T3) had significantly higher values of water holding capacity than non-castrates. However, the result showed statistical similarities with unilateral castrates (T2) in water holding capacity values (0.66 and 0.49) respectively.

**Table 4.5: Meat Quality Parameters of Castrates and Non-Castrates Weaner Rabbits**

| Parameters | T1 | T2 | T3 | SEM | P-value |
|---|---|---|---|---|---|
| pH | 6.23 | 6.18 | 6.23 | 0.04 | 0.23 |
| Water holding capacity | $0.42^{b}$ | $0.49^{ab}$ | $0.66^{a}$ | 0.05 | 0.04 |
| Cooking loss | 27.16 | 31.96 | 25.48 | 1.95 | 0.41 |
| Cooking yield | 72.88 | 67.88 | 74.83 | 1.99 | 0.38 |

[ab] means on the same row having different superscripts differs significantly($P<0.05$)
SEM=standard error of mean
T1= Control (intact males)
T2=Unilateral castrates
T3= Bilateral castrates

## 4.2 Discussion

### 4.2.1 Growth performance of castrates and non-castrates weaner rabbits

The higher total body weight gain with significant ($p<0.05$) values of bilateral castrates (601.50 g) over the unilateral and intact male (536.75 g and 527.50 g) agrees with the findings of Zhang *et al.* (1996) who observed significant value (1288 g) in the total body weight gain of castrates over non-castrates (1050 g). The result also agreed with the findings of Saheed *et al.* (2020) which reported significant ($p<0.05$) values of total weight gain by castrates (304.33 g) over non-castrates (204.33 g). This could be that castrates utilized all the digested feed consumed in gaining weight while non-castrates used some parts of the digested feed in sex organs development and sperm formation.

The feed conversion ratio result of this study showed significant better performance ($p<0.05$) value (5.59) of bilateral castrates over unilateral castrates (6.62) and non-castrates (6.99). This could be that the feed supposed to be used in testicle development and semen formation was utilized by the body. This agrees with the findings of Saheed *et al.* (2020) who reported similar performance of better feed conversion ratio (14.84) of castrates when compared to non-castrates (21.52).

This study revealed significantly higher protein efficiency ratio and energy efficiency ratio in favoured of bilateral castrates (0.99 and 22.19) over unilateral castrates (0.85 and 19.80) and intact males (0.80 and 19.46). This could be that testicles utilize some portion of protein and energy in the feed consumed.

### 4.2.2 Carcass characteristics of castrates and non-castrates weaner rabbits

The non-significant difference observed in this study in line with the report of Dikko *et al*. (2011) who reported no significant difference in the live weight and dressing weight among castrates and non-castrates mixed breed of rabbits. Jehl *et al.* (2000) no significance difference in dressing percentage among castrates and non-castrates rabbits.

This might be that castration has no influence on the carcass characteristics of weaner rabbits.

### 4.2.3 Visceral organs characteristics of castrates and non-castrates weaner rabbits

There was no significant difference observed in the carcass attributes of the bucks. All the carcass parameters were statistically similar. This might be that castration has no influence on the visceral organs characteristics of weaner rabbits.

### 4.2.4 Apparent nutrient digestibility of castrates and non-castrates weaner rabbits

The significant higher ($p<0.05$) value of crude protein and crude fibre revealed in this study which favoured intact males over castrates could be that testicles utilize significant portion of crude protein and crude fibre of the feed consumed. This is contrary to the findings of Dikko *et al.* (2011) who revealed higher significant ($p<0.05$) value in unilateral castrates (98.93) above intact males (98.38) and bilateral castrates (92.43).

The crude fibre value of non-castrates (82.13) revealed significantly higher ($p<0.05$) value above unilateral castrates (76.83) bilateral castrates (77.49). This result agreed with the work of Dikko *et al.* (2011) who reported that non-castrates had significantly higher ($p<0.05$) value (99.11) above unilateral castrates (99.00) bilateral castrates (97.32) on fibre content values on growing rabbits.

The ash and nitrogen free extract (NFE) of this study which favoured unilateral castrates (68.59 and 67.49) and bilateral castrates (67.49 and 79.27) over non-castrates (62.03 and 76.35) is in line with the findings of Saheed *et al.* (2020) who revealed better performance ($p<0.05$) of castrates (56.66) over non castrates (40.83) in ash and nitrogen free extract in rabbits. On the contrary, Dikko *et al.* (2011) work shows significantly higher value (99.33) in non-castrates above castrates (unilateral, 98.89 and bilateral, 97.83) in ash content. The differences in the values of crude protein, crude fibre, ash content and

nitrogen free extract (NFE) results recorded in this study could be attributed to factors such as the effect of castration as well as management system used for the experimental animals.

### 4.2.5 Meat quality parameters of castrates and non-castrates weaner rabbits

This study revealed statistical similarity on the water holding capacity between unilateral castrates (0.49) and bilateral castrates (0.66). However, bilateral castrates revealed significantly higher ($p<0.05$) values when compared to non-castrates (0.42) in water holding capacity. This finding is in line with that of Lebas *et al.* (2000) who reported that castrates (rabbits) loss less water (2.89) at 20 weeks of age than non-castrates (3.62). This phenomenon could be that castration influenced the increase in water holding capacity of mixed breed weaner rabbits.

# CHAPTER FIVE

# 5.0 CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

Based on the results of this work, it can be concluded that bilateral castrates are superior to non-castrates in total body weight gain, average daily gain, feed conversion ratio and protein efficiency ratio. Also, bilateral castrates had better water holding capacity than non-castrates. Non-castrates are significantly better in dry matter (DM), crude protein (CP) and crude fibre (CF) digestibility compare to castrates.

## 5.2 Recommendations

i. Bilateral castration is recommended as it can be effectively used in rabbit production to boost body weight gain.

ii. It is recommended that mixed breed of rabbit fed (concentrate) can be supplemented with cowpea haulms for optimum growth.

iii. It is recommended that more research effort should be made on the influence of castration on different breeds of rabbits

iv. It is also recommended that research should be carry out to check the influence of difference types of castration such as close and open castration.

v. Further research can be carried out to investigate the influence of castration on the immunity level of rabbits.

## 5.3 Contribution to Knowledge

The thesis revealed that different castration methods (unilateral and bilateral castration) carried out on mixed breed of growing rabbits positively influenced total body weight gain (TBWG) and water holding capacity (WHC) of meat quality at the rate of 12.30 % and 36.36 % respectively, when compared to the control group (intact males).

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