EFFECTS OF COOKING METHODS ON MEAT QUALITY OF GROWING RABBITS FED GRADED LEVELS OF LOCUST (*Zonocerus variegatus*) MEAL

BY

ALIYU Zuwaira Isah
(P16AGAN8008)

DEPARTMENT OF ANIMAL SCIENCE,
FACULTY OF AGRICULTURE,
AHMADU BELLO UNIVERSITY,
ZARIA

AUGUST, 2021

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A DISSERTATION SUBMITTED TO THE POSTGRADUATE SCHOOL, AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE (ANIMAL SCIENCE)

DEPARTMENT OF ANIMAL SCIENCE,
FACULTY OF AGRICULTURE,
AHMADU BELLO UNIVERSITY,
ZARIA

AUGUST, 2021

DECLARATION

I hereby declare that the work reported in this Dissertation title "**EFFECTS OF COOKING METHODS ON MEAT QUALITY OF GROWING RABBITS FED GRADED LEVEL OF LOCUST** (*Zonocerus variegatus*) **MEAL**" has been performed by me in the Department of Animal Science, Ahmadu Bello University under the supervision of Prof. M. Jibir and Prof. S.B. Abdu. The information derived from literature has been duly 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.

____________________ __________________

Aliyu, Zuwaira Isah Date

CERTIFICATION

This dissertation titled "**EFFECTS OF COOKING METHODS ON MEAT QUALITY OF GROWING RABBITS FED GRADED LEVEL OF LOCUST (*Zonocerus variegatus*) MEAL**" by Aliyu, Zuwaira Isah meets the regulations governing the award of the degree of Master of Science (Animal Science) in Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

__________________ _______________
Prof. M. Jibir **Date**
Chairman, Supervisory Committee,

____________________ ________________
Prof. S. B. Abdu **Date**
Member, Supervisory Committee,

_______________________ ________________
Prof. M. Kabir **Date**
Head, Department of Animal Science
Ahmadu Bello University, Zaria

_______________________ ________________
Prof. Sani A. Abdullahi **Date**
Dean, School of Postgraduate Studies
Ahmadu Bello University, Zaria

DEDICATION

This work is dedicated to my beloved parents: Alhaji Aliyu Abdu and late Hajiya Amina Hamza, who died during my undergraduate study. May Allah forgives her and grant her Jannatul Firdaws, Ameen.

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I wish to express my profound gratitude to Almighty Allah (SWT) for His infinite blessings and mercies upon me and all His creatures. May His infinite mercies and blessings be upon His noble prophet Muhammad (SAW), members of his family, his rightly guided caliphs and all those who follow their path till the last hour.

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ABSTRACT

Twenty eight (28) weaned rabbits aged 6 weeks (with average weight 500±12g) of mixed sex and breeds (Dutch and New Zealand White) were used in this research to evaluate the effects of cooking methods on meat quality growing rabbits fed graded levels of locust (*Zonocerous variegatus*) meal (LM). There were four graded levels of LM (0, 5, 10 and 15%), three cooking methods; Simmering (SM), Pan-frying (PF) and Grilling (GR) and two storage periods(1 and 7 days) in 4 × 3 × 2 factorial arrangement in a completely randomized design (CRD). Results showed that meat of rabbits fed the control diet had significantly higher (P<0.05) crude protein (CP) and nitrogen free extract (NFE) contents (23.42 vs. 2.86%, respectively) than in other treatments, except in rabbits fed 15% LM. Rabbits fed 5% LM had significantly (P<0.05) higher moisture and ash contents (76.48 vs.2.33% respectively), compared to other treatments. Ether extract (EE) and gross energy (GE) contents were higher (P<0.05) in rabbits fed diet containing 15% LM (10.70% vs. 198.9 Kcal/100g, respectively). Processing methods had significant effect (P<0.05) on proximate composition and GE content of rabbit meat. SM and PF had higher (P<0.05) and similar CP contents (16.67 vs. 17.91%, respectively); while PF had significantly higher (P<0.05) EE, ash and GE contents (17.31, 3.08% and 248.27 Kcal/100g, respectively) compared to other processing methods. Interactions between inclusion levels of LM in the diets and processing methods were all significant (P<0.05) and (P<0.001). Organoleptic properties of rabbit meat were affected by inclusion levels of LM and processing methods. Meat of rabbits fed the control, 5 and 15% LM diets were rated best (P<0.05) by the panelists in terms of taste compared to those fed 10% LM diet. Meat of rabbits fed 5% LM diet had better (P<0.05) colour (2.24%), texture (2.31%), juiciness (2.56%), tenderness (2.48%) and overall acceptability attributes (2.57%). Processing method had significant effects on organoleptic properties of rabbit meat. SM had significantly better (P<0.05) colour, taste, texture, flavor, aroma and overall acceptability attributes (2.64, 2.81, 2.29, 2.68, 2.62, 2.37, 2.66%, respectively). However, juiciness and tenderness attributes of rabbit meat processed using GR and SM methods were similar (P<0.05) and better than PF. Interactions were significant (P<0.05) in taste, tenderness and overall acceptability, respectively. Results of microbiological load of rabbit meat indicated that there were significant differences (P<0.05) in all parameters measured, although values were lower than the threshold levels. However, rabbit meat stored up to 7 days had 52, 54, 82 and 50% higher (P<0.05) TAPC, TCC, TYC and TFC, respectively compared to storage at day 1. The return on investment of rabbits fed 0 and 5% inclusion levels of LM were similar, however, there was 18% higher (P<0.05) return on investment (₦ 163.45) in rabbits fed 5% LM than those fed 15% inclusion level (₦ 138.79). It was concluded from the result of this study that meat of rabbits fed 5% locust meal in their diet and processed by simmering cooking method had better meat quality properties and overall acceptability. It was recommended that LM should be included in rabbit's diet at 5% level and the meat should be processed by simmering. Rabbit meat could be stored up to 7 days at ambient temperature without spoilage provided it is processed in hygienic environment in Zaria, Northwest Nigeria.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

The demand for meat and milk is expected to be 58 and 70% higher in 2050 than their levels in 2010 and a large part of this increase will originate from developing countries (FAO 2011). In order to bridge this gap of the demand, rearing of short cycled animals like rabbits has been advocated (Khan *et al.*, 2017). Rabbit has been shown to grow rapidly and for them to perform optimally; they require good quality feed (Khan *et al.*, 2017). However, the conventional feed resources available are expensive and out of reach of the poor resource farmers, due to increasing costs of these feed resources (Ramos *et al.*, 2002). It has been reported that feed cost constitute over 70-80% cost of production (Akinmutimi and Ezea, 2006), resulting in high cost of producing animals and subsequently the cost of animal products like meat.

There is a growing global need for alternative protein source for human and livestock use. One of the potential sources of high value protein which is increasingly being investigated over the last decade are insects (Josianne, 2015). The rearing and use of insects could be one of the ways to enhance food and feed security (Josianne, 2015). They grow and reproduce easily, have high feed conversion efficiency (since they are cold blooded) and can be bio-waste streams (FOA, 2011). Several studies on the use of insect meal in animal feeding trials have been reported (Olaleye, 2015; Laura, 2017).

Despite the use of unconventional feed sources for rearing of farm animals with successes, in terms of performance, feed and animal products quality and consumer acceptability has been an issue of concern. Several factors affect carcass and meat quality and all of them can be divided into two categories: endogenous factors directly linked with the animal (breed, age, sex etc.) and exogenous factors (diet, weather, slaughtering procedures etc.) indicated by the generic expression ‘environment’. Among the environmental factors, feeding plays an important role in the determination of quality (Edgar *et al.,* 2018).

Feed ingredients have been reported to have influence on carcass characteristics. Partida *et al.* (2007) showed that diet had a significant effect on tenderness, fibrosity, and acid flavor. In another work, diets containing different percentage of dehydrated lucerner in concentrates for bulls produced significant effect in juiciness, but tenderness, flavour and instrumental meat quality remained unchanged (Alberti *et al.,* 1992).

1.2 Problem Statement

There is a reduction in the quantity of soybean meal and exorbitant cost in the Nigeria market as a result of banditry and kidnapping in the country and the demand for animal protein indicates that livestock should be reared in large scale over a decrease land resource which is not feasible, as such other alternative animal protein are necessary. Insects are important sectors of African economy that have the potential to improve quality and quantity of livestock product (Niassey *et al.*, 2018). Despite the nutritional quality of rabbit meat, its acceptability and consumption is still limited in Nigeria. The effect of diet composition on carcass characteristics of rabbit meat has been an issue of concern (Liu *et al.*, 2018). Meat generally has a lesser shelf life, as micro-organisms have better chance of multiplying due to its higher moisture content (Alan, 2001). Cooking method and cooking conditions could lead to undesirable modification such as decrease in nutritional value due to nutrient loses (Brugiapagelia and Destefanis, 2012)

1.3 Justification for the Study

Globally, the importance of healthy foods including meat continues to be a concern for consumers (Amenan *et al.,* 2018). Rabbit meat has been reported to stand for its healthier characteristics due to its higher protein content, low unsaturated fats rich in polyunsaturated ones, absence of uric acid and purines, compared to beef meat (Nistor *et al.*, 2013). However, annual consumption of rabbit meat remains limited worldwide (0.30 kg per capita) in comparison to beef (6.4kg), pork (12.5 kg) and poultry (13.5 kg) (Amenan *et al.*, 2018).

Abanikannda (2012) reported the replacement of 25% fish meal by migratory locust (*Locusta migratoria*) meal in iso-protein diets of Nile tilapia fingerlings without any adverse effect on the nutrient digestibility, growth performance and haematological parameters. Also reported, broiler birds given desert locust meal (*Schistocerca gregaria*) as a substitute for fishmeal, replacing 50% fishmeal protein with locust meal (1.7% in the diet), resulted in higher body weight gain, higher feed intake and higher feed conversion ratio (Adeyemo *et al*., 2008). It has been reported that different factors, such as age at slaughter, weight, breed, and sex, have an influence on different carcass traits (Bianospino *et al.,* 2006).

There is currently a growing interest in the use of some of the protein-rich insect species as a low-cost protein ingredient in livestock ration (Van-Huis *et al*., 2013). According to Rafi Ullah *et al.* (2017), insects grow and reproduce very fast, have high feed conversion efficiency and can be fed on bio-wastes materials.

Consumers consider the meat obtained from animals raised on pasture to be different from that obtained from animal raised on concentrates, especially in terms of flavours (Liu *et al.*, 2018).

Flavour differences found between animals raised in different production systems have an effect on consumers' acceptability of a meat product (Martínez-Álvaro and Hernández, 2018).

There are many culinary techniques that strongly influence physical properties and sensory quality of meat. Proper cooking methods have been reported by Mohammad *et al*. (2010), to have the greatest impact on sensory perception of the final product. Also Wharton *et al.* (2008) reported heat treatment has a major impact on meat tenderness, as the water and fat binding ability and texture are closely linked with the heating conditions applied during the process. In Nigerian livestock industry, limited work has been done on the nutritional value of Locust meal and its effect on meat quality of rabbit. Therefore, the present study was designed to assess the effect of feeding growing rabbits with replacement levels of locust meal on growth performance, carcass yield, cooking methods and quality of rabbit meat.

1.4 Objectives of the Study

i. To determine the effects of locust meal on growth performance and carcass yield of growing rabbits

ii. To investigate the chemical composition and sensory quality (organoleptic properties) of rabbit meat as affected by inclusion levels of locust meal and cooking methods

iii. To investigate the microbial load in rabbit meat under different inclusion levels of locust meal, cooking methods and storage periods

1.5 Research Hypotheses

H_{01}: Inclusion levels of locust meal have no effect on growth performance and carcass yield of growing rabbits

H_{A1}: Inclusion levels of locust meal have effect on growth performance and carcass yield of growing rabbits

H_{02}: Inclusion levels of locust meal and cooking methods have no effect on chemical Composition and sensory quality (organoleptic properties) of rabbit meat

H_{A2}: Inclusion levels of locust meal and cooking methods have effect on chemical Composition and sensory quality (organoleptic properties) of rabbit meat

H_{03}: Inclusion levels of locust meal and cooking methods have no effect on microbial load in rabbit meat

H_{A3}: Inclusion levels of locust meal and cooking methods have effect on microbial load in rabbit meat

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Chemical Composition of Meat

Meat is placed among one of the most remarkable, nourishing and recommended food item to man, which helps in achieving most of the body needs (Amenan *et al.,* 2018). Meat plays an important role in human development and constitutes a vital well-balanced diet. It is a very good source of iron, protein, selenium, zinc and phosphorus accompanied by vitamin A and B-complex (Amenan *et al.,* 2018). The mean value of meat protein is about 23% which varies from higher to lower values depending on the meat type (Adam *et al.,* 2015). According to Alan (2001), fat and fatty acid outline of meat is of great concern and therefore, with regards to its consumption, physicians and nutritionists give more emphasis on its average utilization, in order to live a healthy life. Fat constituent in meat ranges from 8 to 20% (Amenan e*t al.,* 2018). These authors further reported that nutritional component and quality attributes of meat is dependent on the breed type of the animal, source of feeding, animal genetics and its post mortem techniques.

2.1.1 Water

Water is a principal component of all food substances and based on moisture content, food products have been classified into three categories (Alan, 2001). Firstly, perishable foods consisting of more than 70% moisture, non-perishable foods consisting about 50-60% moisture and stable food items with less than 15% moisture content, respectively (Alan, 2001; Amenan *et al.,* 2018). It has been established that the higher the moisture content of a food material (meat), the lesser its shelf life as micro-organisms have better chances of multiplying (Alan, 2001; Amenan *et al.*, 2018).

Meat is placed among the perishable food items because it contain more than 70% moisture (Alan, 2001). Apart from decreasing its shelf-life, it also has great influence on the colour, flavour and texture of the meat (Amenan *et al.*, 2018). Also, Adam and Abugroun (2015) reported that fatty tissues (on the abdominal part of the animal) has less moisture content in it and this contribute to the fact that the higher the fat content, the lesser the content and vice-versa. Younger animals have been reported to have higher moisture content about 72% than older animals (Amenan *et al.*, 2018).

The main part of moisture content in meat tissues is found to exist in free-state inside muscle fibres and a little portion of it exists in the connective tissues (Brugiapaglia *et al.*, 2012). Other authors opined that when processing meat through curing and heat treatment accompanied by the storage, little percentage of the water is retained inside the muscle fiber and hence termed as bound water (Amenan *et al.*, 2018). It has also been reported that during processing, other conditions applied under pressure and specific temperature lead to little water retention in the muscle which leads to most of it being lost as free water (Brugiapaglia *et al.*, 2012). Hence, any interference of the muscle fibers of the meat might affect the water holding capacity of the meat, which helps in the improvement of the shelf life of meat products (Amenan *et al.*, 2018). These authors further suggest that acidity (pH) of the meat is a factor that can affect the final water content of meat products through various methods which may include grinding, freezing, chopping, salting, breaking down of connective tissues by enzymatic or chemical means, heat application and use of chemicals or organic additives, respectively.

2.1.2 Protein and Amino Acids

Meat is placed among the protein-rich foods of high biological value in human nutrition (Amenan *et al.,* 2018). The main building blocks of meat are proteins which have been known to occur naturally as complex nitrogenous compounds having very high molecular weight comprising of hydrogen, carbon, oxygen and most importantly nitrogen (Laura *et al.,* 2019). These authors further reported that some may have phosphorus and sulphur in their structures. The structural components are linked together chemically to form various types of individual proteins, displaying various properties (Amenan *et al.,* 2018). However, variations could occur within the same living organism from one tissue to another and also in similar tissues of various species. The protein content of meat varies greatly depending on the type of meat (Laura *et al.*, 2019). Generally, the amount of meat protein has been reported to be about 22%, but it may range from high value protein of 34.5% in chicken breast to as low as 12.3% protein in duck meat (Aderonke and Ifeanyi, 2020). Amenan *et al.* (2018) further suggest that the quality of protein is mainly concern with the amino acid availability present in it. Grasscutters (*Thryonomis swinderianus and Thryonomis gregorianus*) was reported to contain 22% protein; Guinea pig (*Cavia porcellus*) contains approximately 21% (Hoffman, 2008).

Cristina *et al.* (2010) reported that the protein building block consists of amino acids and that the nutritional value of meat may vary by the presence or absence of many amino acids. The authors further reported that beef meat seems to have higher contents of lysine, leucine and valine compared to meat of pork and lamb, respectively. Studies by Laura *et al.* (2019) have shown that the major reason for differences in the proportion of amino acid contents lies in rabbit breeds, location of muscle fibre and age of the animal, respectively. Various parts of carcass have different contents of essential amino acids (Amenan *et al.,* 2018). Meat composition has been reported to be affected by the application of various techniques of processing such as heat treatment and ionization radiations, but only when severe prolonged mode of these techniques are applied (Amenan *et al.,* 2018). Sometimes, these amino acids may not be available for human use. Some researchers in a study revealed that only 50% of lysine was available at 160°C, while 90% was observed at 70° C which indicates that the relationship between the various constituents and proteins has effect on availability of essential amino acids (Amenan *et al.*, 2018). In this regards, salting and smoking could also play a vital role. Aside the effect of processing conditions, storage has been reported to have effect on availability of amino acids in case of canned meat (Amenan *et al.*, 2018).

2.1.3 Carbohydrates

A study by Lenka and Anna (2016) and Amenan *et al.* (2018) revealed that liver is the main source of carbohydrate in the body of animals, because it contains ½ the total carbohydrate present in their body which are stored in the form of glycogen mainly in the liver and muscles, some glands and organs in minor content. These authors further reported that considerable amount is also present in the blood in the form of glucose. Glycogen has indirect effect on the texture, tenderness, water holding capacity and meat colour (Amenan *et al.*, 2018). The transformation of glycogen to glucose and to lactic acid involves a sophisticated process which are modified and governed by enzymes and hormonal action (Niassy *et al.*, 2018).

According to Ranken (2000), at the initial stage of meat aging, lactic acid content of muscles increases rapidly thereby lowering the meat pH. The author further reported that the average muscle pH is around 5.6 which significantly influence the meat sensory parameters (tenderness, colour, texture and water holding capacity). It has also been reported that when an animal is stressed severely or exercise prior to slaughter and do not have the chance to regain its normal glycogen level, a little amount of glycogen will be available for conversion into lactic acid and thus causing a rise in pH around (6.5), and as a result of this, the meat muscle becomes darker, firm and dry (DFD) (Amenan *et al.,* 2018). The DFD in meat is disgust by customers and retailers, strongly having effect on its sensory and nutritional attributes. In this case, stress and animal cruelty prior to slaughter should be avoided (Amenan *et al.*, 2018).

A rapid postmortem causes a fall in the muscle pH of meat around (5.0) accompanied by a pale, soft and exudative condition (PSE), a situation that is mostly common in pork meat (Ranken, 2000). PSE has been reported to occur as a result of low water-holding capacity making the muscle portion of meat to have soft texture and pale yellow colour which affect the nutritional quality of the meat (Amenan *et al.,* 2018).

2.1.4 Lipids

Van Huis *et al.* (2013) defined lipids as organic compounds (usually consisting of carbon, oxygen, hydrogen, phosphorus and nitrogen) which are insoluble in aqueous solutions but highly soluble in organic solvents, mostly chloroform, hexane, dichloromethane and diethyl ether.

A typical meat sample has total lipids mostly ranging between 50-100 mg/g, but much significant variation may occur in fish between 10-200 mg/g depending on the species (Van Huis *et al.,* 2013). Aderonke and Ifeanyi (2020) reported that larger amount of total lipids obtained are based on analysis of whole cuts from different meat, while in analysis of small sample, 1 g of sample is normally used after been exercised carefully of any invisible fat. Total phospholipids ranged between 3.5 mg/g in (pork) to 6.0 mg/g in (chicken) or based on percentage of total lipids, approximately 9% in (pork) to 25% in (chicken) (Van Huis *et al.,* 2013). As the animal aged, the total amount of phospholipids in the muscle remains relatively unchanged but the amount of triacylglycerol may increase drastically (Van Huis *et al.,* 2013; Wahidu *et al.,* 2013). In steers, from 12 to 24 months of age, Mohammad *et al.* (2010) and (Van Huis *et al.,* 2013) reported that the relative amount of phospholipids reduces from around 30% to about 10% of the total lipids while in pigs it starts from an initial weight of 40 kg then subsequently dropped from about 45% to 30% in 80 days period of feeding. However, variations could occur in the amount of total phospholipids and lipids with age of the meat and other potential factors such as diet depending on the meat type (Van Huis *et al.,* 2013). Meats typically consist mostly of PE, PC and PS roughly with 40%, 15% and 10% of total phospholipids, respectively. Phingomyelin makes up another ~ 5% of the phospholipids while the remaining are mixed ether- linked species, alyl and alkenyl ethers like plasmologens etc (Van Huis *et al.,* 2013).

Hoffman (2008) stated that farm raised guinea pigs contain approximately 8% fat, Grasscutters 4% fat, camel 84% fat and 139 mg cholesterol per 100g wet weight and 166 mg cholesterol per 100g lipid, respectively. The author further reported that the hump contains most of the fat around (49% fat) rather than being distributed throughout the body.

2.1.5 Vitamins

Amenan *et al.* (2018) and Alan (2001) defined vitamins as a class of organic materials that work in various aspects in human body. The authors further stated that vitamins are required in fewer amounts and they are key components for growth, development and maintenance of the body. They are essential at the early stage of development of children and they function in many metabolic processes associated with series of biochemical and chemical reactions (Alan, 2001).

Generally, they are classified into two groups; and the first groups are the water soluble vitamins such as B-vitamins (thiamine, pyrodixine, riboflavin, nicotinic acid, cyanocobalamin, choline, folic acid, inositol, biotin etc.) and vitamin C. Secondly, they include fat soluble vitamins such as vitamins A, D, E and K, respectively (Amenan *et al.*, 2018). These authors further stated that meat is a good source of vitamin B including riboflavin, thiamine, nicotinic acid, vitamin B_6 and vitamin B_{12}, respectively. It also contains biotin and pantothenic acid, but poor in folacin.

2.1.6 Minerals

Minerals are nutrients found in food materials which do not contain carbon element in them and are essential for growth, development and maintenance of the body (Ranken, 2000). Based on their requirement by the body, they are classified into two groups which help to perform many functions in the body; first, macro-minerals like sodium, potassium, calcium, chloride, sulphur, magnesium and phosphorus these are required in larger amount by the body. Second, micro-minerals like iron, zinc, cobalt, manganese, iodine, copper, selenium and fluoride which are required in smaller amount (Amenan *et al.,* 2018).

Meat is a good source of iron, zinc and selenium. Iron is one of the main mineral found in meat, which have a significant role in human health and its deficiency poses many impediments in the normal functioning of the body, especially at child's early stage of growth and development (Amenan *et al.,* 2018). Iron metabolism in the body is quite different compared to other minerals, because, more than 90% of it is utilized internally in the body (Amenan *et al.,* 2018). These authors further stated that iron is present in most food stuff and are categorized into two forms; heme and non-heme iron. Heme like comes from hemoglobin and myoglobin, so it is available in animal only and has a high degree of bioavailability that could be absorbed easily in the intestinal lumen.

2.2 Nutritional Benefits of Meat

Paula *et al.* (2013) reported that meat plays a significant role in human evolution and it is a vital component of a healthy and well balanced diet due to its nutritional value. Meat is a beneficial source of high biological value protein, iron, and vitamin B_{12} with other B-vitamins, selenium, zinc and phosphorus (Alan, 2001). Ranken (2000) emphasized the importance of meat, particularly red meat as a protein source as indisputable. However, variation occurs in the protein content of meat and excess protein in the diet is used as energy source (Laura, 2015). Protein is required for growth, maintenance and repair of the body tissues (Alan, 2001). On average, red meat contains 20-24 g protein per 100 g (in raw form), thus considered as a high protein source. Many developed countries of the world consume more than the minimum protein requirement for good health (Laura, 2015).

According to Ranken (2000), the quantity of energy provided by red meat varied and the richest dietary source of energy is fat; although with a vast difference of fat content as seen in red meat, which depends on the type of cut and degree of trimming. The author also stated that variations may occur on the fatty acid outline of red meat, depending on the proportions of lean meat and fat present. Lean meat has high proportion of polyunsaturated fatty acid (PUFA) and lower saturated fatty acids (SFA) compared with untrimmed meat (Laura, 2015). Trimming off meat can affect the fatty acids proportions, as visible fat is higher in SFA; contain around 37 g SFA per 100 g meat. Beef, lamb and other meat from ruminants normally contain more SFA than pork (or meat from non-ruminants) because majority (>90%) of the dietary unsaturated fatty acids are hydrogenated to SFA in the rumen during digestion (Laura, (2015).

Meat is made up of vitamins and minerals which are important for healthy body maintenance. Some of these vitamins include vitamin E and B including B2, B6 and B12, respectively (Paula *et al.,* 2013). Vitamin E has strong antioxidant property that helps to reduce damage caused by oxygen to cell as such allowing faster muscle repair and recovery. All B vitamins have been reported to work together to help transform food into energy but all has individual uses (Wang *et al.,* 2018). Vitamin B2 is essential for the manufacture of red blood cells, which then transport the oxygen around the body. B6 is vital for protein synthesis and B12 is imperative for good nerve functions (Wang *et al.*, 2018).

According to Christine *et al.* (2020), meat has a very high mineral content including essential minerals such as zinc, iron and magnesium, respectively. Iron helps to maintain energy levels as well as maximize oxygen transport throughout the body. Magnesium is essential for bone strength as it improves vitamin D synthesis as well as helps to decrease net acid production. Zinc is important for the body immune system and is essential for growth and repair of muscle (Sheriff and Doaa, 2018).

2.3 Effect of Meat Source on Chemical Composition

Ranken (2000) stated that meat production lies upon several environmental factors and management practices. Meat carcass of animals varies in composition via genetic, age and animal sex, nutritional and environmental effects.

Genetic Factors; carcass composition and growth traits among all farm animals differs between breeds (Irshad *et al.,* 2012). Accordingly, these authors further stated that animals undergo an increase in the muscle to bone ratio as they mature, accompanied by a reduction in muscle growth rate and an increase in the ratio of fat to muscle. Other authors have the opinion that late maturing breeds in beef cattle such as the European continental breeds produced heavier carcasses with less fat likewise in larger breeds of lamb (Cristina *et al.,* 2010). Strains and hybrid of improved pig breeds (e.g Landrace, Hampshire etc) are used now in pork and bacon production because they have good carcass composition compared to traditional British pig breeds like Tamworth; due to the reduced level of fat and increased muscle percentage (Irshad *et al.,* 2012). These authors further stated that dairy breeds of cattle and sheep have higher internal body fat deposit proportion compared to meat breeds that have high subcutaneous proportion of fat proportion.

Sex; the effect of sex (male, female and castrated) is usually attributed to the quantity of fat deposited, growth and carcass yield (Ana *et al.,* 2012). It has been established that carcass characteristics of meat are more affected by gender; and females are more affected than males due to their higher precociousness, although steers maintain an intermediate position (Irshad *et al.,* 2013). Carcass differences in fat and conformation may have effect on other meat quality parameters (Nikmaram *et al.,* 2011). A study was carried out by Ana *et al.* (2012).to determine the effect of sex on the appraisal of meat derived from the Spanish beef breed (Avileña-Negra Ibérica). Results from this study showed that consumers' preference and sensory qualities of meat from females were more appreciated than that from the males in terms of juiciness and tenderness. Other variable studies showed that gender may have effect on colour and pH of the meat (Zhang *et al.,* 2014).

Age and Slaughter Weight; Ana *et al.* (2012) reported that age and age at slaughter are analyzed together because, looking at the genetic base, a high weight indicates higher age, unless there is feed maneuver. Weight affects carcass yield and fat proportions. In a study carried out by Tenin *et al.* (2000) on local Spanish sheep breed at two slaughtering weights, it was found that light lamb have less internal fat and lower commercial and slaughter yields with more muscle and bone percentage. Weight at slaughter as reported by Nomasonto *et al.* (2011) had major effect on meat quality and light kids had a higher compression on texture rates (Ana *et al.*, 2012).

Nutrition; Variations in plane of nutrition at any stage of development from foetal to maturity stage not only affect growth generally but also the different regions, tissues and various organs. Although, different planes of nutrition affect greatly animals' form and composition even if they are of the same breed and weight (Liu *et al.*, 2018). For many years back, studies have indicated that there is a strong relationship between plane of nutrition and development of different tissues of the body such as the brain and nervous system which are given priority over bone, muscle and fat (Wahidu *et al.*, 2013). Many authors have claimed that carcass composition is weight-dependent and mainly not influenced by age or nutritional pattern (Uhlirova *et al.*, 2018; Laura *et al.*, 2018). Animals under full-fed high concentrate diets normally produce more carcass fat, and therefore, less efficient in transforming feed to lean meat compared to animals fed little below *ad libitum* feeding even though the *ad libitum* fed animals would be more efficient in total energy retention (Liu *et al.*, 2018). Little to moderate feed restriction has been shown to be an effective method of modifying body or carcass composition (Sihem *et al.*, 2018).

Irshad *et al.* (2013) showed that frozen meat from semi-extensive reared male buffaloes that went through fibre splitting and breaking or stretching of connective tissues significantly improved tenderness and juiciness of the meat. The result further showed that those from intensively reared young male buffaloes had significantly higher moisture, collagen, tenderness, myofibrillar fragmentation, sarcomere length and share force value compared to meat from semi-extensive reared spent male and female buffaloes (Irshad *et al.,* 2013).

Environment

The environments in which animals are reared have significant effect on growth rate and body composition (Irshad *et al.,* 2013). The effect of heat regulation in farm animals has a broad economic value. Living organisms usually accommodate environmental temperatures between 0-40°C, but some animals may live below the freezing point or above 50°C (Irshad *et al.,* 2013). It has been reported that low temperature prolonged animal growth and high temperature retard growth in an un-adapted stock which might affect meat composition (Christine *et al.,* 2020). In hot, humid conditions (e.g. Queensland) many records have shown that cattle with 'Zebu' blood produce a high percentage of better quality carcasses than those of totally temperate blood (Irshad *et al.,* 2013).

Changes in Composition During Pre-Slaughter Handling

Pre slaughter handling of animal is an essential factor that contributes to carcass and meat quality abnormality; therefore it has been an area of concern (Alan, 2001). Improper handling of animals causes reduction in live weight, pale soft exudative (PSE) and dark, firm and dry (DFD) meats (Wharton *et al.,* 2008). These authors further opined that pale soft exudative is mainly associated with chickens and pigs while DFD affects all species of livestock. Short period of stress such as the use of electric goads, fighting among animals prior to slaughter and overcrowding in lairage have been reported to cause PSE and long term stress such as long hours of transportation, food and water deprivation could cause DFD meats (Alan, 2001). PSE and DFD make meat unattractive and much likely discriminated by consumers. A meat with PSE looks pale, lean, soft textured with low water holding capacity and poor functional attributes (Wharton *et al.,* 2008). The authors further reported that meats from DFD look dark, varies in tenderness, has poor functional attributes and is prone to spoilage, respectively.

2.4 Effect of Feeding on Meat Quality

The consumers concern on meat quality has triggered meat producers to focus more on the livestock nutritional aspect (Hyun-Seok *et al.,* 2013). The characteristics of meat quality are affected by the amount and type of nutrient intake by animals. Animals fed grass based diet produce meat with stronger flavour (Wahidu *et al.,* 2013). These authors further reported that diets increased energy density; result in heavier carcasses, higher fatness and marbling, respectively. Shaphan *et al.* (2020) reported that feeding lipids rich in polyunsaturated fatty acids, improves conjugated linolenic acid in beef, polyunsaturated: saturated fatty acids and n-6: n-3 ratio in pigs. According to Wahidu *et al.* (2013), feeding supplemental diet produces heavier carcass, higher dressing percentage, slight increase in fat deposit and pleasing organoleptic properties. These authors further showed that feeding of vitamin E enhances tenderness, colour, juiciness, oxidative stability and extends shelf life of meat.

2.4.1 Colour

The colour of meat plays a significant role in influencing purchasing decisions of consumers. Colour is influenced by the chemical status of myoglobin in the meat (Teye *et al.,* 2020).

Maturity and feeding regime could also affect meat colour. For example, Mohammad Nisar *et al.* (2010) reported that meat from veals and grain fed animals has light meat colour score compared to the older animals. On the contrary, these authors reported that muscles from older animals produced darker meat colour. The authors further attributed the decrease in lightness to be due to an increase in the myoglobin concentration and low number of large 'white' speedy glycolytic fibres and more 'red' slow oxidative fibres. Jointly, the age-induced transition to a slower, more oxidative condition of the muscle could be relating to the darker meat colour observed (Nikmaram *et al.*, 2011; Teye *et al.*, 2020).

In another study by Wharton *et al.* (2008) it was observed that an animal fed pasture based diet has a low percentage of light meat colour with much darker, leaner meat and had a more specific flavour compared to grain-fed animals which had light colour meat that can increase the glycogen and fat content of the animals, resulting in a thicker subcutaneous fat layer. It has also been established that β-carotene is present in high concentrations in fresh leaf tissue which is responsible for the undesirable yellow fat colour in pasture fed beef (Wang et *al.*, 2018).

Pasture fed animals have been observed to have higher concentration of antioxidants, like tocopherol and ascorbic acid which are thought to have higher myoglobin stability and lower levels of lipids and protein oxidation (Nikmaram *et al.*, 2011). The authors reported that this could reduce denaturation of protein, though maintaining the local structure and function of the proteins, as well as improving colour stability.

2.4.2 Flavour

Feed ingredients' effect on flavour of red meat has been reported to rely on the type of diet, and, to a great extent, on the specie: pork, mutton and beef (Melton, 1990). Organoleptic evaluation of meat flavour has been used in many studies to determine feed effect on meat flavour (Wahidu *et al.*, 2013; Teye *et al.*, 2020). Generally, high-energy grain diets produced more desirable or a more extreme flavour in red meats when compared with low-energy or grass diets (Melton, 1990). Pigs fed unsaturated fats increased the fat unsaturation in pork but results in only little changes in pork flavour (Shaphan *et al.*, 2020). In sheep, it was suggested that increase in the unsaturation in their fat to be similar to pork fat must be fed with protected unsaturated fat (Melton, 1990). The author opined that this greater unsaturation of fat results in a greater flavour change in lamb or beef than in pork. The author therefore concluded that many feed ingredients like fish products, canola oil and meal, raw soyabeans, and pasture grasses cause unpleasant flavours in red meat. Lamb and beef produced on different diets have been analysed and has shown that feed type affects the concentration of many flavour volatile compounds (Shaphan *et al.*, 2020).

In a related study, Nikmaram *et al.* (2011) reported that animals fed grass based diet produced a stronger flavoured meat compared to those fed cereals which produced a milder flavoured meat. According to these authors, this difference may be generally due to whether the main dietary fatty acid is a α-linolenic, which produces a stronger flavour, or linoleic acid which produces a mild flavour. In a related study that evaluated pigs fed canola oil, it was observed that the subsequent meat had more off flavour and lower acceptability ratings compared to normal ration fed pigs (Shaphan *et al.*, 2020). Travnicek and Hooper (1968) reported that feed effects on flavour of poultry meat are mainly negative and stem from feeding excessive quantities of n-3 PUFA derived from fish or linseed. In general, flavour difference in beef has been attributed to fatness variation (Nikmaram *et al.*, 2011).

2.4.3 Texture

Meat texture is said to be influenced primarily by the degree of fibre contraction at the time of rigor (Zlender, 2000). In a study to determine the quality attributes of white meat floss, Zahraddeen *et al.* (2020) reported that culinary significantly affects tenderness of meat properties and the intended meat products. According to these authors, meat texture is affected much by number of pre and post mortal factors. Pre-mortal factors include: breed, sex, animal species, connective tissue and animal stress resulting in PSE and DFD meat with their specific texture (Zlender, 2000). This author opined that post-mortal factors affecting meat texture include: development of rigor mortis in relation to muscle temperature, pH (hot, cold and thaw shortening), electrical stimulation; degree of muscle shortening in relation to carcass suspension, hot vs. cold boning and pre-rigor cooking. Post-rigor storage like proteolysis or meat ageing together with meat cooking methods help to accelerate tenderization (Zlender, 2000).

2.4.4 Juiciness

Juiciness may define as moisture discharged by meat when chewing, together with the moisture from the saliva. In a study carried out by Mcmillin and Hoffman (2009) as reported by Jacques *et al.* (2017) it was reported that feeding system has little influence on lamb meat tenderness and juiciness but has some influence on flavour. Accordingly, these authors found no significant difference in juiciness from lamb among the dietary treatments. This result was consistent with the report of Hughes *et al.* (2014) which reported significant differences in the intramuscular fat content which is known to increase the secretion of saliva which makes meat juicier. Meat from stall fed lambs fed at 85% and 15% hay was juicier than for grazed lambs (Hughes *et al.*, 2014).

According to Tenin *et al.* (2000) and Hughes *et al.* (2014), feeding concentrate based diet enhanced flavour and juiciness in chevon and beef meat. Feed restriction could also affect the juiciness of meat but not on other sensory parameters even though large content of fat was reduced (Nikmaram *et al.,* 2011). Laura *et al.* (2019) reported that vegetable or animal source of added fat has effect on the lipid component, flavour and juiciness of rabbit meat. The authors further reported that meat juiciness from rabbits fed animal fat diet was more "liver" tasted, compared to those fed vegetable fat which had an "aniseed" or "grass" flavour.

2.5 Cooking Methods

Different types of cooking methods exist and the best one to use depends largely on the muscle cut. Generally, it is seen that moist heat cooking is usually slow and dry heat cooking is fast (Chris, 2013). The author opined that the reason could be due to different factors such as type of heat transfer and ambient humidity. Dry heat cooking can be used to cook meat very fast whereas moist heat can be used for a slow-type cooking (Mohammad *et al.,* 2010).

The use of any of the two cooking methods can yield different results. Studies have shown that using roasts from the rib and round of beef could cause a change of tenderness profile (Nomasonto *et al.,* 2010). According to these authors, the muscle cuts subjected to slower cooking method produced more tender meat. It has also been reported that using cooking temperature of 93^{0}C and 149 ^{0}C; and the cuts from the round took ~2.5 times longer to cook and the cuts from the rib took ~1.5-1.75 times longer when cooked at the lower temperature than the cuts at the higher temperature (Chris, 2013).

2.5.1 Dry Heat Method

Dry heat cooking methods are methods that use dry heat. They include grilling, broiling, roasting and baking (Nomasonto *et al.,* 2011). These authors reported that heat from cooking causes a change in the muscle protein structure. According to them, the bond within the protein is broken and new bonds are formed when exposed. This process helps in adhesion for products that are reformed or comminuted such as deli loafs, cased sausages and boneless hams (Chris, 2013).

2.5.1.1 Grilling

Grilling is a type of dry heat cooking method that uses high heat from below which sears the outside with frequent turning during cooking of the meat thereby locking in the juices within the muscle (Tenin *et al.*, 2000). This type of cooking usually cooks the meat faster and can confer flavour through maillard reaction (Cristina *et al.*, 2020; Chris, 2013). These authors reported that cooking method does not solubilize collagen as in moist heat methods. Meat cuts ideal for this type of cooking include steaks that are low in connective tissue like *Psoas major, longissimus dorsi*, and the *infraspirnatus* (Chris, 2013). Ground products and hamburgers may also aid from high heat searing the outside of the meat (Aderonke and Ifeanyi, 2020).

2.5.1.2 Broiling

Broiling is similar to grilling, but involves the use of oven with heating from above (instead of below) (Adam and Abugroun, 2015). These authors reported that in broiling, a food cooks faster and evenly due to its exposure to very high heat for a short period of time. The food is placed on top the rack of an oven and set to boil. Broiling has been reported to be an excellent technique for different meat cuts like the loin or chops of beef, pork or lamb (Brugiapaglia and Destefanis, 2012).

2.5.1.3 Roasting

Roasting is usually done in an oven. Here, dry heat is allowed to circulate and evenly cook the food (Adam and Abugroun, 2015). These authors reported that roasting differs from baking because it usually requires a high temperature at the start of cooking so as to get a crisp, brown surface. Roasting is sometime used for roast beef like prime rib, whole or cut up chicken pieces and pork (Warner *et al.,* 2010).

2.5.1.4 Baking

Baking is done by placing the food inside a heated closed chamber called oven. The air inside the oven get hot as a result of the fire that is lit from its base or with electricity and the food is prepared with the hot air as it is placed inside the oven (Wahidu *et al.,* 2013). These authors reported that the temperature range maintained in an oven is 120^0C-260^0C in which the flavour and texture are improved.

2.5.2 Moist Heat Method

Moist heat cooking method uses either liquid or high humidity in cooking the meat. According to Chris (2013), this cooking method include; stewing, boiling, deep frying and pan-frying. This author reported some advantages and impacts of moist heat cookery on texture and flavour of meat. Nikmaram *et al.* (2013) suggested that the liquid used during cooking can add flavour to the product. These authors further reported that Maillard reaction will not occur when cooking in liquid (water). This is as a result of the fact that the boiling point of water is much lower than the temperature needed to attain the reaction. Hence they opined that Maillard reaction can be attained through the use of deep fryers and oils as the cooking liquid, because oils have a much higher boiling point.

Chris (2013) suggested that moist heat cooking has advantage over dry heat cookery mainly due to the breakdown collagen or connective tissue. The author further reported that moist heat has the ability to swell the collagen and break it down so that the meat becomes tenderer and that this process causes the meat to lose its structural integrity.

2.5.2.1 Frying

Frying is a cooking method where fat or oil is used as the medium of heat transfer, in direct contact with the food by immersing the food into hot oil (Pankaj and Anthony, 2016). The heat is transferred via contact between the pan and the meat (Cristina *et al.*, 2010). These authors reported that the heat and mass transfer between the meat and frying medium makes frying a complex process. According to them, a number of chemical changes, such as colour change via Maillard reactions, moisture loss, oil uptake etc promote simultaneous heat, air and mass transfer.

Temperature is a vital component of frying even to the extent of meat flavour, time of cooking and weight loss of products (Pankaj and Anthony, 2016). The authors opined that the cooking time is usually short due to the high frying temperature, and browning surface of the meat occur as a result of Maillard reaction.

2.5.2.2 Simmering

In this method, food is immersed in a pan with a tight fitting lid using small quantity of water to cover only half of the food kept below boiling point for a long time (Nikmaram *et al.,* 2011). According to these authors, after boiling starts, the flame is reduced and the food is allowed to cook slowly maintaining the simmering temperature of about 82^0C-90^0C. These authors suggest that the main advantage of this method is that the juices of the food are retained as well as the taste of the food.

2.5.2.3 Steaming

Steaming is a cooking method in which the food is cooked with the heat generated from water vapours (Brugiapaglia and Destefanis, 2012). These authors further suggest that the time of cooking is shorten and also helps to conserve the nutritive value, colour, flavour and palatability of food which help to make the product light and easily digested.

2.5.2.4 Boiling

Nikmaram *et al.* (2011) reported that boiling involves immersing the food in water at 100^0C and maintaining the water at that temperature till the food becomes tender. Uniform cooking can easily be achieved through boiling which does not require any special skill and equipment (Wahidu *et al.,* 2013). However, these authors opined that boiling takes more time to cook and that water soluble nutrients may be lost.

2.5.2.5 Pan-frying

This type of cooking method involves the use of minimal cooking oil or fat in (comparison with deep-frying), mostly using just enough to lubricate the pan (Mohammad *et al.,* 2010). In the case of oily food, no fat or oil may need to be added. The technique here depends on the fat or oil as a medium of heat transfer, ensuring proper temperature and time so as not to overcook the food (Raj *et al.,* 2005). The authors stated that some moisture in foods is retained and the food is frequently turned at least once to ensure that the food is cooked properly on both sides. Lower heat is required in cooking the food so that the exterior of the food does not overcook by the time the interior reaches the required temperature ((Mohammad *et al.*, 2010).

2.6 Effect of Cooking Methods

Meat and meat products can be considered cooked when the middle of the product is maintained at a temperature of 65^0C -70^0C for 10 minutes up to the time the protein coagulate and the meat gets tenderized by hydrolysis of the collagen partially (Raj *et al.*, 2005). According to these authors, a change of colour from red to brown (red to pink in cured products) and flavour development generally indicates the completion of the cooking process.

2.6.1 Effect of Cooking Methods on Fat

Valeria and Pamela (2011) reported a significant loss of fat even in deep frying because lean muscle does not absorb the cooking fat. These authors stated that in a rump steak containing 18.9% protein and 13.5% fat, a total of 32.4% dry matter (ignoring minerals) was recorded. When expressed as a proportion of dry matter, there was 58.3% protein and 41.6% fat, respectively. Cristina *et al.* (2010) reported that cooking by radiant heat, i.e when grilled with fat added to the loss of water and fat which reduces the total fat to 320.7% on dry matter basis while the protein increased proportionately to 69.3%. Also, Raj *et al.* (2005) reported that loss of water is higher in frying than in grilling but fat loss is less so that the protein proportion becomes

66.2% and the fat 33.7% on dry matter basis. The greater loss of water occurs in boiling than roasting while loss of fat is higher in the boiled products (Raj *et al.*, 2005).

2.6.2 Effect of Cooking Methods on Protein

Nutritionally, protein can be damaged when part of an essential amino acid is rendered unavailable (Mohammad Nisar *et al.*, 2010). Lysine has been reported to be denatured at temperatures around 100^0C, cysteine and methionine at temperatures around 120^0 C while other amino acids can become damaged after a long heating (Raj *et al.*, 2005). The authors further stated that there is little loss of available lysine with no loss of methionine and cysteine of meat cooked at low temperature. The outer part of roasted meat reaches a high temperature and turns brown due to the reaction between the lysine and reducing substances present (Maillard reaction) which produces the desired roast flavour (Nikmaram *et al.,* 2011).

2.6.3 Effect of Cooking Methods on Vitamin

Thiamine is one of the most affected vitamins; it is both water and heat soluble (Chris, 2013). Accordingly, it has been reported by this author to be altered by oxygen at neutral alkaline pH. It is very susceptible to destruction by sulphur dioxide and sulphites which are used in some countries to preserve comminuted meat products (Cristina *et al.*, 2010). Cooking loss for thiamine had been reported to range from 15-40% for boiling, 40-50% on frying, 30-60% on roasting and 50-70% on canning, respectively (Chris, 2013). The author stated that these figures are based on average values since they depend on time, temperature and conditions of cooking the product in particular, meat size and heat penetration.

Riboflavin and Niacin;

Riboflavin is relatively stable to many cooking practices (with the exception of high temperature of roasting), dehydration and canning (Chris, 2013). It has been reported to be damaged by sun-drying and under any alkaline condition (Cristina *et al.,* 2010). Niacin has been observed to be stable to heat, light, oxygen, acids and alkaline. Loss average leached from food is about 10% (Chris, 2013).

2.6.4 Effect of Cooking Methods on cooking loss

Pankaj and Anthony (2016) defined cooking loss as a mixture of liquid and soluble matters lost from meat during cooking. According to them, it is a very important factor in meat industry because it determines the technical yield of the cooking process. With respect to nutritional point of view, cooking loss brings about loss of soluble proteins, vitamins and different nutriennts (Nikmaram *et al.*, 2011). These authors reported that cooking loss is calculated as the weight difference between fresh and cooked meat samples with respect to the weight of fresh meat samples multiplied by hundred. Ranken (2000) stated that development of cooking loss begins at 40^0C and in meat with low pH (below 5.4 like pork), cooking loss begins at 30^0C. The author further suggested that the greatest cooking loss development begins between 50^0C and 70^0C from which it falls. Total cooking losses depends upon temperature and rate of heating (Nikmaram *et al.,* 2011).

Pankaj and Anthony (2016) studied the effect of four different cooking methods (roasting, grilling, microwave and frying), on cooking loss of foal meat. Their results indicated that microwave cooking recorded the highest cooking loss, as a result of high electromagnetic field, high power and short time related in microwaving that brought about protein denaturation and broke down of the texture matrix which brought on by heat shock to the proteins and, eventually, a lot of water and fat liberalization, which were in agreement with other researchers (Mohammad *et al.,* 2010; Cristina et *al.,* 2010).

2.6.5 Effect of Cooking Methods on yield

Cooking yields describe changes that occur in cooked meat weight as a result of lost in moisture (Alan, 2001). The author attributed cooking yields to moisture evaporation, water absorption or fat losses during food preparation. According to the author, yield percentage indicates changes in food weight and cooked food weight which occurs during the process of cooking.

Cooking yield can be calculated as: Yield (%) = 100 × (Wch / Wcr) (Roseland *et al.*, 2012)

Where; Wcr = raw sample weight before cooking

Wch = hot sample weight after it has been cooked and allowed to rest for a while

Cooking yields are used in formulations of food and recipes by converting nutrient values for uncooked foods into values for cooked foods. According to Roseland *et al*. (2012), cooking yield, moisture and fat change for beef cuts varied according to cut/cooking method used. These authors compared beef and pork meat cuts for their cooking yields and the results showed that they differed according to the method of cooking used with broiling having the highest yield. Similarly, their results indicated that cooking yields and moisture changes varied with regard to cut/cooking method, but they did not detect any difference in fat change of pork. However, in ground beef products, their results showed that cooking yield were inversely related to fat levels. No difference was observed in ground pork product among the fat levels. Ground pork had the lowest yield, which varied significantly than yields obtained for all the other ground meat, but with the exception of ground beef (Roseland *et al*., 2012).

2.7 Effect of Cooking Methods on Meat Quality

Cooking plays a significant role in obtaining a safe and palatable meat product (Pankaj and Anthony, 2016). It may also have impact on essential qualities recognized with consumer inclinations, like tenderness and flavour (Aderonke and Ifeanyi, 2020). Cooking methods have been reported to have significant effect on meat nutritive values (Mohammad *et al.,* 2010). Normally, heat is applied to meat in different ways to boost its hygienic quality by deactivation of infectious microorganisms so as to improve its taste and flavour, and increased its shelf life (Alan, 2001). The nutritional value of meat could also be changed due to physiochemical reactions during cooking (Pankaj and Anthony, 2016).

2.7.1 Effect on Texture

According to Adam and Abugroun (2015), the most important attribute in meat with regards to its consumption is its textural property in which tenderness is a factor to be considered. Meat tenderness influences consumers' satisfaction, hence it is essential to meet the consumers' tenderness demand (Wahidu *et al.,* 2013). These authors stated that meat is consumed cooked and the cooking process is a major factor in tenderness determination. Cooking influences meat tenderness as the water – and fat – binding characteristics, and texture related closely to the heating condition applied (Alan, 2001). Product yield, texture, moisture and general quality of meat are affected by heat changes which occur in muscle proteins and the development of another protein network (Wahidu *et al.*, 2013).

With respect to cooking, changes in meat texture occur as a result of the heat-induced structural changes joined with enzymatic breakdown of the proteins (Nikmaram *et al.*, 2011). The effect of the temperature/time element and the core temperature depends on the piece of meat. The collagen in meat is solubilized by heat which result in tenderization, although, warmth denatures myofibrillar proteins that result in toughening (Pankaj and Anthony, 2016). These authors reported that time and temperature induced heat changes, and the main effect of toughening or tenderization depends upon cooking conditions. However, generally there is lack of consistency or standards to choose and report a set of tenderness values even within researchers on the same type of meat.

2.7.2 Effect on Juiciness

Juiciness in meat occurs as a result of moisture discharged by meat when chewing, and moisture from saliva (Brugiapaglia and Destefanis, 2012). Moisture loss in meat has been reported to influence juiciness, which can occur as a result of evaporation in dry heat cooking and by exudation and diffusion in moist heat cooking (Tennin *et al.*, 2000). These authors further stated that cooking methods and raw meat quality have effect on meat juiciness. However, until now, the only reliable and consistent measure of juiciness is obtained using sensory methods. The complication of juiciness also causes difficulties in carrying out objective measurements (Pankaj and Anthony, 2016).

The center temperature has great effect on juiciness of meat and increase of the core temperature has been reported to lessen the juiciness (Tennin *et al.*, 2000). Pankaj and Anthony (2016) reported that low temperature gives a more juicy meat compared with meat cooked at a higher temperature with the same core temperature. In beef cooking, cooking loss and juiciness have been found to negatively correlate, which showed that a high cooking loss results in low juiciness (Nikmaram *et al.,* 2011). Cooking loss has a great influence on the meat juiciness (Pankaj and Anthony, 2016).

2.7.3 Effect on colour

Zhang *et al.* (2014) reported that one of the analytical attribute characterizing the meat quality and influencing consumer's preference is colour**.** It is said to be an indicator of meat freshness and level of doneness (Ranken, 2000). It is known that the myoglobin protein is the important haeme pigment that is responsible for meat colour (Wahidu *et al.,* 2013). These authors opined that colour assessment in cooked meat could give credible information about eating quality attributes. Many consumers consider the cooked meat colour as a reliable indicator of doneness and safety (Alan, 2001). This author further reported that dull-brown interiors indicate well-done item, while pink appearance is identified with uncooked meats.

According to Valeria and Pamela (2011), there is a rise in colour blurriness when the meat internal temperature is between 45^0C and 67^0C due to the denaturing of the meat proteins (myosin and actin), which do not add to the red colour, compared to the red colour of myoglobin. Heated samples have brighter colour more than raw samples. Brightness was reported to be reduced in roasted samples due to its dark surface but inside the meat, brighter colours were found (Raken, 2000). In general, the author stated that samples following heating due to pigment oxidation become colourless. Pankaj and Anthony (2016) reported that there is a tendency for meat to be lighter as a result of increased light reflection which results from light scattering by denatured protein due to increased cooking temperature. These authors also stated that decrease in meat redness could occur when cooking temperature rise from 50 to 80^0C and remained at a very low value above 80^0C.

2.7.4 Effect on flavour

Cooking methods have effect on meat flavour since many volatile compounds are produced during cooking (Aderonke and Ifeanyi, 2020). Mohammad *et al.* (2010) reported that high heat treatment involves production of volatile flavoring compounds as a result of Maillard reaction. These authors further stated that warm-off flavours are the main factors that affect the sensory and eating quality of meat. Warm-off flavour means undesired flavour which result from flavour changes and deterioration in heated, pre-cooked, or chilled-stored meat. Membrane oxidation of phospholipids has been shown to be the main cause of warm-off flavour found in cooked meat (Aderonke and Ifeanyi, 2020).

Wahidu *et al.* (2013) conducted an experiment to determine the effect of cooking methods on sensory qualities of meat. Their results revealed that dry-heat cooking method affect meat flavour. They also observed that in broiling and grilling, cooking of meat was important during the products preparation. In another study, Nikmaram *et al.* (2011) reported that during roasting, many of the flavouring compounds are lost as compared to boiling, that stores many flavouring compounds such as heterocyclic compounds. Frying is used mostly for uniform meat cuts, but there is a tendency of flavour loss depending on the condition of frying (Aderonke and Ifeanyi, 2020).

Wang *et al.* (2018) reported that moist-heat cooking methods help in conservation of flavour. In these methods; liquid is used in various proportions to conserve flavour at various high temperatures and with varying time. Aderonke and Ifeanyi (2020) stated that moist-heat cooking methods use low heat in a tight covered pan in which liquid has been added. These authors further suggested that moist heat cooking method helps to solubilize the collagen and produce natural meat flavours in less tender cuts, and the steam produced by the liquid converts the tough collagen into tender gelatin. According to these authors, sometimes long/slow cooking in moist heat might results from the meat flavour compounds which leached into the cooking liquid thereby creating a delicately flavoured meat.

2.7.5 Effect on acceptability

Cooking methods affect overall consumer acceptability of meat products Nomasonto *et al.* (2011). The authors further stated that new cooking methods are developed globally based on local cultures and resources available to provide quality meats for consumers' satisfaction. When meats are cooked, their physical and chemical structures change which affect consumers' acceptability and eating quality of the meat (Nomasonto *et al.,* 2011). These authors opined that cooking methods affect nutritional value, freshness, juiciness, flavour and tenderness of the meat resulting in overall acceptability by consumers. Therefore, it was concluded that acceptability of goat meat (Chevon) in South Africa was further influenced by gender, tribe and age of panelists.

2.8. Nutritional Composition of Edible Insects

Diverse variations occur in insects' nutritional value mainly due to the large number and specie variability (Lenka and Anna, 2016). According to Christine *et al.* (2020), variations on insect nutritional value occur even among group of insects, depending on the insect origin and its diet, and stage of metamorphosis. In another study, Laura *et al.* (2019) reported that nutritional value of edible insects changes according to the processing and preparation method like (cooking, drying etc.) before consumption. Nutritional value score for palm weevil larvae, crickets, and mealworm are healthier significantly when compared to beef and chicken (Lenka and Anna, 2016). Most edible insects provide proteins and energy sufficiently, and amino acid requirements in human nutrition. Insects have been reported to contain high content of mono- and polyunsaturated fatty acids and they are rich in trace minerals such as iron, manganese (etc.) (Lenka and Anna, 2016).

2.8.1 Energy

The energy value of consumable insects depends mainly on their composition and fat content. According to Lenka and Anna (2016), insect larvae are mostly richer in energy when compared with the adults. However, it was reported by the same authors that high protein insects have lower energy content.

2.8.2 Proteins

The protein content of insect species varies greatly based on the species. For example, Lenka and Anna (2016) reported the protein content of 100 species of insects determined in an experiment. The protein content was found to be between the ranges of 13 to 77% by dry matter indicating the large variability of tested species. Also in another study, eighty-seven consumable insects' species were determined in Mexico, and the results indicated that the protein content ranges between 15 to 81%. (Lenka and Anna, 2016) Insect protein digestibility was also determined in this study which was found to range between 76 to 96%. On the average, these values are a little lower than those obtained for eggs (95%) and beef (98%) and even higher than in the case of much plant protein source (Lenka and Anna, 2016). The authors concluded that insects nitrogenous substances measured might be higher than their actual protein content since some nitrogen is found in their exoskeleton.

Insects contain a number of nutritionally valuable amino acids including high tyrosine and phenylalanine levels when looking at their amino acid composition (Niassy *et al.*, 2018). Some insects may contain much amount of threonine, tryptophan and lysine which might be deficient in some cereal protein (Shaphan *et al.*, 2020). According to these authors, this occurring nutritional gap can be recompense by consuming larvae of the *Rhynchophorus* family beetle that have much amount of lysine. On the other hand, tubers contain a large amount of tryptophan, and aromatic acids which are present in smaller quantities in the larvae and it has been reported that nutritionally, eating of such a diet is balanced (Lenka and Anna, 2016).

2.8.3 Lipids

Averagely, insects have been reported to contain 10 to 60% of fat in dry matter which is apparently higher in the larval stages than in adults (Niassy *et al.*, 2018). In contrast, insects in grasshopper and related O*rthoptera* species have fat content ranging from 3.8% to 5.3% per 100 g (Lenka and Anna, 2016). In insects, fat is stored in several forms with Triacylglycerol making up of about 80% of fat (Niassy *et al.*, 2018). This group of fat serves as energy reserve for periods of high energy intensity like long fliths. Phospholipids are the second most important group of fat which have been reported to be less than 20%, but varies according to different stages of life and species (Niassy *et al.*, 2018). High content of C_{18} fatty acids like linolenic, linoleic, and oleic acids are relatively high in the fat of insects (Lenka and Anna, (2016).

The most abundant sterol in insects is the cholesterol. Cholesterol content of 3.6% has been reported in the fat of caterpillar *Imbrasia belina* and termites' *Macosus* mostly consume in Nigeria (Niassy *et al.,* 2018). Other sterols such as stigmasterol, campesterol, β-sitosterol and other sterols may also be found in consumable insects (Lenka and Anna, 2016).

2.8.4 Minerals

Consumable insects may be fascinating in terms of minerals nutritional content like calcium, potassium, sodium, copper, manganese etc. For example, Lenka and Anna (2016) reported that grasshopper (*Locust migratoria)* contains 8-20 mg per 100 g of dry matter, large caterpillar moth *Gonimbrasia belina* contains 31-77 mg per 100 g of dry matter, which could serve as a good source of zinc (14 mg per 100 g of dry matter) especially when considered jointly with palm weevil larvae (*Rhynchophorus phoenicis)* which contains 26.5 mg per 100 g of dry matter. The heavy metal content of consumable grasshopper (*Oxya chinensis formosana)* was determined to be low and safe for human consumption (Lenka and Anna, 2016).

2.8.5 Fibre

Consumable insects contain armful amount of fibre. The most common form of fibre in the body of insects is the insoluble chitin contained mainly in their exoskeleton (Lenka and Anna, 2016). These authors further reported that commercially, farmed insect chitin range between 2.7 to 49.8 mg per kg of fresh weight (11.6 to 137.2 mg per kg of dry matter). Chitin is considered as an indigestible fibre even though the enzyme chitinase is in the gastric juice of human. A finding suggests that this enzyme may be active (Lenka and Anna, 2016). The response of active chitinase in the body among people is mostly from tropical countries where the consumption of this insect has been a long-term tradition. Its removal could improve protein digestibility in insects (Lenka and Anna, 2016). Chitin could help to improve the immune response of certain group of people. They help individuals to be more resistance against pathogenic bacteria and viruses. They could also reduce allergic reaction to certain group of people (Lenka and Anna, 2016). The African migratory locust had high content of chitin while the Jamaican field cricket has the least on analysis carried out on 7 different edible insect species (Lenka and Anna, 2016).

2.8.6 Vitamins

Insects contain many water soluble vitamins. For example, Thiamine has been reported to be present in a variety of insects ranging from 0.1 to 4 mg per 100 g of dry matter; Riboflavin ranged from 0.11 to 8.9 mg to 100 g.; Vitamin B_{12} is found abundantly in the larvae of yellow mealworm beetle (0.47 µg per 100 g in adults, 8.7 µg per 100 g in nymphs) (Lenka and Anna, 2016). However, many species being analyzed contained only a negligible amount of Vitamin B_{12} (Lenka and Anna, 2016). β -carotene and Retinol were also determined in some butterfly caterpillars, such as *Imbrasia oyemensis, Imbrasia epimethea* etc, containing 32-48 µg of retinol and 6.8-8.2 µg of β-carotene per 100 g of dry matter (Lenka and Anna, 2016). These authors opined that the retinol content per 100 g of dry matter was less than 20 µg, and β-carotene was less than 100 µg in the case of yellow mealworms *T. molitor*, superworms *Z. morio* and house crickets, respectively. The palm weevil larvae *Rhynchophorus ferrugineus* was found to contain vitamin E at 35 mg of α-tocophenol and 9 mg of tocophenols β + γ per 100 g of dry matter (Niassy *et al.*, 2018). The vitamins and minerals content of wild edible insects have been reported to be seasonal but in the case of farm bred species, it could be controlled through feed (Lenka and Anna (2016).

2.8.7 Nutritional Composition of Grasshopper (*Zonocerous variegatus*)

Main Analysis		**Average**
Dry matter	(% as fed)	91.7
Crude protein	(% DM)	57.3
Crude fibre	(% DM)	8.5
Ether extract	(% DM)	8.5
Ash	(% DM))	6.6
Gross energy	(MJ/kg DM)	21.8
Calcium	(g/kg DM)	1.3
Phosphorus	(g/kg DM)	1.1
Potassium	(g/kg DM)	1.1
Sodium	(g/kg DM)	3.2
Magnesium	(/kg DM)	1.5
Zinc	(mg/kg DM)	10
Iron	(mg/kg DM)	13

Source: https://www.feedipedia.org/node/198

Nutritional Composition of Grasshopper

Locusts, grasshopper (mostly Acrididae and Pyrgomorphidae) are insects of the order Orthoptera. Many are edible and more than 80 species are consumed as food in Africa, Asia and South America (Heuze and Tran, 2020). They are generally rich in protein, about 50-65% on DM, although some values have been reported (less than 30%). The dry matter ranges between 23-35%. The fat content varied and ranged from low values of (less than 5%) to over 20%. The calcium content is low like in other insects species. The fibre content may be significant and increases with age (Heuze and Tran, 2020).

2.9 Economic Importance of Insects as Feed Resources for Human and Livestock

Presently, the high demand for animal protein indicates that livestock should be reared in large-scale over decrease land resource which is not feasible and as a result, other alternatives for animal protein are necessary to be taken-up in order to control this problem. Edible insects have several advantages which include;

As source of food; several species of insect has been used in many countries of the world as a source of food mostly during other food type shortage, and when they are readily available for harvesting (Niassy *et al.*, 2018). According to these authors, insects can be eaten either as raw or in processed form; fried, roasted etc due to their nutritional composition which depends mainly on the type of insect, stage of development, diet fed on, method of processing used, the insect species and sex.

Source of protein; edible insects on their potential to addressing nutrition and food security can serve as sources of good quality protein which could be obtained within a short period of time due to their short life-cycle which range between 35 to 61% when compared to conventional livestock protein sources. They are reported to contain 27-54g per 100g of edible portion (Niassy *et al.*, 2018).

Source of livelihood; in rural community, women and children collect insects from the wild as a means to earn them a living in form of cash for purchase of other basic needs such as food, farm inputs and education (Niassy *et al.*, 2018).

As source for environmental control; Insects act as pollinators for some plants through wind by transporting the pollen from one plant to another to ensure efficient fertilization of the embryo (Lenka and Anna, (2016).

Decomposition of organic matter; dead leaves and all other forms of refuse are done by insects. For example, literature shows that bacteria act upon the refuse thereby releasing important ingredients like nitrogen into the soil. Also, consumption of insects leads to low greenhouse gas emission in which keeping livestock constitutes 18% of the greenhouse gas emission (Niassy *et al.*, 2018). Insects reduce pesticides application, as such minimizing the negative environmental effects and the possible appearance of pesticide residues in foods (Niassy *et al.*, 2018). Also, the high feed conversion efficiency of some insects such as crickets which convert feed more efficiently to' Meat 'as in poultry, cattle and pigs poses less hazard to environment (Niassy *et al.*, 2018).

As feed for livestock; Insects can be used as a replacement for fish oil and fish meal in animal feed. Meal and oil from fish and Soyabean are used to compound aquatic animal feed (Shaphan *et al.*, 2020). Aquaculture has been reported to provide 4% of global supplies of livestock feed in

1970 to 38% in 2008 (Van Huis *et al.*, 2013), thus increasing the cost of producing fish meal and oil. Price of Soyabean and oil has also increased tremendously due to high demand as a result of growing world population (Van Huis *et al.*, 2013). With the price hike in these feed ingredients, other alternative needs to be sourced for sustainable livestock enterprise and the most promising are insects.

House fly maggots have been proposed to be used for poultry feed in both western and tropical countries (Van Huis *et al.*, 2013). For example, diet which contains 10-15% maggots was reported to increase carcass quality and growth performance of broiler chicken (Niassy *et al.*, 2018). Acridids can be used as natural food source for various kinds of vertebrate like fish, lizard, birds etc. *Acrida cinerea*, the (Chinese grasshopper) may replace 15% chicken diet containing fish and Soyabean meal between 8-20 after hatching without causing any effect on broiler weight gain, feed intake, and feed conversion ratio (Sihem *et al.*, 2018). Grasshopper *Zonocerous variegatus* has been used widely to replace fish meal in rabbits while yellow mealworms has been shown to be an accepted protein source for broiler chickens and cat fish (*Clarias gariepinus)* (Van Huis *et al.*, 2013).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The experiment was conducted at the Rabbitry Unit of the Teaching and Research Farm of Department of Animal Science, Ahmadu Bello University, Zaria. The site is located in the Guinea Savanna Zone of Nigeria (Latitude 11^0 9' 46" N and Longitude 7^0 37' 45" E) at an altitude of 610m above sea level (GPS, 2020). The temperature ranges between 26^0C -40^0C depending on the season while the relative humidity during the dry and wet seasons ranged between 21% and 72%, respectively. The wet period in Zaria starts between April and May and ends in October with annual rainfall of about 1500mm (Institute for Agricultural Research, 2020).

3.2 Experimental Design and Animal Management

Twenty eight (28) weaned rabbits at the age of 6 weeks (average weight 500±12g) of mixed sex and breeds (Dutch and New Zealand White) sourced from an open market in Samaru were used for this study. The animal care and handling procedures was approved by the Ahmadu Bello University Committee on Animal Use and Care (ABUCAUC), which strictly adheres to the International Standards on Animal Use and Care (Amenan *et al.*, 2018). Prior to the commencement of the experiments, the rabbits were acclimatized for two weeks and fed commercial grower concentrates feed. The rabbits were weighed individually on arrival before they were randomly allotted to four dietary treatment groups with seven rabbits (7) per treatment (0.37 m^2 per rabbit) in a completely randomized design (CRD). Each rabbit served as a replicate. Each of the rabbits was individually caged and were properly housed in well ventilated pens.

The rabbits were allowed adjustment period of seven days during which they were fed the experimental diets to acclimatize with the environment and the feed. Each of the rabbits was given 0.2mls of Ivomec intra-muscular ingestion against ecto and endoparasites. Anticoccidial drug (Vitacox Plus 100g) was used in drinking water to manage coccidiosis. Fresh and clean drinking water was provided *ad libitum* throughout the experimental period. Any disease sign observed during the experimental period was treated accordingly. The experiment was laid out in 4 × 3 × 2 factorial arrangement in a completely randomized design (CRD). The factors include four dietary graded levels of locust meal (0, 5, 10 and 15%) with three cooking methods (Simmering, Pan-frying and grilling) and 2 storage periods (1 and 7 days).

3.3 Experimental Diets and Feeding Trial

The locust (*Zonocerous variegatus*) was purchased from an open market in Sabon Gari, Zaria, cleaned, milled and incorporated into the experimental diets. Four iso-nitrogenous diets were formulated to contain graded levels of locust meal (LM) at 0, 5, 10 and 15%, respectively (Table 3.1) as replacement for soya bean meal. The diets were formulated to meet the NRC (1995) nutritional requirements of rabbits. Initial weights of the rabbits were recorded and thereafter they were weighed on weekly basis. At the end of each week, total left over feed for each rabbit was bulked and the weight deducted from the total weight of feed offered and the amount of feed intake was calculated. Each day, the volume of left over water was taken and deducted from the total volume of water supplied the previous day in order to determine the volume of water consumed. The same volume of water supplied to each rabbit was also kept in an empty cage. The left over water was taken and deducted from the total volume of water supplied in the previous day which was used to determine the water loss via evaporation. The rabbits were weighed weekly and the weight gains determined. Daily feed intake, weight gain, water consumption (ml), feed conversion ratio, and cost per kilogram weight gain (₦) were computed from the data available. The rabbits were weighed at the end of the experiment to get the final live-weight. The trial lasted for eight (8) weeks.

Table 3.1: Ingredient composition of experimental diets (%) containing varying levels of Locust Meal as Replacement for Soyabean Cake

Ingredients	Replacement levels of Soyabean Meal (%)			
	0	5	10	15
Maize	20.00	20.00	20.00	20.00
Maize offal	23.45	23.45	23.45	23.45
Rice offal	30.00	30.00	30.00	30.00
Locust Meal	0.00	1.20	2.40	3.60
Soya cake	24.00	22.80	21.60	20.40
Common salt	0.35	0.35	0.35	0.35
Bone meal	1.50	1.50	1.50	1.50
Lysine	0.20	0.20	0.20	0.20
Methionine	0.25	0.25	0.25	0.25
Vitamin premix*	0.25	0.25	0.25	0.25
Total (%)	100	100	100	100
Calculated Analysis				
Metabolizable Energy (kcal/kg)	2523.10	2519.40	2515.70	2512.00
Crude Protein (%)	16.30	16.50	16.70	17.00
Crude fiber (%)	13.23	13.20	13.17	13.14
Ether extract (%)	3.86	3.86	3.85	3.85
Lysine (%)	0.69	0.72	0.77	0.71
Methionine (%)	0.45	0.48	0.47	0.43
Calcium (%)	1.40	1.50	1.71	1.69
Phosphorus (%)	0.87	0.81	0.84	0.85
Dry matter (%)	90.50	90.50	90.60	90.60
Cost/kg diet (₦)	93.67	107.23	120.79	133.67

*A Vitamin mineral premix provides per kg diet: Vitamin A, 13.340 iu, vitamin D_3 2680 iu, vitamin E_{10}iu, vitamin K, 2.68 iu, Calcium pentothenate, 10.68mg, Vitamin B_{12} 0.022mg; Folic acid, 0.668mg; Choline chloride 400mg; Chlorotetracycline, 26-28mg; Manganese, 133.34mg; Iron, 66.68mg; Zinc, 53.34mg; Copper, 3.2mg; Iodine, 1.86mg; Colbalt, 0.268mg; Selenium, 0.108mg.

3.4 Carcass Preparation

At the end of the experimental period, all the animals were kept off feed for sixteen hours before slaughter according to the current commercial practice. The animals were then transported to the Animal Product Processing Laboratory for slaughtering.

They were slaughtered by severing the jugular veins using sharp knife according to the recommended method (Amenan *et al.,* 2018). The animals were bled by turning them upside down for 30 minutes, skinned, washed, eviscerated and separated into wholesale cuts. Slaughter weight, dress weights and all other carcass characteristics were recorded accordingly. Product processing was carried out at the Animal Product Laboratory of the Department of Animal Science, Ahmadu Bello University, Zaria.

3.5 Meat Processing

The thigh and loin from the slaughtered rabbits were deboned, washed and cut into smaller chops about 2.5-3cm using a knife according to their treatment groups. Three cooking methods: Simmering, Pan-frying and Grilling were used to process the meat.

Simmering: this method consists of cooking small meat chops (2.5cm) with a small amount of water (1. litres) in a metal pot tightly covered at about 90^0C for 60 minutes using a kerosene stove. The meat was allowed to cook slowly below the boiling point until tender.

Pan-frying: is cooking meat chop cuts at about 2.5cm or less. The meat was then placed in a hot frying pan with little oil added (5ml/10)g, it was then cooked slowly over moderate heat of about 55^0C for 35 minutes using a kerosene stove and turning occasionally until browning of meat was obtained from both sides.

Grilling: is cooking meat chop cuts at about 2.5cm on a grill (open wire grid), with dry heat applied to the surface of the meat commonly from above, below or from the side at about 71^0C for 45 minutes, using charcoal and turning occasionally until browning of meat was obtained. Care was taken that the charcoal did not produce flames and overheating was prevented.

3.6 Quality Evaluation

The quality of rabbit meat was evaluated using both sensory and chemical means. For the sensory evaluation, a team of panelist (40) were selected and screened for the organoleptic assessment of meat quality parameters to detect possible differences between the treatment groups. The panelists were semi trained and offered double blind testing samples of the meat (12 samples per panelist) wrapped in aluminum-foil paper to detect possible differences in sensory qualities (aroma, colour, flavour, texture, tenderness, taste, fatness, juiciness and general acceptability) using the modified 5-point hedonic scale of Teye *et al.* (2020) (1 = like very much, 2 = like moderately, 3 = Neither like nor dislike, 4 = Dislike moderately, 5 = Dislike very much). The panelists were provided with a tooth pick for picking each of the samples and water was also provided to rinse their mouth after each sampling in order to avoid cross contamination.

3.7 Microbial Assessment

Meat samples from each treatment were collected at days 1 and 7, respectively for microbial count, and identification at the Department of Public Health and Preventive Medicine, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria. Meat samples were tested for microbial counts (total aerobic plate count, total coliforms count, yeast and fungi) using standard plate count procedure (Gunter and Peter, 2010; Eke *et al.*, 2013).

3.8 Chemical Analysis

Meat, locust and feed samples were analyzed for proximate composition which include: moisture content (MC), dry matter (DM), crude protein (CP), crude fat (EE), crude fiber (CF) and ash (A) contents using AOAC (2012) methods, while the nitrogen free extract (NFE) was determined by difference [NFE = 100 – (% CP + % CF + % EE + % Ash)] at the Food Science Laboratory, Institute for Agricultural Research, Ahmadu Bello University, Zaria. The energy content of meat samples was estimated following the method of Sherief and Doaa (2018).

3.9 Statistical Analysis;

All data obtained from the study were properly checked for outliers and transformed where necessary before they are subjected to analysis of variance (ANOVA) using SAS (2005) software package. A significant level of 5% was used. Treatment means that were significantly different were compared using Dunnet's Test of the SAS package.

Model used in the analysis; $\mathbf{Y_{ijkl} = \mu + T_i + P_j + Sp_k + (T\times P)_{ij} + (T\times Sp)_{ik} + (P\times Sp)_{jk} + (T\times P\times Sp)_{ijk}} + e_{ijkl}$

Where Y_{ijkl} = any dependent variable

μ = Overall mean

T_i = Effect of i^{th} treatment (0, 5, 10 and 15% inclusion level of locust meal)

P_j = Effect of j^{th} processing methods (grilling, simmering and pan-frying)

Sp_k = Effect of k^{th} storage periods (1 and 7 days)

$(T\times P)_{ij}$ = Effect of interaction between treatments and processing methods

$(T \times Sp)_{ik}$ = Effect of interaction between treatment and storage periods

$(P \times Sp)_{jk}$ = Effect of interaction between processing methods and storage periods

$(T \times Sp \times P)_{ijk}$ = Effect of interactions between treatments, processing methods and storage periods

e_{ijkl} = Random error.

CHAPTER FOUR

RESULTS

4.0 Laboratory Studies

4.1 Proximate Analysis of the Experimental Diets and Locust Meal

Result of proximate analysis of the experimental diets and locust meal is presented in Table 4.1. The result obtained shows that the dry matter (DM) of the diets ranged from 87% in the diet with 10% inclusion of locust meal to 89% in the diet with 5% inclusion level. However, the locust meal had 91% dry matter content. The crude protein (CP) content of the diet with 10% inclusion level of locust meal was lowest (18% CP) and highest in the diet with 5% inclusion level of locust meal (19% CP). Locust meal had 30% CP which was the highest value obtained. However, the crude fibre (CF) of locust meal was the least (6%) compared to those of the diets. The result further indicates that diet containing 5% inclusion level of locust meal had the highest value of crude fibre (13%) than in the diet with 15% level of inclusion of locust meal (10.82%), respectively. The ether extract (EE) content of the diet containing 10% inclusion level of locust meal was higher (1.34%) than that of the diet with 5% level of inclusion of locust meal (1.13%). Locust meal had 4.55% content of ether extract. The ash contents of locust meal and diet containing 5% inclusion level of locust meal were higher and comparable (7%) than in the other diets (6%). The nitrogen free extract (NFE) of the locust meal was the least (49%) compared to diets containing 5 and 15% inclusion levels of locust meal (60 vs. 64%), respectively.

4.2 Growth Performance and Feed Conversion Ratio

Results of growth performance and feed conversion ratio of growing rabbits fed diets containing varying inclusion levels of locust meal as replacement for Soyabean cake are presented in Table 4.2. Initial weight of the rabbits was similar ($P>0.05$) across the treatments.

Rabbits fed diets containing 5 and 15% levels of inclusion of locust meal in the diet had statistically similar and higher ($P<0.05$) final weight than those fed diet containing 10% level of inclusion of locust meal. Also, rabbits fed diet containing 5% level of inclusion of locust meal had the highest ($P<0.05$) weight gain compared to those fed 10% inclusion level. The average daily weight gain of rabbits fed the control diet and diets containing 5 and 15% levels of inclusion of locust meal were similar and statistically ($P<0.05$) higher than those fed 10% level of inclusion of locust meal. The average daily feed intake of rabbits fed 5% level of inclusion of locust meal in the diet was significantly higher ($P<0.05$) than those who received 10% level of inclusion of locust meal in the diet.

Rabbits fed the control diet and diets containing 5 and 15% levels of inclusion of locust meal had significantly lower ($P<0.05$) feed conversion ratio than those fed 10% level of inclusion of locust meal in the diet. However, rabbits fed diets containing 10% and 15% levels of inclusion of locust meal had significantly higher ($P<0.05$) feed cost per kg gain compared to those fed the control diet. Similar trend was observed in average daily water intake of rabbits ($P<0.05$). There was 1% mortality in rabbits fed the control diet compared to those fed diets containing varying inclusion levels of locust meal.

4.3 Carcass Characteristics, Prime Cuts and Organs Weights of Rabbits Fed Diets Containing Varying Inclusion Levels of Locust Meal as Replacement to Soyabean Cake

Table 4.3 shows results of carcass characteristics of growing rabbits fed diets containing varying inclusion levels of locust meal. Rabbits fed diets containing 5 and 15% levels of inclusion of locust meal had significantly higher ($P<0.05$) live weight than those fed diet containing 10% inclusion level of locust meal. Results of slaughter weight of the rabbits followed a similar trend

(P<0.05). However, rabbits fed diet containing 15% level of inclusion of locust meal had significantly higher (P<0.05) carcass weight compared to those fed the control diet and diet containing 5% inclusion level of locust meal, respectively. There were significant (P<0.05) treatment effects on dressing percentage of the growing rabbits; with those fed diet containing 10% inclusion level of locust meal having the highest value compared to those fed 5% level of inclusion.

Results of prime cuts of growing rabbits fed diets containing varying inclusion levels of locust meal is presented in Table 4.4. Rabbits fed diet containing 10% inclusion level of locust meal had significantly higher (P<0.05) percentages of shoulder, loin and legs, respectively than those fed diet containing 5% inclusion level of locust meal. The highest percentage of thigh was recorded in rabbits fed the control diet (P<0.05) compared to those fed diet containing 15% inclusion level of locust meal. However, the relative percentage of head of the rabbits fed diet containing 15% inclusion level of locust meal was significantly higher (P<0.05) than those fed the control diet.

Results of organs weight of growing rabbits fed diets containing varying inclusion levels of insect meal expressed as percentages of live weight are presented in Table 4.5. Significant differences (P<0.05) were detected in all the parameters measured except in weights of small and large intestines (P>0.05). It was noted that rabbits fed diet containing 10% inclusion level of locust meal had significantly higher (P<0.05) percentages of heart, liver, lungs, kidneys, skin and stomach weights, respectively compared to rabbits fed diet containing 5% locust meal in the diet. It was also noted that the spleen of rabbits fed the experimental diets was significantly (P<0.05)

Table 4.1: Proximate Composition of Locust Meal and the Experimental Diets (%) Containing varying levels of Locust Meal as Replacement for Soyabean Cake

Parameters	Replacement levels of Soyabean Meal (%)				
	0	5	10	15	Locust Meal
Dry matter (%)	88.86	89.24	86.64	88.87	90.65
Crude protein (%)	18.94	19.00	18.23	18.38	30.01
Crude fibre (%)	10.94	13.01	12.78	10.82	6.07
Ether extract (%)	1.25	1.13	1.34	1.16	4.55
Ash (%)	5.60	6.89	5.60	5.76	7.01
NFE (%)	63.20	59.90	61.90	63.88	48.98

Table 4.2: Growth performance of growing rabbits fed diets containing varying levels of Locust Meal as Replacement for Soyabean Cake

	Replacement levels of Soyabean Meal (%)				
Parameters	0	5	10	15	SEM
Initial weight (g)	830.25	868.30	909.70	918.45	53.39^{NS}
Final weight (g)	1418.96^{b}	1517.86^{a}	1353.36^{c}	1515.02^{a}	20.63
Weight gain (g)	588.96^{b}	649.86^{a}	443.66^{c}	596.57^{b}	12.58
Ave daily weight gain (g)	10.52^{a}	11.60^{a}	7.94^{b}	10.66^{a}	0.50
Ave daily feed intake (g)	56.52^{b}	61.86^{a}	50.83^{c}	58.34^{b}	0.93
Feed conversion ratio	5.37^{a}	5.33^{a}	6.40^{b}	5.47^{a}	0.23
Feed cost/kg gain (₦)	503.01^{c}	571.54^{b}	773.06^{a}	731.17^{a}	25.54
Ave daily water intake (ml)	82.24^{c}	125.20^{b}	165.32^{a}	173.45^{a}	13.33
Mortality %	1	0	0	0	0.00

^{abc}Means with different superscripts on the same row differed significantly (P<0.05); SEM = Standard error of mean; NS = Not Significant

Table 4.3: Carcass characteristics of growing rabbits fed diets containing graded levels of Locust Meal as Replacement for Soyabean Cake

	Replacement levels of Soyabean Meal (%)				
Parameters	0	5	10	15	SEM
Live weight (g)	1538.96 ^{b}	1639.86^{a}	1450.76 ^{c}	1642.52 ^{a}	19.14
Slaughter weight (g)	1461.96 ^{b}	1565.80 ^{a}	1380.76 ^{c}	1570.52 ^{a}	13.35
Carcass weight (g)	829.71 ^{c}	817.14 ^{c}	894.57 ^{b}	914.43 ^{a}	7.66
Dressing (%)	53.91 ^{b}	49.83 ^{c}	61.66 ^{a}	55.67 ^{b}	1.01

^{abc}Means with different superscript on the same row differ significantly (P<0.05); SEM = Standard error of mean

Table 4.4: Prime cuts of growing rabbits (% of LWt) fed diets containing graded levels of Locust Meal as Replacement for Soyabean Cake

	Replacement levels of Soyabean Meal (%)				
Parameters (%)	0	5	10	15	SEM
Shoulder	5.33 [b]	5.16 [c]	6.55 [a]	5.39 [b]	0.04
Loin	5.10 [d]	5.17 [c]	8.33 [a]	5.50 [b]	0.10
Thigh	11.08 [a]	9.38 [c]	10.72 [b]	8.64 [d]	0.11
Head	5.01 [d]	5.28 [c]	5.51 [b]	5.59 [a]	0.03
Legs	1.89 [b]	1.82 [c]	1.99 [a]	1.87 [b]	0.01

[abcd]Means with different superscript on the same row differ significantly ($P<0.05$); LWt = Live weight (g); SEM = Standard error of mean

higher in weight than those fed the control diet. However, rabbits fed diet containing 15% inclusion level of locust meal had higher ($P<0.05$) percentages of head and tail compared to those fed diet containing 5% inclusion level of insect meal

4.4 Proximate Composition and Gross Energy Content of Fresh and Processed Rabbit Meat as Affected by Levels of Inclusion of Locust Meal and Processing Methods

Results of proximate composition and gross energy content of fresh and processed rabbit meat as affected by levels of inclusion of locust meal and processing methods are presented in Table 4.6. It was observed that rabbits fed the control diet had significantly higher ($P<0.05$) crude protein (CP) and nitrogen free extract (NFE) contents than in other treatments except in rabbits fed 15% inclusion level of insect meal which were at par with those fed the control diet. Rabbits fed diets containing 5% inclusion level of insect meal had significantly ($P<0.05$) higher moisture and ash contents compared to other treatments. Values of ether extract (EE) and gross energy were observed to be higher ($P<0.05$) in rabbits fed diet containing 15% inclusion level of insect meal, respectively.

Table 4.5: Organs weight of growing rabbits (% of LWt) fed diets containing varying levels of Locust Meal as Replacement for Soyabean Cake

	Replacement levels of Soyabean Meal (%)				
Parameters	0	5	10	15	SEM
Length of Small intestine (cm)	236.00 [b]	239.57 [ab]	246.00 [a]	232.57 [b]	6.02
Length of Large intestine (cm)	191.14 [a]	177.29 [b]	176.71 [b]	185.29 [a]	3.33
Heart (%)	0.15 [b]	0.12 [c]	0.24 [a]	0.13 [b]	0.01
Liver (%)	1.32 [b]	1.36 [b]	1.58 [a]	1.30 [b]	0.03
Lungs (%)	0.43 [b]	0.37 [c]	0.51 [a]	0.31 [d]	0.02
Kidneys (%)	0.38 [b]	0.26 [d]	0.46 [a]	0.35 [c]	0.01
Spleen (%)	0.04 [b]	0.06 [a]	0.07 [a]	0.08 [a]	0.01
Weight of stomach (g)	1.37 [a]	1.41 [a]	1.39 [a]	1.33 [b]	0.11
Weight of Small intestine (g)	2.68	2.71	2.63	2.55	0.20
Weight of Large intestine (g)	2.96	2.83	2.57	3.09	0.33

[abcd]Means with different superscript on the same row differ significantly ($P<0.05$); SEM = Standard error of mean

Table 4.6: Proximate composition (%) and Gross Energy content of fresh and processed rabbit meat as affected by graded levels of Locust meal and processing methods

Parameters	MC	CP	EE	CF	Ash	NFE	Gross Energy (Kcal/100g)
ILLM (%)							
0	66.08 [d]	23.42 [a]	6.33 [b]	0.00	1.31 [d]	68.94 [b]	162.09 [b]
5	76.48[a]	17.28 [b]	1.12 [c]	0.00	2.33 [a]	79.27 [a]	88.52 [d]
10	73.58 [b]	16.50 [b]	7.23 [b]	0.00	1.39 [c]	74.88 [a]	136.07 [c]
15	70.00 [c]	24.64 [a]	10.70 [a]	0.00	1.66 [b]	62.94 [b]	198.90 [a]
SEM	1.33	1.43	0.51	0.00	0.13	2.38	5.55
Processing (P)							
Grilling	51.20 [b]	14.70 [b]	10.09 [c]	0.00	2.81 [b]	72.40 [a]	234.45 [b]
Simmering	63.92 [a]	16.67 [a]	12.62 [b]	0.00	2.91 [b]	67.80 [b]	201.14 [c]
Pan-Frying	56.71 [b]	17.91 [a]	17.31 [a]	0.00	3.08 [a]	62.30 [b]	248.27 [a]
SEM	3.01	0.63	0.17	0.00	0.01	2.75	6.01
Interactions							
T× P	<0.01	<0.001	<0.001	0.00	<0.001	<0.01	<0.001

[abcd]Means with different superscripts along the column differed significantly ($P<0.05$); SEM = Standard Error of the Mean; ILLM = Inclusion Level of Locust Meal (0, 5, 10 and 15%); P = Processing Methods (Grilling, Simmering and Pan-Frying); T = Treatment; P = Processing Method; MC = Moisture content; CP = Crude protein; EE = Ether extract; CF = Crude fibre; NFE = Nitrogen free extract; ND = Not determined.

Processing methods had significant effect (P<0.05) on proximate composition and gross energy contents of fresh and processed rabbit meat as affected by levels of inclusion of locust meal in the diet (Table 4.6). Grilling had significantly higher (P<0.05) NFE than other methods. Simmering and pan frying had higher (P<0.05) CP contents than grilling method; while pan frying had significantly higher (P<0.05) EE, ash and gross energy contents, respectively compared to simmering and grilling methods. Interactions between levels of inclusion of insect meal in the diets and processing methods were all significant at (P<0.05) and (P<0.001).

4.5 Organoleptic Properties of Rabbit Meat as Affected by Level of Inclusion of Locust Meal and Processing Methods

Table 4.7 shows the result of organoleptic properties of rabbit meat as affected by level of inclusion of locust meal and processing methods. Meat of rabbits fed the control diet and diets containing 5 and 15% inclusion levels of locust meal were rated best (P<0.05) by the panelists in terms of taste compared to rabbits fed diet containing 10% level of inclusion of locust meal. It was also revealed that meat of rabbits fed diet containing 5% inclusion level of locust meal had significantly better (P<0.05) colour, texture, juiciness, tenderness and overall acceptability attribute. The tenderness of meat from rabbits fed the control diet had the least attribute compared to other treatments which were at par; while the aroma of meat from rabbits fed diets containing 10 and 15% inclusion levels of locust meal were similar and best rated (P<0.05) by the panelist compared to other levels. Flavour of meat from rabbits fed diet containing 15% level of inclusion was better (P<0.05).

Processing method had significant effects on organoleptic properties of rabbit meat (Table 4.7). Simmering had significantly better (P<0.05) colour, taste, texture, flavor, aroma and overall acceptability attributes, respectively. However, juiciness and tenderness attributes of rabbit meat processed using grilling and simmering methods were at par (P<0.05) and better than meat processed using pan frying. Interactions were significant (P<0.05) in taste, tenderness and overall acceptability, respectively.

4.6 Microbiological Analysis of Rabbit Meat as Influenced by Levels of Inclusion of Locust Meal, Processing Methods and Storage Period

Table 4.8 presents the result of microbiological analysis of rabbit meat as influenced by levels of inclusion of locust meal, processing methods and storage period. The total aerobic plate count (TAPC) of meat from rabbits fed diet containing 15% inclusion level of locust meal was significantly higher (P<0.05) compared to other treatments which were similar. The total coliform count (TCC) of meat from rabbits fed diet containing 10% inclusion level of locust meal was higher (P<0.05) than values observed in other treatments. It was noted that meat of rabbits fed the control diet and 5% inclusion level of locust meal had similar total yeast count (TYC) which were higher (P<0.05) than meat of rabbits fed diet containing 10% inclusion level of locust meal. Meat of rabbits fed the treatment diets had significantly lower (P<0.05) total fungal count (TFC) compared to the meat of rabbits fed the control diet.

Processing method affected the microbial load of rabbit meat (P<0.05) (Table 4.8). Values of TAPC, TCC, TYC and TFC were significantly higher (P<0.05) in meat processed through simmering compared to pan frying and grilling, respectively. Storage period had significant effect (P<0.05) on microbial load of rabbit meat. Meat stored for seven days had significantly higher (P<0.05) values of all the parameters measured compared to day one. All interactions between the factors were significant (P<0.05).

Table 4.7: Organoleptic Properties of rabbit meat as affected by graded levels of Locust meal and Processing Methods

Parameters	Colour	Taste	Texture	Flavour	Juiciness	Tenderness	Aroma	Overall Acceptability
ILLM (%)								
0	2.01^{b}	2.60^{a}	1.93^{c}	2.24^{d}	2.28^{c}	1.99^{b}	2.15^{b}	1.98^{c}
5	2.24^{a}	2.56^{a}	2.31^{a}	2.52^{b}	2.56^{a}	2.48^{a}	2.28^{b}	2.57^{a}
10	1.96^{b}	2.35^{b}	2.15^{b}	2.48^{c}	2.50^{b}	2.23^{a}	2.30^{a}	2.36^{b}
15	1.93^{b}	2.45^{a}	2.13^{b}	2.57^{a}	2.56^{a}	2.28^{a}	2.35^{a}	2.36^{b}
SEM	0.11	0.10	0.01	0.01	0.01	0.10	0.03	0.01
Processing (P)								
Grilling	1.80^{b}	2.33^{b}	2.17^{b}	2.31^{c}	2.49^{a}	2.28^{a}	2.14^{b}	2.11^{b}
Simmering	2.64^{a}	2.81^{a}	2.29^{a}	2.68^{a}	2.62^{a}	2.37^{a}	2.66^{a}	2.74^{a}
Pan-Frying	1.67^{c}	2.31^{b}	1.93^{c}	2.37^{b}	2.32^{b}	2.09^{b}	2.01^{c}	2.12^{b}
SEM	0.01	0.01	0.01	0.01	0.10	0.12	0.01	0.01
Interactions								
T× P	<0.425	<0.017	<0.673	<0.229	<0.304	<0.019	<0.643	<0.003

[abcd]Means with different superscripts along the column differed significantly (P<0.05); SEM = Standard Error of the Mean; ILLM = Inclusion Level of Locust Meal (0, 5, 10 and 15%); P = **Processing Methods** (Grilling, Simmering and Pan-Frying); 5-Point Hedonic Scale **(Colour**: very pale (1), pale (2), intermediate (3), dark (4), very dark (5); **Taste**: very good (1), good (2), intermediate (3), bad (4), very bad (5); Texture: very smooth (1), smooth (2), intermediate (3), rough (4), very rough (5); **Tenderness:** very tender (1), tender (2), intermediate (3), tough (4), very tough (5); **Juiciness:** very juicy (1), juicy (2), intermediate (3), dry (4), very dry (5); **Flavour**: liked strongly (1), liked (2), intermediate (3), dislike (4), dislike strongly (5); **Aroma**: very nice (1), nice (2), intermediate (3), unpleasant (4), very unpleasant (5) ; **Overall acceptability**: liked very much (1), liked (2), intermediate (3), dislike (4), dislike very much (5) (Teye *et al.*,, 2020).

Table 4.8: Microbiological analysis of rabbit meat (log_{10}cfu/g) as affected by graded levels of Locust meal, processing methods and storage Period

Parameters	TAPC	TCC	TYC	TFC
ILLM (%)				
0	0.80 [b]	0.22 [b]	0.38 [a]	0.33 [a]
5	0.77 [b]	0.25 [b]	0.44 [a]	0.22 [b]
10	0.67 [b]	1.66 [a]	0.18 [c]	0.21 [b]
15	1.03 [a]	0.42 [b]	0.34 [b]	0.14 [c]
SEM	0.01	0.02	0.01	0.01
Processing (P)				
Grilling	0.79 [b]	0.16 [b]	0.22 [c]	0.23 [b]
Simmering	0.92 [a]	0.37 [a]	0.45 [a]	0.30 [a]
Pan-Frying	0.74 [c]	0.13 [c]	0.33 [b]	0.16 [c]
SEM	0.01	0.01	0.02	0.03
Storage Period (Days)				
1	0.53 [b]	0.15 [b]	0.67 [b]	0.23 [b]
7	1.10 [a]	0.33 [a]	3.70 [a]	0.46 [a]
SEM	0.03	0.02	0.01	0.02
Interactions				
T× P × S	<0.01	<0.001	<0.001	<0.003

[abc]Means with different superscripts along the column differed significantly (P<0.05); **SEM** = Standard Error of the Mean; ILLM = Inclusion Level of Locust Meal (0, 5, 10 and 15%); P = Processing Methods (Grilling, Simmering and Pan-Frying);T = Treatment; P = Processing Method; S = Storage period; TAPC = Total Aerobic Plate Count; TCC = Total Coliform Count; TYC = Total Yeast Count; TFC = Total Fungal Count; LOG10 (50) = 1; LOG10 (100) = 2; LOG10 (1000) = 3; LOG10 (10,000) = 4.

4.7 Cost-Benefit Analysis of Including Varying Levels of Locust Meal as Replacement to Soyabean Meal in the Diet of Growing Rabbits

Results of cost-benefit analysis of including varying levels of locust meal as replacement to soyabean meal in the diet of growing rabbits are presented in Table 4.9. There were significant ($P<0.05$) treatment effects in all parameters measured except in profit and cost-benefit ratio ($P>0.05$) which were similar across the treatments. The cost of rabbits at final body weight was statistically higher and similar ($P<0.05$) in rabbits fed 5 and 15% inclusion levels of locust meal in the diet compared to those fed diet containing 10% inclusion level. It was also noted that rabbits fed the control diet and diet containing 5% inclusion level of locust meal were at par in terms of returns on investment (ROI) which were higher ($P<0.05$) than those fed 10 and 15% inclusion levels of locust meal in the diet.

Table 4.9: Cost-benefit analysis of feeding inclusion levels of Locust meal as replacement for Soyabean meal in the diets of growing rabbits

	Replacement levels of Soyabean Meal (%)				
Parameters	0	5	10	15	SEM
Cost/kg diet (₦) = a	93.67 [d]	107.23 [c]	120.79 [b]	133.67[a]	5.21
Total feed consumed (kg) = b	3.16 [a]	3.46 [a]	2.85 [b]	3.27 [a]	0.11
Cost of feed/rabbit (₦) (Cr = a*b)	296.47 [d]	371.44 [b]	343.77 [c]	436.70 [a]	12.03
Final Body weight (g) = c	1418.96 [b]	1517.86 [a]	1353.36 [c]	1515.02 [a]	20.63
Cost at Final Body weight (₦/kg) = (Sp = c *400/1000)	567.58 [b]	607.14 [a]	541.34 [c]	606.01 [a]	8.30
Profit (₦) = (Sp-Cr)	271.18	235.70	197.58	169.38	26.60
Cost: Benefit Ration (CBR) = (Sp/Cr)	1.91	1.63	1.57	1.39	2.77
Returns on Investment (ROI) = (Sp/Cr) * 100	191.45 [a]	163.45 [a]	157.47 [b]	138.79 [b]	15.65

[abcd]Means with different superscripts along the row differed significantly (P<0.05); SEM = Standard Error of the Mean; Cr = Cost price of feed consumed per rabbit; Sp = Selling price per rabbit at final weight; Live weight of rabbit was considered to be ₦ 400 per kg

CHAPTER FIVE

5.0 DISCUSSION

5.1 Growth Performance of Growing Rabbits Fed Diets Containing Graded Levels of Locust Meal as Replacement to Soyabean Meal

The use of locust meal in rabbit diet has been advocated due to its friendly nature and ability to satisfy the nutritive requirements and social behavior of rabbits (Tracino *et al.,* 2018). Insects are important sectors of African economy that have the potential to improve quantity and quality of livestock products (Niassy *et al.,* 2018). The feed intake of rabbits fed 5% level of inclusion of locust meal in the diet was higher than in the control treatment, although the value was lower than the 79g per day reported by Frederic *et al.* (2012). This result could be related to the crude protein and fibre contents of the diets. According to Andrade *et al.* (2019), the initial crude protein content of the diet affects feed intake and growth performance in rabbits. Liu *et al.* (2018) reported that the crude fibre content of the diet is the main driving force for determining growth performance in fattening rabbits. These authors further reported that the higher crude fibre in rabbit diets affects the intestinal transit in the gut which further affects the digestibility of dry matter (DM), crude protein (CP), ether extract (EE) and nitrogen free extract (NFE), respectively. This assertion can be observed in rabbits fed 5% inclusion level of locust meal than those fed other treatments. This indicates that the level of fibre in rabbit diets should be between 10-13% for optimum performance (Frederic *et al.,* 2012).

The significant decrease in the final weight of rabbits fed 10% level of inclusion of locust meal in the diet could be due to increase concentration of fermentable substrates which might decrease protein utilization (Liu *et al.*, 2018). It could also be possible that the rabbits were stressed due to cage confinement which prevented them from expressing their natural behavior. Bai *et al.* (2019) reported that stress condition affects growth performance in rabbits. The average daily weight gain (ADWG) of rabbits in this study was lower than the reported values of 52g/day and 54g/day, respectively (Marin-Garcia *et al.*, 2018; Uhlirova *et al.*, 2018). This difference could be attributed to differences in rabbit breeds and the feed ingredients used. This was evident in the feed conversion ratio (FCR) recorded in this study (5.33) (Table 4.2) compared to (2.62) reported in hybrid rabbits with high feed conversion efficiency (Uhlirova *et al.,* 2018). Generally, results obtained in this study agreed with the findings of Liu *et al.* (2018) in Hyla rabbits and Sihem *et al.* (2018) when black soldier defatted meal was used as partial replacement for soyabean meal in broiler chickens.

5.2 Carcass Characteristics, Prime Cuts and Organs Weights of Growing Rabbits Fed Diets Containing Graded Levels of Locust Meal as Replacement to Soyabean Meal

Rabbits are cherished by many people because of their likeable body structure and potential meat quality (Ozkan *et al.*, 2012). In this study, it was evidently clear that including locust meal in the diet of growing rabbits had effect on carcass characteristics, prime cuts and organ weights, respectively. The effect of diet composition on carcass characteristics of rabbits has been a matter of concern (Liu *et al.,* 2018). The values of carcass weight, prime cuts and organ weights recorded in this study were lower than the reported values of Uhlirova *et al.* (2018) and Laura *et al.* (2019). This difference can be explained by differences in rabbit breeds used and the test ingredients. Although rabbits of mixed breeds and sexes were used in this study, the dressing percentage recorded agreed with the findings of Oloruntola *et al.* (2018) and Uhlirova *et al.* (2018). However, the values recorded for dressing percentage and skin were lower than the reported values of 69% and 284g, respectively (Kadi *et al.*, 2018). This difference might be related to the physical adaptation of the digestive tract of rabbits fed 5% inclusion level of locust meal to increase in feed intake and crude fibre level of the diets.

The dressing percentage of rabbits fed 10% inclusion level of locust meal was higher than the reported value of 58% in broiler rabbits (Laura *et al.*, 2018). This result indicates that rabbits have the potential to supply high quality meat for consumption from less competitive feedstuffs available in the society (Burnett *et al.*, 2006; Petracci *et al.*, 2018). The values recorded for prime cuts in this study were however lower than the reported values of Sihem *et al.* (2018) in Hyplus rabbit. It was found that in this study lower levels of inclusion of locust meal in the diet of growing rabbits (5-10%) had the best slaughter weights, dressing percentages, prime cuts and organ weights, respectively. This therefore shows that feeding treatments had positive effect on carcass traits of growing rabbits which are the most desirable traits cherished by consumers in different parts of the globe (Burnett *et al.*, 2006; Ozkan *et al.*, 2012; Petracci *et al.*, 2018).

5.3 Proximate Composition and Gross Energy Contents of Fresh and Raw Rabbit Meat as Influenced by Graded Levels of Locust Meal and Processing Methods

The acceptability of rabbit meat by consumers is largely based on its nutritional quality (Sherief and Doaa, 2018). Rabbit meat is generally suitable for good health, since it has been reported to contain low cholesterol and monounsaturated fatty acids. It also contains high amount of essential amino acids, vitamin B family nutrients and polyunsaturated fatty acids (Wang *et al.*, 2018; Sherief and Doaa, 2018). In this study, both inclusion levels of locust meal in the diet and processing methods affected the nutritional quality of rabbit meat. The moisture content recorded in this study agreed with the values of Wang *et al.* (2018) but were however lower than the reported values of Sherief and Doaa (2018) in fore and hind quarters meat samples. The lower moisture content of the meat in this study could be due to net charge effect, steric effect and meat ion exchange. It might also be related to the processing methods since previous findings established that the moisture content of rabbit meat could be lower due to occurrence of protein oxidation, tissue alternation as well as protein iso-electrical points during processing (Wang *et al.,* 2018). These authors further reported that during cooking of rabbit meat samples, fat melting and its associated protein denaturation may contribute to the liberation of chemically bound water in the muscle. Although the moisture content of the meat in this study was low but it could affect the quality traits of the meat since water holding capacity of meat has been shown to influence many of the meat physical properties (such as colour, texture and firmness of raw meat and juiciness and tenderness of cooked meat) (Adam and Abugroun, 2015).

In this study, pan-frying appeared to have severe moisture loss than simmering even though pan-frying and grilling had considerable similar effects on moisture content of the meat (Table 4.6). This result agreed with the report of Zhang *et al.* (2014) that pan-frying reduced moisture content better than cooking. The low moisture content of rabbit meat processed through grilling and pan-frying can be explained by the fact that water molecules are highly polar and are therefore attracted to muscle protein by ionizable basic and acidic groups such as essential amino-acids, and heating of the meat could have led to protein denaturation and subsequent release of the ionizable water molecules in the meat leading to low moisture content (Hyun-Seok *et al.,* 2013; Zhang *et al.,* 2014). The high moisture content of meat processed through simmering could be related to the low temperature boiling since temperature affects the degree of moisture release in meat (Hyun-Seok *et al.,* 2013; Zhang *et al.,* 2014).

The crude protein content of rabbit meat recorded in this study agreed with the report of Sherief and Doaa (2018) in fore and hind fore quarters of rabbit meat and Aderonke and Ifeanyi (2020) in raw and boiled rabbit meat samples, respectively. Christine *et al.* (2020) reported lower CP mean value (12.75%) while Laura *et al.* (2019) reported similar CP values (22.60%). Nikmaram *et al.* (2011) reported much higher values of CP (20-35%) in *Longissimus dorsi* muscle of camel. Grilling had lower CP value than other methods and this can be attributed to the formation of polycyclic aromatic hydrocarbons and heterocyclic amines during grilling which could limit the CP value of the meat (Zhang *et al.*, 2014). Also, it could be possible that the lower CP value observed in grilling might be due to seepage of greater amounts of sarcoplasmic proteins out of the meat compared to simmering and pan-frying (Nikmaram *et al.*, 2011). However, Hyun-Seok *et al.* (2013) reported that the low CP value in grilling could be related to protein hydrolysis and leaking out of sarcoplasmic proteins in the meat. This therefore indicates that this study has led to increase loss of protein thereby losing more nitrogen in form of nitrogenous compounds.

The fat and ash contents of rabbit meat in this study are comparable to the report of Christine *et al.* (2020) and Laura *et al.* (2019). However, Sherief and Doaa (2018) reported a value of 18.10% for fat in Belgian Giant male and female rabbits. In *Longissimus dorsi* muscle of camel, Nikmaram *et al.* (2011) reported a range of values for fat (4-8%) which are lower than the values recorded in this study. Aderonke and Ifeanyi (2020) reported higher values of ash (5.91% and 3.33%) in boiled and raw rabbit meat than in this study (3.08%). The higher fat and ash contents in meat processed through pan-frying can be attributed to the diet fed to the rabbits, oil used and their age (Lenka and Anna, 2016; Sherief and Doaa, 2018). Mohammad *et al.* (2010) attributed the scenario to the length of cooking period in pan-frying which supersedes those of grilling and simmering. Results in this study support the fact that fat and moisture contents of rabbit meat are directly proportional during cooking (Cristina *et al.*, 2010). The values of fat recorded in this study are contrary to the report of Brugiapaglia and Destefanis (2012) that rabbit meat has very low fat content and a reduced proportion of saturated fatty acids. The high fat content of meat in this study might be related to increased fat losses due to decreased meat thickness as a result of processing. It has been established that cooking methods and cooking conditions (such as heating rate, cooking time and temperature or end point temperature) modify the chemical composition of meat with subsequent changes in nutritional value due to nutrient loses (Brugiapaglia and Destefanis, 2012).

Cooking method has influence on the magnitude of fat losses (Nikmaram *et al.,* 2011). In this syudy, grilling had higher fat losses which indicates high fat oxidation due to the magnitude of the direct heat applied to the meat (Nikmaram *et al.,* 2011). The high fat content recorded in this study is contrary to the report of Cristina *et al.* (2010) that in beef fat content of less than 5% is considered safe for consumption. However, this difference can be explained by differences in diets and processing methods. Fat content of meat can be related to the colour of the meat especially under different cooking methods which affects consumer acceptability of the meat (Wahidu *et al.,* 2013). The decreasing fat contents in meat processed through grilling and simmering in this study might be related to decreased texture scores. This relationship has been observed in previous studies (Tennin *et al.,* 2000; Adam and Abugroun, 2015).

Rabbit meat has been reported to contain low energy value compared to red meat (Sherief and Doaa, 2018). The authors further reported that the gross energy content of rabbit meat is 120kcal/100g which is lower than the range of values (89 – 248 kcal/100g) obtained in this study. The values recorded in this study are comparable to the reports of Mohammad *et al.* (2010). The higher gross energy content of meat processed through pan-frying could be related to the protein content of the meat (18% CP). Previous findings reported that the gross energy content of rabbit meat depends less on glycogen and fat contents rather than protein (Sherief and Doaa, 2018). Wahidu *et al.* (2013) reported that varying amounts of different meat components such as water, fat and minerals are lost during cooking of meat which affects fat consumption and energy intakes, respectively.

5.4 Sensory Properties of Rabbit Meat as Influenced by Graded Levels of Locust Meal and Processing Methods

The sensory attributes of meat is a strong indicator of consumer patronage and acceptability (Wahidu *et al.,* 2013). In this study, sensory qualities of rabbit meat were influenced by inclusion levels of locust meal in the diets and processing methods. Although meat consumption has been associated with chronic diseases (such as heart diseases, obesity, cancer etc) especially in developed countries, changes in consumer demand and growing market competition are drinving forces for producing high quality meat and meat products with beneficial health properties (Wahidu *et al.,* 2013). Warner *et al.* (2010) defined meat quality as those traits the consumer perceives as desirable which include both visual and sensory traits.

Generally, the values for sensory attributes recorded in this study are higher than the reported values of Martinez and Hernandez (2018) but lower than the values of Zahraddeen *et al.* (2020). This could be explained by the tender nature of the meat used in this study and the location where the meat was sampled from the rabbits since toughness of rabbit meat has been reported in cranial and caudal parts (Martinez and Hernandez, 2018). Sensory traits are affected by biological, structural and physiological mechanisms (Warner *et al.,* 2010). The colour of rabbit meat in this study falls within the range of pale to intermediate based on the 5-point hedonic scale used. This result can be explained by the fact that meat colour is influenced by myoglobin oxidation due to moisture migration from intramuscular spaces which leads to changes in light reflectance on the surface of the meat thereby increasing lightness (Dalvi-Isfahan *et al.,* 2016). Another possible reason is that the colour of the meat appeared pale/whitish because soluble protein has been precipitated which could have led to absorption of other colours by the natural coloring matters in the meat (Ranken, 2000; Zhang *et al.,* 2014).

According to Valeria and Pamela (2011), meat colour is related to freshness by consumers and hence it is the most important quality parameter. Change in clour is related to change in oxymyoglobin to metmyoglobin. The implication of this finding is that acceptability and consumption of rabbit meat might likely increase in Nigeria in the near future since rabbit meat is white/pale in colour which attracts consumers who care much about health implications of consuming red meat. Similarly, rabbit farmers in Nigeria might have the opportunity to export their products to other countries thereby following the footsteps of China who produces 49% of world's rabbit meat for export (Wang *et al.,* 2018).

Cooking of meat is essential to achieve a palatable and safe product (Nikmaram *et al.,* 2011). However, heat treatment due to cooking of meat could lead to undesirable modifications such as decrease in nutritional value (mainly due to vitamin and mineral losses) and changes in fatty acid composition due to lipid oxidation (Nikmaram *et al.,* 2011). Cooking time and temperature play a role in the degree of doneness of meat (Cristina *et al.,* 2010). The sensory panelists used in this study scored higher for simmering and grilling rather than pan-frying. This indicates that the panelists found all the sensory parameters more appealing in simmering and grilling probably due to low flavor of the meat cooked through pan-frying, although Nikmaram *et al.* (2011) reported protein denaturation in cooked meat due to heating to sufficiently high temperature. Also, cooking methods has been known to affect the overall acceptability of meat products (Nomasonto *et al.,* 2011).

Raj *et al.* (2005) and Zhang *et al.* (2014) reported that low flavor and rough texture in processed meat using cooking could be due to the absence of surface drying, Maillard browning reaction and the formation of heterocyclic amines which might have caused the tough texture of the meat in this study. Similarly, the toughness of the meat in this study could be related to cooking method which is known to increase the intramuscular connective tissues' contribution to shrinkage at temperature above 65^{o}C which helps to increase the volume of the meat (Wahidu *et al.,* 2013). The superior values of grilling and simmering for colour, juiciness, flavour and tenderness could be attributed to peculiar mouth feel due to surface fat which might have led to softer touch and better juiciness (Mohammed *et al.,* 2010). It might also be possible that the pH value of the meat at the time of cooking was lower since cooikng methods have been reported to affect the organoleptic properties of cooked meat (Travnicek and Hooper, 1968). This assertion was demonstrated by the overall acceptability of the sensory panelists with high preference to simmering better than grilling and pan-frying.

The overall acceptability of meat processed using simmering agreed with the findings of Nikmaram *et al.* (2011). This result can be explained by the fact that high electromagnetic field, high power and short time to final temperature associated with simmering might have caused protein denaturation, disintegration of texture matrix and rapid protein destruction caused by heat shock to the protein thereby liberating high amount of fat and water that increased juiciness and overall acceptability (Nikmaram *et al.,* 2011).

5.5 Microbiological Quality of Rabbit Meat as Influenced by Graded Levels of Locust Meal, Processing Methods and Storage Period

The overall microbiological quality in this study indicated that there were low microbial load in the meat samples. All the microbial parameters measured in this study were lower than the values reported in previous studies (Sherief *et al.,* 2018; Monika *et al.,* 2020; Zahraddeen *et al.,* 2020). All the values for the microbial quality in this study were lower than the reported values of $\log_{10}$7cfu/g, $\log_{10}$ 4cfu/g and $\log_{10}$ 3cfu/g for standard plate counts (SPC), psychotrophic counts and total coliform count (TCC), respectively that could cause microbial spoilage of meat (Mohammad *et al.,* 2010). This indicates that in Nigerian context, rabbit meat could be processed using any of the three methods in this study as they pose no danger of meat spoilage even with the epileptic power supply in both rural and urban areas.

The significantly higher microbial counts in meat processed using simmering can be explained by the fact that there might be low penetration of moist heat into the meat which might have killed less number of microbes during cooking than in pan-frying. Sherief *et al.* (2018) reported similar results (2.15-2.60 cfu/g) in thighs of rabbit carcasses. Also, the significantly low values of microbes in rabbit meat processed using pan-frying might be related to the high fat content of the meat which could have acted as a shield for smooth growth of microbes except lipolytic organisms (Mohammad *et al.,* 2010). It could also be possible that the meat processed through simmering was more susceptible to bacterial decomposition which resulted in the production of off-odour followed by slime production and structural breakdown (Ranken, 2000). The aim of meat processing and storage is to delay this decomposition process by changing the properties of the meat or the storage condition.

The significant higher microbial load in the meat stored for 7 days might be related to microbial contamination of the meat which occurred during meat processing, packaging and storage (Alan, 2001; Sherief *et al.,* 2018). The shelf life of meat is greatly affected by some factors such as the holding temperature, storage period, processing methods, initial microbial load and colour of the meat (Alan, 2001). In this study, there was gradual increase in the number of microbial load from day 1 of storage to day 7 where the number of microbes was highest. What was striking in this result is that at day 7 of storage, the total yeast count (TYC) (3.70 logcfu/g) was far greater than the total aerobic plate count (TAPC) (1.10 logcfu.g) in the meat samples. Sherief *et al.* (2018) reported similar values of 3.76 logcfu/g and 3.92 logcfu/g for yeat count in rabbit meat, respectively.

This therefore indicates that the condition for favourable growth of harmful bacteria that cause meat spoilage was not met in this study due to the hygienic nature of the slaughter house, equipment and the processing method. Ranken (2000) reported a similar finding that when the condition of meat becomes less suitable for spoilage microbes (mainly bacteria), it becomes more suitable for other microbial species that could tolerate such conditions. Storage period helps to improve the quality of meat by affecting protein carboxylation which is related to meat colour, texture and water holding capacity and changes in these sensory properties of rabbit meat are related to changes in extracellular locations and volume alternations in cellular structures due to storage (Wang *et al.*, 2018).

5.6 Cost-Benefit Analysis of Feeding Graded Levels of Locust Meal as Replacement for Soyabean Meal in the Diets of Growing Rabbits

The profitability or otherwise of including locust meal (LM) in the diet of growing rabbits helps to assess the economic advantage of using the insect meal as alternative to Soyabean meal (Shapan *et al.,* 2019). The comparative results obtained for the control (0% LM) and diets containing graded levels of locust meal (5, 10 and 15% LM) in terms of cost-benefit ratio suggests that inclusion of locust meal in diets of growing rabbits has the advantage of improving growth performance, carcass traits as well as profitability of the rabbit enterprise in Nigeria. For good returns on investment, rabbit farmers in Nigeria should consider the use of 5% LM to replace Soyabean in the diet.

This study demonstrates that LM can be included in the diets of growing rabbits to produce a similar return on investment as the Soyabean meal (Olabode *et al.*, 2018). With the reduction in the quantity of soyabean meal and its exorbitant cost in the market in Nigeria due to kidnapping and banditry in the country the use of locust meal in the diet of growing rabbits remains a valuable option for providing good quality rabbit meat to consumers.

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

This study was conducted to assess the effect of feeding growing rabbits with replacement levels of locust meal on growth performance, carcass yield and quality of rabbit meat as affected by 3 different cooking methods.

Results revealed that diet containing 5% locust meal (LM) had the higest dry matter (89.24%), crude protein (19.00%), crude fibre (13.01%) and ash (6.89%), respectively. However, the nitrogen free extract (NFE) of other diets was higher than the 5% LM inclusion diet. Similarly, rabbits fed diet containing 5% graded level of LM had significantly ($P<0.05$) higher weight gain (649.86g), average daily weight gain (11.60g/d), daily feed intake (61.86g/d) and lower feed conversion ratio (5.33) than the control. Results of carcass analysis showed that rabbits fed diet containing 10% graded level of LM had significantly ($P<0.05$) higher dressing percentage (61.66%), prime cuts and organs weight values, respectively.

Results revealed that crude protein (24.64%), ether extract (10.70%) and gross energy content (198.90kcal/100g) of meat from rabbits fed diet containing 15% LM were significantly higher ($P<0.05$) than those fed the control diet. Meat processed through pan-frying had significantly higher ($P<0.05$) proximate parameters except in moisture (56.71%) and NFE (5.21%) contents, respectively. Panelists rated meat from rabbits fed diet containing 5% LM higher ($P<0.05$) (2.57%) than the control and other inclusion levels. The overall assessment of panelists indicated that they liked meat processed through simmering very much ($P<0.05$) than grilling and pan-frying. LM inclusion levels of 10 and 15% in the diet of growing rabbits led to significant ($P<0.05$) increase in total coliform count (1.66 logcfu/g) and total aerobic plate count (1.03 logcfu/g), respectively although the levels were lower than 100 cfu/g which is safe for human consumption. All the processing methods used had significantly lower ($P<0.05$) microbial counts (<50 cfu/g). However, storing rabbit meat at 7 days significantly ($P<0.05$) encouraged the growth of yeast (3.70 cfu/g). The return to investment of including 5% LM in the diet of growing rabbits had similar ($P<0.05$) economic advantage with the control diet containing soyabean meal.

6.2 Conclusions

Based on the results obtained from this study, it is therefore concluded that:

I. Dietary replacement of Soyabean meal with locust meal (LM) improved growth performance, carcass characteristics and sensory quality of rabbit meat using different processing methods with reduced microbial contamination of meat and positive economic gain.

II. Rabbits fed diet containing 5% LM inclusion in the diet had better growth performance and were rated higher by the panelists in terms of overall acceptability. Meat processed using simmering tasted better in all sensory parameters assessed.

III. Microbial load was directly proportional to the storage period in days. Cost-benefit analysis results suggest that including locust meal in growing rabbits' diets at 5% is a worthwhile business for rabbit farmers who are willing to provide wholesome and quality rabbit meat for consumption in Nigeria.

6.3 Recommendations

It can be recommended from the result this study that rabbit farmers in Nigeria:

I. Locust meal can replace Soyabean at 5% level in the diet of growing rabbits for better growth performance, higher meat quality properties, overall acceptability by consumers and better economic returns

II. Rabbit meat processed by simmering method had better shelf stability up to 7 days in northwestern Nigeria

III. The use of locust meal as replacement for Soyabean should be explored in other species of animals especially at this period of post-Covid-19 pandemic where prices of Soyabean are extremely high

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