EFFECT OF MORINGA LEAF MEAL (MOLM) ON NUTRIENT DIGESTIBILITY, GROWTH, CARCASS AND BLOOD INDICES OF WEANER RABBITS

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN ANIMAL NUTRITION

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CERTIFICATION

I, Nuhu Frederick, hereby certify that the work herein submitted as a thesis for the Master of Science (Animal Nutrition) degree has neither in whole nor in part been presented nor is being concurrently submitted for any other degree elsewhere. However, works of other researchers and authors which served as sources of information were duly acknowledged by references of the authors.

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ABSTRACT

The study involved the cultivation of moringa and the use of the moringa leaf meal (MOLM) to determine its effect on nutrient digestibility, growth, carcass characteristics and haematological and biochemical indices of weaner rabbits.

Five (5) treatment diets were formulated to contain MOLM inclusion levels of 0% (control), 5%, 10%, 15% and 20%. Thirty (30) weaner rabbits of mixed breeds and sexes were used for the experiment. They were randomly divided into 5 groups of 6 animals per treatment with 2 animals per replicate, in a Completely Randomized Design (CRD). Feed and water were provided *ad libitum*.

Data obtained from the moringa cultivation showed that on dry matter (DM) basis, 425.10 kg/ha of moringa leaves could be produced at first harvest at 90 days of age using a planting spacing of 1.3 × 1.3 m. Elemental analysis of the moringa leaf meal (MOLM) on DM basis indicated that the leaves contained 24.65% DM, 29.25% CP, 2.23% EE, 19.25% CF, 7.13% ash, 41.98% NFE, 0.33% P and 8.64% Ca.

The dry matter (DM) and CP digestibility values were affected ($p<0.05$) by dietary treatments whilst the CF and EE digestibility values were not ($p>0.05$).

The average daily feed intake and FCR did not differ between dietary treatments ($p>0.05$), however, the average daily weight gain was higher ($p<0.05$) in rabbits on the MOLM based-diets (13.49, 13.69, 14.03, 15.01 g/d) compared to those on the control diet (11.71 g/d).

Except for meat crude protein and ether extract, which were influenced by dietary treatment ($p<0.01$), the carcass characteristics studied did not differ between treatments ($p>0.05$). All the blood parameters studied did not vary between treatments ($p>0.05$).

The cost of feed to gain a kilogramme weight, although not significant ($p>0.05$), was highest when soyabean meal (SBM) was completely replaced with MOLM due solely to the large price disparities between MOLM and SBM.

The study revealed that the MOLM is rich in nutrients. It also showed that the MOLM could be used as a partial or total replacement for SBM without any adverse effect on the productive performance and blood indices of weaner rabbits.

CHAPTER ONE

1.0 INTRODUCTION

Protein supplementation is often important to improve livestock performance, and this needs to be done with respect to the requirements of the animal in addition to the balance of other nutrients available. Soyabean meal and fish meal have been widely and successfully used as conventional protein sources for livestock.

However, the prices of these protein sources have been escalating continuously in recent times, whilst availability is often erratic. The problem has been worsened due to the increasing competition between humans and livestock for these protein ingredients as food. According to Odunsi (2003) the rapid growth of human and livestock population, which is creating increased needs for food and feed in the less developed countries, demand that alternative feed resources must be identified and evaluated.

In Low-Income Food-Deficit Countries (LIFDCs), surplus of cereals is generally not available; therefore, it is not advisable to develop a wholly grain-based feeding system. The recommended policy is to identify and use locally available feed resources to formulate diets that are as balanced as possible(Guèye and Branckaert, 2002). There is the need, therefore, to explore the use of non-conventional feed sources that have the capacity to yield the same output as conventional feeds,and perhaps at cheaper cost.

Hence, any similar high protein ingredient which could partially or completely be used as a substitute for soyabean meal or fishmeal is desirable.

This strategy could help reduce the cost of production, and ensure cheaper meat production thereby making available the major crops for human consumption. The economization of feed cost using cheaper and unconventional feed resources (Vasanthakumar *et al*., 1999; Bhatt and Sharma, 2001; Muriu *et al*., 2002) is an important aspect of commercial rabbit production.

One possible source of cheap protein is the leaf meals of some tropical legume browse plants. Leaf meals do not only provide protein source but also some essential vitamins such as vitamins A and C, minerals and oxycarotenoids. The constraints to enhanced utilization of leaf meals reside chiefly on factors such as fibre content, the presence of anti-nutritive compounds and deficiencies of certain amino acids.

Recently, there has been interest in the utilization of moringa (*Moringa oleifera*) commonly called horseradish tree or drumstick tree, as a protein source for livestock (Makker and Becker, 1997; Sarwatt *et al*., 2002). Moringa leaves have quality attributes that make it a potential replacement for soyabean meal or fish meal in non-ruminant diets. Moringa can easily be established in the field, has good coppicing ability, as well as good potential for forage production. Furthermore, there is the possibility of obtaining large amounts of high quality forage from moringa without expensive inputs due to favourable soil and climatic conditions for its growth. Sarwatt*et al*. (2004) reported that moringa foliages are a potential inexpensive protein source for livestock feeding. The advantages of using moringa for a protein resource are numerous, and include the fact that it is a perennial plant that can be harvested several times in one growing season and also has the potential to reduce feed cost.*Moringa oleifera* is in the group of high-yielding nutritious browse plants with every part having food value (Duke, 1998).

Despite the high crude protein content of moringa leaf meal, there is little information available on the use of this unconventional feed resource, especially as an alternative protein supplement for rabbit production.

The present study aimed at assessing the possibility of replacing soyabean meal either partially or completely with moringa leaf meal for weaner rabbits.

The objectives of the study were to:

- Evaluate the chemical content of cultivated, air-dried moringa leaf meal.
- Assess the performance of weaner rabbits fed on diets containing varying levels of moringa leaf meal.
- Determine the carcass and blood haematological and biochemical indices of the weaner rabbits fed the varying levels of the moringa leaf meal, and
- Assess the economics of rabbit production using moringa diets.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and distribution of moringa

Moringa (*Moringa oleifera Lam*), according to Makkar and Becker(1997), belongs to the moringaceae family, and is considered to have its origin in the north-west region of India, south of the Himalayan mountains. It is now widely cultivated and has become naturalized in many locations in the tropics (Fahey*et al*., 2001). Kristin (2000) reported that there are thirteen species of moringa trees in the family moringaceae and that *Moringa oleifera* is the most widely cultivated species. It was further stated that they are native to India, the Red Sea area and/or parts of Africa including Madagascar. *Moringa oleifera* is indigenous to Northern India and Pakistan (Bosch, 2004) and was introduced throughout the tropics and sub-tropics becoming naturalized in many African countries. This rapidly-growing tree also known as horseradish tree or drumstick tree was utilized by the ancient Romans, Greeks and Egyptians.

2.2 Uses of moringa

All parts of the moringa tree are edible and have long been consumed by humans. Fuglie (1999) reported the many uses of moringa as follows: alley cropping (biomass production), animal forage (leaves and treated seed-cake), biogas (from leaves), domestic cleaning agent (crushed leaves), blue dye (wood), fertilizer (seed-cake), foliar nutrient (juice expressed from the leaves), green manure (from leaves), gum (from tree trunks), honeyand sugar cane juice-clarifier (powdered seeds), honey (flower nectar), medicine (all plant parts), ornamental plantings, biopesticide (soil incorporation of leaves to prevent seedling damping off), pulp (wood), rope (bark), tannins for tanning hides (bark and gum), and water purification(Powdered seeds).

In the West, one of the best known uses for moringa is the use of powdered seeds to flocculate contaminants and purifying drinking water (Berger *et al*., 1984; GassenSchmidt *et al*., 1995; Olsen, 1987), but the seeds are also eaten green, roasted, powdered and steeped for tea or used in curries (GassenSchmidt *et al*., 1995). Moringa seed oil (yield 30-40% by weight), also known as Ben oil, is a sweet non-sticking, non-drying oil that resists rancidity. This tree according to Faheyet *al.* (2001) has in recent times been advocated as an outstanding indigenous source of highly digestible protein, calcium, iron, vitamin C, and carotenoids suitable for utilization in many of the so-called "developing" regions of the world where undernourishment is a major concern.

The cytokinine-type hormones extracts of moringa leaves in 80% ethanol as a foliar spray can be used according to Foidl *et al*. (2001) to accelerate the growth of young plants such as soyabean, blackbean, maize, onion, sorghum, tomato, coffee, and sugar cane. Moringa leaves have also been shown to increase breast milk production (Estrella *et al*., 2000). In many Asian and African countries (Fuglie, 2001) women consume moringa leaves to enhance breast milk production.

Moringa leaves have very strong antioxidant activity (Siddhuraju and Becker, 2003; Yang *et al*., 2006).

2.3 Nutritive value of moringa plant

Grubben and Denton (2004) reported that the leafy tips of *Moringa oleifera* contain per 100 g edible portion: water 78.7 g, energy 268 kJ (64 kcal), protein 9.4 g, fat 1.4 g, carbohydrates 8.3 g, total dietary fibre 2.0 g, Ca 185 mg, Mg 147 mg, P 112 mg, Fe 4.0 mg, Zn 0.6 mg, vitamin A 7564 IU, thiamine 0.3 mg, riboflavin 0.7 mg, niacin 2.2 mg, folate 40 µg, and ascorbic acid 51.7 mg.

The raw fruits of the plant, according to Bosch (2004), contain per 100 g edible portion: water 88.2 g, energy 155 kJ (37 kcal), protein 2.1 g, fat 0.2 g, carbohydrates 8.5 g, total dietary fibre 3.2 g, Ca 30 mg, Mg 45 mg, P 50 mg, Fe 0.4 mg, Zn 0.4 mg, vitamin A 74 IU, thiamin 0.05 mg, riboflavin 0.07 mg, niacin 0.6 mg, folate 44 µg, and ascorbic acid 141.0 mg. The analysis of nutritional value of moringa is presented in Table 1.0.

Table 1.0: Analysis of nutritional value of Moringa pods, fresh (raw) leaves and dried leafy powder per 100 g of edible portion.

Components	**Pods**	**Leaves**	**Leaf powder**
Moisture (%)	86.9	75.0	7.5
Calories	26	92	205
Protein (g)	2.5	6.7	27.1
Fat (g)	0.1	1.7	2.3
Carbohydrates (g)	3.7	13.4	38.2
Fibre (g)	4.8	0.9	19.2
Minerals (g)	2.0	2.3	-
Ca Calcium (mg)	30	440	2003
Cu Copper (mg)	3.1	1.1	0.57
Fe Iron (mg)	5.3	7.0	28.2
K Potassium (mg)	259	259	1324
Mg Magnesium (mg)	24	24	368
P Phosphorus (mg)	110	70	204
S Sulphur (mg)	137	137	870
Se Selenium (mg)	-	-	0.09
Zn Zinc (mg)	-	-	3.29
Oxalic acid (mg)	10	101	1600
Vitamin A (mg)	0.11	6.8	18.9
Vitamin B (mg)	423	423	-
Vitamin B_1(mg)	0.05	0.21	2.64
Vitamin B_2 (mg)	0.07	0.05	20.5
Vitamin B_3 (mg)	0.2	0.8	8.2
Vitamin C (mg)	120	220	17.3
AMINO ACIDS			
Arginine (mg)	90	402	1325
Histidine (mg)	27.5	141	613
Isoleucine (mg)	110	422	825
Leucine (mg)	163	623	1950
Lysine (mg)	37.5	288	1325
Methionine (mg)	35	134	350
Phenylanaline (mg)	108	429	1388
Threonine (mg)	98	328	1188
Tryptophan (mg)	20	127	425
Valine (mg)	135	476	1063

Source: Booth and Wickens (1988)

Moringa oleifera leaves could serve as a valuable source of nutrients for all age groups. For example, in Haiti and Senegal, health workers have been treating malnutrition in small children, pregnant and nursing women with Moringa leaf powder (Price, 1985). The leaves are known to be great source of vitamins and minerals being served raw, cooked or dried.

Fugile (2005) reported that 8 g serving of dried leaf powder will satisfy a child within ages 1-3 years with 14% of the protein, 40% of the calcium, 23% of the iron, and nearly all vitamin A that the child needs in a day.

One 100 g portion of leaves could provide a woman with over a third of her daily need of calcium and give her important quantities of iron, protein, copper, sulphur, and B-vitamins. It is estimated that only 20-40% of vitamin A content will be retained if leaves are dried under direct sunlight, but that 50-70% will be retained if leaves are dried in the shade (Subadra *et al*., 1997).

The nutritional characteristics of the moringa tree are excellent so it can easily be used as a fresh forage material for animals. The leaves are rich in protein, carotene, iron and ascorbic acid and the pod is rich in the amino acid lysine (CSIR, 1962). In an experiment where extracted and unextracted leaves of moringa were used as a component of animal feed, Makker and Becker (1996) analyzed these samples for nutrients and antinutrients.

Table 2.0 presents the chemical composition of both the extracted and unextracted moringa leaves. The extracted and unextracted moringa leaves gave crude protein values of 43.5 and 25.1% respectively, suggesting that both the extracted and unextracted leaves are good sources of protein for livestock. As expected, the crude protein and fibre contents of the extracted leaves were higher than those of the unextracted leaves due to the loss of some cell solubles and lipids during the treatment with 80% ethanol.

The crude protein, crude lipids and ash values of 26.4%, 6.5% and 12%, respectively were reported for the unextracted leaves by Gupta *et al*. (1989).Also, higher levels of NDF (28.8%) and ADF (13.9%) were reported (Gupta *et al*., 1989).

The variations in the reported values may be due to differences in agro-climatic conditions or to different ages of trees, and possibly not due to different stages of maturity, since tender green leaves have been used in both studies.

Table 2.0: Chemical composition of extracted and unextracted moringa leaves

Type of leaf	Crude Protein	Lipid	Ash	NDF	ADF	ADL	Gross energy ($MJkg^{-1}$)
Extracted leaves	43.5	1.4	10.0	47.4	16.3	2.2	17.7
Unextracted leaves	25.1	5.4	11.5	21.9	11.4	1.8	18.7

All values except gross energy are expressed as percentage dry matter. NDF = Neutral Detergent Fibre, ADF = Acid Detergent Fibre, ADL = Acid Detergent Lignin
Source: Fuglie (1999).

2.4 Phytochemicals of moringa and their uses

An examination of the phytochemicals of moringa species affords the opportunity to examine a range of fairly unique compounds (Faheyet *al*., 2001).

In particular, this plant family is rich in compounds containing the simple sugar, rahmnose, and it is rich in a fairly unique group of compounds called glucosinolates and isothiocyanates (Bennett *et al*., 2003; Faheyet *al*., 2001).

Some of the compounds that have been isolated from moringa preparations which are reported to have hypotensive, anticancer and antibacterial activity include 4-(4'-*O*-acetyl-a-L-rhamnopyranosyloxy)benzyl isothiocyanate**,** 4-(a-L-rhamnopyranosyloxy)benzyl isothiocyanate**,** niazimicin, pterygospermin**,** benzyl isothiocyanate**,**and 4-(a-L-rhamnopyranosyloxy) benzyl glucosinolate (Daxenbichler *et al*., 1991; Fahey *et al*., 2001; Bennett *et al*., 2003; Mekonnen and Dräger, 2003). Antioxidant activity of these compounds has also been reported (Win and Jongen, 1996).

Flowers of moringa have been reported to contain flavonoid pigments such as quercetin, kaempferol, rhamnetin, isoquercitrin and kaempferitrin (Nair and Subramanian, 1962). According to Foidl *et al*. (2001) extracts of moringa leaves in 80% ethanol contain cytokinine-type hormones.

The flavonoids such as quercetin and kaempferol were identified as the most potent antioxidants in moringa leaves. Their antioxidant activity was higher than the conventional antioxidants such as ascorbic acid, which is also present in large amounts in moringa leaves (Siddhuraju and Becker, 2003).

The extracts of moringa leaves as reported by Siddhuraju and Becker (2003) also appear to have cancer preventive effect, when assayed by the differentiating activity against human promyelocytic leukaemia cells (HL-60). Seeds of moringa contain a glucosinolate that on hydrolysis yields 4-(a-L-rhamnosyloxy)-benzyl isothiocyanate, an active bactericide and fungicide (Grubben and Denton, 2004). Duke (1983) reported that moringa root-bark yields two alkaloids: moringine and moringinine.

2.5 Moringa leaf production

A study consisting of many trials to discover the optimum density at which moringa should be planted to produce a maximum amount of fresh green matter was conducted by Makker and Becker (1997); spacing in the trials ranged from 1 m × 1 m or 10,000 plants per ha to 2.50 cm × 2.50 cm or 16,000,000 plants per ha.

The optimum density in sandy, well drained and fertile soils was found to be 10 cm ×10 cm or 1,000,000 plants per ha, the results of the trials are shown in Table 3.0.

Table 3.0: Production parameters of moringa at first cutting

Plant Density (plants/ha)	Fresh Matter (metric tons/ha)	Dry Matter (metric tons/ha)
95,000	19.60 (19600 kg/ha)	3.33 (3330 kg/ha)
350,000	29.70 (29700 kg/ha)	5.05 (5050 kg/ha)
900,000	52.60 (52600 kg/ha)	8.94 (8940 kg/ha)
1,000,000	78.00 (78000 kg/ha)	13.26 (13260 kg/ha)

Source: Makker and Becker (1997)

In smaller trial areas, (10 m^2) densities of 4,000,000 per ha and 16,000,000 plants per ha were tried. The results of these trials are also presented in Table 4.0.

Table 4.0: Production parameters of moringa at first cutting on test plots with high density plants.

Density fresh (plants/ha)	Fresh Matter (metric tons/ha)	Dry Matter (metric tons/ha)
4 million	97.40 (97400 kg/ha)	16.56 (16560 kg/ha)
16 million	259.00 (259000 kg/ha)	44.03 (44030 kg/ha)

Source: Makker and Becker (1997)

Boimasa (1996) reported that whether produced for use as a green manure for livestock or human consumption, moringa can be grown intensively with yields up to 650 metric tons of green matter per ha. Akinbamijo *et al*. (2001) under high density cultivation using a planting

density of 15 cm × 15 cm, biomass yields in excess of 15 tons DM per ha in a 60-day growing cycle was obtained at the international Trypanotolerance Centre in the Gambia.

2.6 Soya bean meal (SBM)

According to Kellems and Church (2006), soya bean meal is the product obtained by grinding the flakes which remain after removal of most of the oil from either whole or dehaulled soya beans by a solvent extraction process.Soya bean meal is a highly favoured feed ingredient because it is quite palatable, highly digestible, has high energy value and results in excellent performance when used for different animal species (Kellems and Church, 2006).Table 5.0 shows crude protein and essential amino acids in soyabean meal.

Table 5.0: Crude protein and essential amino acids in soya bean meal (DM basis)

Item	Soya bean meal, solvent extracted
Dry matter, %	89.1
Crude protein	52.4
Essential amino acids (%)	
Arginine	3.8
Cysteine	0.8
Histidine	1.4
Isoleucine	2.8
Leucine	4.3
Methionine	0.7
Lysine	3.4
Phenylalanine	2.8
Threonine	2.2
Tryptophan	0.7
Valine	2.8

Source: NRC (1994)

The protein in soya bean meal contains all the essential amino acids but the concentrations of cysteine and methionine are sub-optimal (McDonald *et al*., 1988).Methionine is the first limiting amino acid and may be particularly important in high energy diets.

The quality of protein in soya bean meal is dependent on the cultivar and processing method. Under processing may lead to deleterious level of anti-nutritional factors which may impact negatively on the growth and performance especially in young animals. By contrast, excessive heating reduces the availability of some amino acids particularly lysine in soya bean meal (Parkhurst and Mountney, 1988). Raw soya bean should not be fed to animals, because of the presence of trypsin inhibitor that must be destroyed by heat or other methods. In the case of young growing chicks, raw soya beans will produce only about two-thirds of the growth achieved with processed soya bean meal (North and Bell, 1990). Say (1987) reported that soya bean meal must be subjected to heat treatment that improves its digestibility and also destroys some of the toxic factors present in the raw soya bean. Apart from problems associated with either under or over processing, a major concern with the use of soya bean meal is its relatively low metabolizable energy content. Soya bean meal is best supplemented with some animal or fish protein to make up its deficiencies of certain amino acids (North and Bell, 1990). Soya bean meal is adequate in magnesium and a good source of potassium and supplies a fair amount of trace elements (Lassiter and Hardy, 1982). According to Say (1995), soya bean meal is very often used in large proportions, of the order of 30% for growing poultry and 20% for layers.

2.7 Nutritional evaluation of leaf meals on the performance of animals

Some plant leaves have been used as feedstuffs for rabbits and other animals as a partial substitute for the conventional grains and forages. *Leucaena leucocephala* has been successfully used in rabbit diets when incorporated in low levels.

The presence of mimosine, a toxic amino acid can cause growth depression at higher incorporation levels (Parigi-Bini and Xiccato, 1998).

A 20-week feeding trial was conducted by Odeyinka *et al*. (2008) to evaluate the reproductive performance of rabbits fed *Moringa oleifera* as a replacement for *Centrosema pubescens*. Freshly harvested *C. pubescens* and *M. oleifera* leaves were offered to the animals at 20% of their liveweight at the ratios of 100:0 (MO), 75:25 (M25), 50:50 (M50), 25:75 (M75), and 0:100 (M100), in addition to the concentrate feed offered to the animals. There were significant differences in the total DM intake, litter size at weaning, average daily weight gain per kid and milk yield of does, on the different treatments ($P<0.05$). However, there was no significant difference in crude protein intake, initial average body weight, and gestation length as well as litter weight at birth. It was concluded that *Moringa oleifera* can be used to replace *Centrosema pubescens* without adverse effects on the reproductive performance of rabbits.

Iheukwumere *et al*. (2007) carried out a 25-day feeding trial in Nigeria with 120 five-week old Anak broilers to evaluate growth, blood chemistry and carcass yield of broilers fed cassava leaf meal at dietary levels of 0, 5, 10, or 15%. Results of the trial indicated that, feed intake, body weight gain, feed conversion ratio of the control (0% leaf meal) were superior ($p<0.05$) to the group on 10 and 15% leaf meal. The total serum protein, albumin and haemoglobin at 0 and 5% leaf meal were superior to the values at 10 and 15% leaf meal, however, cholesterol, creatinine and urea showed no significant differences ($p>0.05$) between the treatment groups.

The cut parts of the carcass showed superior values ($p<0.05$) in the control treatment and they differed significantly ($p<0.05$) from broilers on 5, 10 and 15% leaf meal in carcass yield. In conclusion, it was suggested that 5% inclusion of cassava leaf meal could be used in broiler

finisher diet without any deleterious effect on growth, blood chemistry and carcass yield of broilers.

In a study by Odunsi *et al*. (2002) 72 laying hens were allotted to four dietary treatments containing 0, 5, 10 or 15% gliricidia leaf meal (GLM). The inclusion of the GLM in the layer diets significantly ($p<0.05$) reduced feed consumption in a linear function. Layers fed 0 and 5% GLM had similar ($p>0.05$) hen-day egg production, body weight changes and feed conversion efficiency which worsened significantly at 10 and 15% GLM levels. Egg quality values showed no significant differences ($p>0.05$) in terms of egg weight, haugh units and shell thickness while yolk index increased ($p<0.05$) with GLM and was found to be best at 10 and 15% GLM. Yolk colour was positively enhanced at all levels of GLM. Proportionally, egg membrane values were lower ($p<0.05$) on GLM diets compared to the control while the egg yolk, albumen and shell were not affected. Boiling of egg resulted in little yolk and albumen but heavier shell and membrane with a 43% reduction ($p<0.05$) in egg yolk colouration. Results of the study indicated that at dietary levels greater than 5% GLM depressed feed intake and egg production.

Smith (1988) compared the rumen degradability of some foliages in cattle and goats. In all these ruminants, a similarly high 48-hour degradability of 84.3% (mean) for cassava leaves was obtained which was higher than the degradability of *Leucaena leucocephala*, *Gliricidia sepium*, bamboo and oil palm leaves.

Cassava foliage is thus a valuable feed material for ruminants. The feed value apparently decreases with age, and Müller (1977) suggested the foliage should be harvested at 3-4 months to ensure high nutrient content and to avoid reduction in tuber yield. Ross and Enriquez (1969) used up to 20% cassava leaf meal in poultry diets and found a decrease in weight and feed efficiency

when the diet had more than 5% leaf meal. When cassava leaf meal was used up to 10%, no differences were observed in egg production, feed efficiency and egg weight. However, when 0.15 to 0.30% methionine and 3.0% corn oil were added, the results were similar to those from the control. Cassava leaf meal has some yellow pigment that gives good egg yolk pigmentation, and it can be a substitute for all the alfalfa in the diet of laying hens.

In an experiment to determine the nutritional potential of two leafy vegetables (*Moringa oleifera* and *Ipomoea batatas),* Oduro *et al*. (2008) reported that *Moringa oleifera* leaves contained crude protein 27.51%, crude fibre 19.25%, crude fat 2.23%, ash 7.13%, moisture 76.53%, carbohydrates 43.88%, and caloric value 1296.00 kJ/g (305.62 cal/g).Calcium and Iron content in mg/100 g (DM) were 20.09and 28.29, respectively. They concluded that *Moringa oleifera* leaves could contribute to the nutrient requirements of humans and should be strongly recommended in Ghana. An experiment on the nutritional potentials of*Chromolaena odorata* (siam weed)leaf meal (SWLM) on laying hens: biochemical and haematological implications was carried out by Fasuyi *et al*. (2005) using 24 laying hens in their eighth month of lay in an 8-week trial. In the experiment diet 1 served as the control diet and had no SWLM inclusion. SWLM was introduced at 2.5%, 5.0% and 7.5% in diets 2, 3 and 4 respectively. The haematological and biochemical investigations revealed no statistical differences ($p>0.05$) among the mean values of treatments 1, 2 and 3.

However, the mean value of treatment 4 (7.5% SWLM inclusion level) was statistically different ($P<0.05$) from the others. The numerical values of most haematological indices showed an initial increase up to treatment 3 followed by a decrease in treatment 4. Almost all haematological indices studied (PCV, RBC counts, Hb content) progressively increased up to diet 3 (5% SWLM

inclusion) after which there was a decline indicating a probable acceptance limit of 5% SWLM dietary inclusion in layer diets without any serious health implication.

Bamikole *et al*. (2005) investigated the potential of Mulberry leaves in rabbit production in a 12-week long experiment where feed intake, weight gain, and nutrient digestibility of the rabbits were monitored. Thirty weaner rabbits were allocated to five experimental diets. The percentage of concentrate in the rations was incrementally replaced with mulberry leaves: 100:0, 75:25, 50:50, 25:75, 0:100 were fed in a completely randomized design. Total dry matter (DM) intake of the concentrate: mulberry diet remained at the level of that of the all- concentrate ration until mulberry leaves comprised greater than 50% of the ration before it declined significantly. The intakes of crude protein (CP) and crude fibre (CF) increased significantly whilst those of ether extract (EE), ash, and nitrogen free extract (NFE) decreased significantly with increasing level of mulberry leaves in the diets, following the trends of the concentrations of the nutrients in the materials. The nutrient digestibilities of the diets were high and there were no significant differences among the means for dry matter, organic matter, crude protein, crude fibre, and ash. Digestibility of ether extract and nitrogen free extract significantly declined with increasing levels of mulberry leaves in the rations.

Weight gain of rabbits on diets containing 20% and 50% mulberry leaves (5.14 and 4.72 g /d respectively) was not significantly different ($p>0.05$) from that of all-concentrate ration (5.72 g/d),but these were significantly higher than those of 25:75 and 0:100 concentrates: mulberry leaves (3.43 and 2.27 g/d respectively). It was concluded that mulberry leaves could support feed intake, digestibility and satisfactory weight gain in rabbits, and could reduce reliance on and cost of expensive concentrate diets.

Famounyan and Meffega (1986) feeding rabbits sun-dried cassava leaves diets containing 13, 14 or 16% crude fibre contents observed that the rabbits consumed 65.8, 73.5 and 71.8 g/d and gained 17.4, 19.4 and 18.2 g/d, respectively. The low weight gains observed in this trial was attributed to the fact that the feed was not pelleted and was scattered.

Ghasi *et al*.(1999) reported that juice extracted from moringa leaves was a potent hypocholesterolemic agent. In their research usingWister rat, they concluded thateven when given at the relatively low dose of 1 mg/g, co-administered with a high fat diet daily over a period of 30 days, cholesterol was reduced in serum, liver and kidney.

Nworgu *et al*. (1999) reported a reduction in feed intake as the percentage of forage meal in the diet of rabbits was increased. Upadhyay (1990) and Oforjindu (2006) reported a decrease in the cholesterol and liver lipid levels in birds and rats when they fed broiler birds and rats with diets containing neem leaf meal (NLM).

2.8 Anti-nutritional factors

Anti-nutritional factors are compounds mainly organic, which when present in a diet, may affect the health of the animal or interfere with normal feed utilization.

Anti-nutritional factors may occur as natural constituents of plant and animal feeds, as artificial factors added during processing or as contaminants of the ecosystem (Barnes and Amega, 1984). Ingestion of feed containing such substances induces, in some cases, chronic intoxication and in others interferes with the digestion and utilization of dietary protein and carbohydrate and also interferes with the availability of some minerals, thus feed efficiency and growth rate and, consequently, the production of the edible products.

Although anti-nutritional factors are present in many conventional feeds, they are more common in most of the non-conventional feeds. Nityanand (1997) classified the various antinutritional factors (ANFs) in feedstuffs according to their chemical nature and their activity in animals as: 1. Chemical nature, in this category are acids, enzymes, nitrogenous compounds, saponins, tannins, glucosinolates and phenolic compounds.2. Factors interfering with the digestion and utilization of dietary proteins and carbohydrates, for example, tannins, trypsin or protease inhibitors, saponins, and haemagglutinins.

3. Factors interfering with the availability of minerals are for example, phytates or phytic acid, oxalates or oxalic acid, glucosinolates and gossypol.

Tannins which are complex polymeric phenols having molecular weight greater than 500 are natural constituents of many plants, and grouped into two forms-hydrolysable and condensed tannins (Nityanand, 1997). Hydrolysable tannins are potentially toxic and cause poisoning if large amounts of tannin-containing plant material such as leaves of oak (Quercus *spp*.) and yellow wood (*Terminalia oblongata)* are consumed (Garg *et al*., 1982). Makker *et al*. (1988) reported that tannins can inhibit the activities of rumen microbes.

The tannins form complexes with protein, cellulose, hemicelluloses, lignin and starch and interfere with their optimum utilization in the digestive tract and systems. Protein sources of plant origin containing high amounts of tannins and in particular hydrolysable tannins should be used with caution (Becker and Makker, 1999). Ranjhan (1999) reported that soaking and washing removes substantial amount of tannins and this is usually accompanied by some loss of dry matter. Tannins have been found to affect digestibility and therefore rate of utilization of

dietary nutrients in both ruminants (Kumar and Singh, 1984) and non-ruminants (Hale and McCormick, 1981; Okai *et al*., 1984).

Saponins are bitter in taste and hence reduce palatability; they are also haemolytic and alter the permeability of cell membranes and produce toxic effects on organized tissues when ingested. Lucerne, white and red clovers, mahua seed cake and soyabean are rich sources of saponins. Soaking and washing in water is quite effective in removing a greater proportion of saponins (Nityanand, 1997). Saponins have been reported to cause depressions in feed intake (Cheeke, 1976). According to Rajhan (2001) ruminants can breakdown saponins but monogastrics cannot.

Phytates (salts of phytic acid) are found in almost all feeds of plant origin. The phytates are present in association with protein and generally high in protein feeds e.g. groundnut cake, soyabean cake and sesame cake. Phytic acid possesses high chelating ability and in plants, it is found as phytates of many minerals which are mostly not available to monogastrics as they lack the enzyme phytase. The use of the enzyme phytase can make minerals such as phosphorus available to monogastrics (Nityanand, 1997).

According to Nityanand (1997) anti-vitamin activities against vitamins A and D have been observed in soyabean, against vitamin E in kidney bean (*Phaseolus vulgaris),* against vitamin K in sweet clover and against pyridoxine in linseed cake. Akinmutimi (2004) had observed that most processing methods employed in improving the food value of non-conventional or alternative feedstuffs do not completely eliminate anti-nutritional factor substances, but only reduce their concentrations to tolerable levels in feedstuffs. It is a common practice in feeding trials to use the weights of some internal organs like liver and kidney as indicators of toxicity. Bone (1979) reported that if there are toxic elements in the feed, abnormalities in weights of liver

and kidney would be observed. The abnormalities will arise because of increased metabolic rate of the organs in an attempt to reduce these toxic elements or anti-nutritional factors to non toxic metabolites.

2.9 Effect of nutrition on biochemical and haematological blood components of rabbits

Blood is a complex fluid containing a large variety of dissolved suspended inorganic and organic substances (Stewart, 1991) or specialized circulating tissues and cells suspended in the intercellular fluid substance (Dellman and Brown, 1976). Blood circulates in the arteries, veins and capillaries of man and animals (Kronfield and Mediway, 1975). Its primary function is to transport oxygen from respiratory organs to body cells (Duke, 1975), distributing nutrients and enzymes to cells and carrying away waste products (Baker and Silverton, 1982), thereby maintaining homeostasis of the internal environment (Bentrick, 1974).

The various functions of blood are made possible by the individual and collective actions of its constituents – the biochemical and haematological components. Generally, both the biochemical and haematological blood components are influenced by the quantity and quality of feed and also the level of anti-nutritional elements or factors present in the feed (Akinmutimi, 2004).

Biochemical components are sensitive to elements or factors present in the feed (Akinmutimi, 2004), including elements of toxicity. They can also be used to monitor protein quality of feeds. Haematological components of blood are also valuable in monitoring feed toxicity especially with feed constituents that affect the formation of blood (Oyawoye and Ogunkunle, 1998). Abu *et al.* (1988) reported that low level haemoglobin (Hb) of treatment diets could imply that dietary proteins were not of high quality. Diets containing poor protein would usually result in poor transportation of oxygen from the respiratory organs to the peripheral tissues (Roberts *et al*.,

2000). Reduction in the concentration of PCV in the blood usually suggests the presence of a toxic factor (e.g. haemagglutinin) which has adverse effect on blood formation (Oyawoye and Ogunkunle, 1998).

High WBC count is usually associated with microbial infection or the presence of foreign body or antigen in the circulating system. High blood urea levels are associated with poor protein quality (Eggum, 1970) or excess tissue catabolism associated with protein deficiency (Oduye and Adadevoh, 1976). There is evidence in literature that haematological characteristics of livestock suggest their physiological disposition to the plane of nutrition (Madubuike and Ekenyem, 2006). Reduction in packed cell volume and red blood cell values are indicative of low protein intake or mild anaemia (Lindsay, 1977). Blood chemistry constituents reflect the physiological responsiveness of the animal to its internal and external environments which include feed and feeding (Esonu*et al*., 2001; Iheukwumere and Okoli, 2002).

Blood chemistry studies are usually undertaken to establish the diagnostic baselines of blood characteristics for routine management practices of farm animals (Tambuwal*et al*., 2002; Onyeyilli *etal*., 1992; Aba-Adulugba and Joshua, 1990).

The haematopoietic system is an important index of physiological and pathological status in animals and man (Harper, 1973) since it is the one which becomes exposed to a high concentration of toxic agents first.

Total serum protein has been reported as an indication of the protein retained in the animal body (Akinola and Abiola, 1991; Esonu *et al*., 2001), while total blood protein and creatinine contents have been shown to depend on the quantity and quality of dietary protein (Eggum, 1970; Iyayi, 1998; Awosanya *et al*., 1999; Esonu *et al*., 2001). Muscle wasting has been shown to be the

source of excess creatinine in the blood of animals and is normally due to creatinine phosphate catabolism during this process (Bell *et al*., 1992). Table 6.0 shows the normal ranges of some haematological and biochemical blood values of rabbits. Increased serum urea concentration may suggest an increase in activities of urea enzymes ominthine, carbonyl transferase and orginase, which may also indicate kidney damage (Ajagbonna *et al*., 1999). Normal range of blood sugar level indicates that animals are not surviving at the expense of body tissues (Ologhobo *et al*., 1992).

Frandson (1986) reported that the number of neutrophils in the blood increases rapidly when acute infection is present, hence a blood count showing this increase is useful in diagnosis of infections. He reported further that eosinophils which normally are scarce increase in numbers in certain chronic diseases, such as infection with parasites and also in allergic reactions.

Table 6.0: Normal Physiological Ranges of Haematological and Biochemical Components for Rabbits.

Parameter	Range
Haematological components	
Haemoglobin (g/dl)	8.0-17.5
Packed cell volume (%)	30.0-50.0
Red blood cell (x 10^6/µl)	4.0-8.0
White blood cell (x 10^3/dl)	5.0-12.0
Neutrophils (%)	35.0-55.0
Lymphocytes (%)	25.0-50.0
Eosinophils (%)	0-5.0
Biochemical components	
Cholesterol (mg/dl)	35.0-60.0
Total protein (g/dl)	5.4-7.5
Albumin (g/dl)	2.5-4.5
Globulin (g/dl)	1.9-3.5

Sources: Hillyer (1994) and Jenkins (1993)

2.10 Importance of rabbit production

Rabbits have a potential as meat producing animals in the tropics due to their characteristics such as small body size, short generation interval, rapid growth rate and ability to utilize forage or agricultural by-products.

The wastes from products grading before selling to the market, such as vegetable wastes, are well utilized as feed resources for rabbits, and the manure from the animals could be used as an organic fertilizer for crops (Mikled, 2005).

Rabbits could contribute significantly to solving the problem of meat shortage (Lebas, 1983; Taylor, 1980).

Production systems with small or large ruminants usually need a long time to give a saleable product and with high cost, especially for feeds. According to Ruiz-Feria *et al*. (1998) rabbits can subsist on inexpensive diets based on forages under small-scale farm conditions in arid and tropical regions.

Agricultural by-products, foliages and weeds such as *Centrosema pubescens*, cassava root meal, rice bran, natural grasses and leucaena can be used as dietary ingredients for rabbits (Lukefahr and Cheeke, 1991; Ha *et al*., 1996; Ruiz-Feria *et al*.,1998). The demand for human food from animal products such as meat, eggs and milk is continually increasing (Delgado *et al*., 1999). The consumers of today pay great attention to the health aspects of food, such as low fat content and organic origin. Meat from rabbits has a low cholesterol level, high protein/energy ratio and is relatively rich in essential fatty acids (Iraqi, 2003). Rabbits utilize waste products more effectively thus offering an alternative to other producing species for the improvement of protein supply to the human population and the realization of monetary income by putting into effective use the waste materials that are inedible for humans (Schlolaut, 1985).

The rabbit offers a role as an alternative food source, particularly for people in developing countries (Owen, 1981). It is claimed that there are few traditional/social taboos concerning the eating of rabbit meat (Mamattah, 1978).

According to one report (Elemele *et al*., 1980), dry rabbit manure contains 18.8% crude protein, 9.0% moisture, 13.5% crude fibre and 19.2 MJ gross energy per kg. In the same study, 100 g of rabbit manure per kg of diet was fed to broiler chickens with no decline in growth rate as compared to performances on a standard diet. Rabbit manure has also been experimentally fed to rabbits (Swick *et al*., 1978) and could be fed to ruminants as well.

Rabbit and other animal manures can be used to produce methane gas as a household source of alternative energy (Sicwaten and Stahl, 1982; Jacobs, 1986; Trujillo *et al*., 1991). Scientists use the animals in experiments dealing in nutrition and medical research; manufacturers use them for testing products and in addition animals are sold as pets.

2.11 Nutrient requirements of rabbits

2.11.1 Crude protein

Protein is perhaps the most frequent nutrient lacking in rabbit diets primarily because the common energy sources such as maize and other cereal grains and tuber crops are low in protein. The rabbit makes its own particular proteins from the proteins and amino acids it obtains from its food (Fielding, 1991; Kellems and Church, 2006). This protein synthesis uses up energy. The ten essential amino acids which must be provided in the diet if the rabbit is to survive and grow are: lysine; methionine; arginine; phenylalanine; histidine; valine; threonine; tryptophan; leucine; isoleucine (Fielding, 1991).

Essential amino acids need to be included in the ration for rabbits. Lysine and methionine are usually the amino acids that are found to be deficient in rabbit ration (Gillespie, 1998). While there is some bacterial protein synthesis in the caecum, it is not enough to meet the essential amino acid requirements of rabbits.

For rabbits the recommended crude protein level in the dry matter of the ration is over 18% for newly weaned rabbits; 16-18% for rabbits from 12-24 weeks; 15-17% for breeding does; and 12-14% for all other stock (Fielding, 1991). Several researchers have investigated the protein requirement of growing rabbits.

In an experiment in which Martina and Damianan(1983) fed rabbits with decreasing crude protein levels of 18.08, 16.32, 14.22 and 12.50%, they found that crude protein could be reduced to 16.32% with lysine and methionine supplementation without affecting weight gain and feed efficiency. Different results were obtained when Carregal and Nikuma (1983) used diets with increasing crude protein levels, 14.3, 17.2 and 21.4%, as they found no significant difference among groups of rabbits with regard to body weight, feed intake or feed conversion efficiency. Abdella *et al*. (1988) conducted an experiment and observed that there were no differences in final body weight, live weight gain and feed intake when diets containing 16, 18 and 20% crude protein were fed to five week-old rabbits. Abdel-Salem *et al*. (1972) using mash diets containing crude protein ranging from 11.63 to 26.85% reported that the diets containing 20.74% crude protein recorded the highest final live body weight and live weight gain.Gillespie (1998) has shown that soya bean meal or fish meal promotes better growth rates than other protein supplements when the alternative supplements do not have essential amino acids added.

He further reported that when essential amino acids were added to protein supplements such as cotton seed meal, rapeseed meal, horsebeans, and peas, growth rates similar to those achieved with soya bean and fish meals were attained. According to Pond *et al*. (1995) dietary protein quality is particularly important for rapidly growing weanling rabbits, which may not have well developed caecal fermentation. Recent research has demonstrated that the amino acid requirements are age dependent and change during the reproduction cycle of the doe. In early growth stage (4-7 weeks of age), rabbits need a higher dietary amount of digestible crude protein and amino acids (Maertens *et al*., 1997). Also, during peak lactation the response to higher amino acids is more pronounced (Taboada *et al*., 1994; Taboada *et al*., 1996).

Many research reports have shown that a reduction of the level of protein and essential amino acids in the diet, from an optimum level for growth in animals, is associated with a decreased growth rate and efficiency of feed utilization and a concomitant increase in body fatness (Wahlstrom and Libal, 1974; Noblet and Henry, 1977; Russell *et al*., 1983). Dietary protein level is one of the several non-genetic factors that influence the amount of body fat in animals (Marks, 1990; Wang *et al*., 1991). Forbes (1995) reported that if the amino acid content in the feed of animals differed widely from the animal's requirement for amino acids, feed intake would be depressed and that if the deficient amino acid was supplemented, intake would be increased.

Estimated nutrient requirements (Table 7.0) and minimum dietary protein and amino acid recommendations (Table 8.0) published by Cheeke (1987) and Maertens (1992) respectively are shown as follows.

Table7.0: Nutrient requirements of rabbits

	Class of rabbit				
	Growing 4-12 weeks	Lactation	Gestation	Maintenance	Does & Litters fed one diet
Crude protein, %	15	18	18	13	17
Amino acid, %					
S-amino acids	0.5	0.6	-	-	0.55
Lysine	0.6	0.75	-	-	0.7
Arginine	0.9	0.8	-	-	0.9
Threonine	0.55	0.7	-	-	0.6
Tryptophan	0.18	0.22	-	-	0.2
Histidine	0.35	0.43	-	-	0.4
Isoleucine	0.60	0.70	-	-	0.65
Valine	0.70	0.85	-	-	0.8

Table 7.0 continued

Leucine	1.05	1.25	-	-	1.2
Phenylalanine	1.20	1.40	-	-	1.25
Crude fibre, %	14	12	14	15-16	14
Indigestible fibre, %	12	10	12	13	12
Digestible energy (kcal/kg)	2500	2700	2500	2200	2500
Metabolizable Energy, (kcal/kg)	2400	2600	2400	2120	2410
Fat, %	3	5	3	3	3
Minerals					
Ca (%)	0.5	1.1	0.8	0.6	1.1
P (%)	0.3	0.8	0.5	0.4	0.8
K (%)	0.8	0.9	0.9	-	0.9
Na (%)	0.4	0.4	0.4	-	0.4
Cl (%)	0.4	0.4	0.4	-	0.4
Mg (%)	0.03	0.04	0.04	-	0.04
S (%)	0.04	-	-	-	0.04
Co(ppm)	1.0	1.0	-	-	1.0
Cu, ppm	5.0	5.0	-	-	5.0
Zn (ppm)	50	70	70	-	70
Fe (ppm)	50	50	50	50	50
Mn (ppm)	8.5	2.5	2.5	2.5	8.5
I (ppm)	0.2	0.2	0.2	0.2	0.2
Vitamins					
Vitamin A (IU/kg)	6,000	12,000	12,000	-	10,000
Carotene (ppm)	0.83	0.83	0.83	-	0.83
Vitamin D (IU/kg)	900	900	900	-	900

Table 7.0 continued

Vitamin E (ppm)	50	50	50	50	50
Vitamin K (ppm)	0	2.0	2.0	0	2.0
Vitamin C (ppm)	0	0	0	0	0
Thiamin (ppm)	2.0	-	0	0	2.0
Riboflavin (ppm)	6.0	-	0	0	4.0
Pyridoxine (ppm)	40	-	0	0	2.0
Vitamin B_{12} (ppm)	0.01	0	0	0	-
Folic acid (ppm)	1.0	-	0	0	-
Pantothenic acid (ppm)	20.0	-	0	0	

Source: (Cheeke, 1987)

Table8.0: Minimum dietary protein and amino acids recommendations for rabbits

Dietary Level (for a DM of 89-90%)	Reproducing Does	Young at weaning	Fattening rabbits
Digestible energy (kcal/kg)	2500	2275	2400
Crude protein (%)	17.5	16.0	15.5
Digestible protein (%)	12.7	11.0	10.8
Arginine	0.85	0.90	0.90
Histidine	0.43	0.33	0.35
Isoleucine	0.70	0.65	0.60
Leucine	1.25	1.10	1.05
Lysine	0.85	0.75	0.70
Methionine + Cystine	0.62	0.65	0.65
Phenylalanine + Tyrosine	1.40	1.20	1.20
Threonine	0.65	0.60	0.60
Tryptophan	0.15	0.13	0.13
Valine	0.85	0.70	0.70

Source: Maertens (1992)

2.11.2 Energy

Although energy is not a nutrient, it is a property of carbohydrates, fats and proteins when they are oxidized during metabolism. The energy needed by rabbits for organic synthesizing is usually supplied by carbohydrates and a lesser extent by fats. Where there is an excess of protein, these also help to supply energy after deamination. Rabbits adjust their feed intake as a function of their dietary energy concentration (Partridge, 1989).

According to Partridge (1989), this regulation of intake to achieve constant daily energy intake is only possible at a dietary digestible energy (DE) concentration above 2250kcal/kg. Several factors influence the energy requirements of rabbits (Kellems and Church, 2002). These include productive function (growth, lactation, maintenance, etc), age, sex, body size and environment (temperature, humidity, air-movement). As temperatures decrease, the rabbit requires more energy to maintain normal body temperature (Gillespie,1998), and to compensate for this increased energy, either the intake level of feed must be increased or the energy content of the ration must be increased.

Average maintenance requirementdetermined in growing rabbits is about 100kcal DE/$kg^{0.75}$ (Maertens, 1992). Fed on energy-concentrated foods, rabbits can satisfy their requirements, but this is not possible on forages alone because forages are usually dilute sources of energy (Fielding, 1991); hence when fed only on forages they cannot obtain as much energy as those fed on concentrated foods such as maize grains or cereal brans.

Rabbits (Cheeke, 1994) require a diet of 2200kcal/kg of diet or 2.2kcal/g of diet. For breeding rabbits (Fielding, 1991), a general recommendation is that the food should contain: 65-66%TDN; or 2600-2700kcalDE/kg DM; or 2.4-3.5 MJ DE/kg DM; or 2.0-3.0 MJ ME/kg DM.

Products of microbial degradation of dietary fibre which contributes to the energy demand of the host animal, are the volatile fatty acids (VFAs). An effective absorption of VFAs from the large intestine has been demonstrated in all non-ruminant herbivores which have been investigated (Hintz *et al*., 1978). In rabbits about 10-20% of maintenance energy expenditure comes from VFAs (Hoover and Heitman, 1972).

Despite the apparently poorer utilization of fibre by rabbits than by horses or ruminants, Parker (1976) concluded from Carbon-14 studies that VFAs absorbed 30% of the maintenance energy requirement, avalue similar to that attributed to those products from the caecum and colon of the horse (Glinsky *et al*., 1976). Pond *et al*. (1995) reported that digestible energy levels in typical rabbit diets are quite low, being in the range of 2400-2800kcal/kg weight diet. They further indicated that higher energy levels impair animal performance and result in reduced energy intake. Rabbits are efficient users of starch in cereal grains and prefer barley to corn (Gillespie, 1998) when given a choice of cereal grains. According to him, diets that are based on corn have produced poorer growth rates as compared to barley- or oat-based diets.

About 3% fat is recommended in rabbit diets;dietary fat is well utilized by rabbits and improves diet palatability and increases energy level without causing carbohydrate overload of the hindgut (Pond *et al*., 1995). The rabbit, for instance the breeding doe, adjusts its feed intake according to the energy concentration of the feed as well as the protein and other dietary components present (Lebas *et al*., 1986); to around 220-240kcal of digestible energy (DE) per kg metabolic weight ($W^{0.75}$).

2.11.3 Crude fibre

According to Maertens (1988) although fibre is not considered a real nutrient in rabbits because of its low digestibility (average dietary digestibility is less than 20%), it is considered a nutrient to maintain the gut motility.

Cell-wall constituents from feedstuffs having low lignin content or young plants have a considerable higher digestibility than highly lignified sources, 40-70% versus 5-20% respectively. It is not clear what the minimum fibre intake for prevention of diarrhoea in rabbits should be.

Research reports from Blas *et al*. (1994) and Gidenne and Jehl (2000) examined the effect of low fibre diets to rabbits, and observed that a sharp decrease in fibre level from 19-9% in the diet doubled the risk of digestive trouble. The population of cellulolytic bacteria decreased in the caecum, and the microbial ecology system in the caecum became unbalanced, which may cause death from diarrhoea.

Feeding rabbits with a diet low in fibre and high in energy or a finely ground concentrate diet; can result in high mortality due to intestinal disorders, such as enterotoxemia (Lukefahr and Cheeke, 1991). The significant role of dietary lignin (ADL) on the rate of passage and its protective effect against diarrhoea has been demonstrated by the French INRA (Institut National de la Recherche Agronomique) team (Gidenne and Perez, 1994; Lebas *et al*., 1998). The mortality rate as a result of digestive disorders was closely related (r = 0.99) to the ADL level in their experiments. The relationship was expressed as follows:

Mortality rate (%) = 15.8-1.08 ADL (%); n >2,000 rabbits.

Quite similar effects were observed by the same team of researchers with various cellulose (ADF-ADL) levels (Gidenne and Perez, 1996; Perez, 1996). They clearly indicate that the recommendations in terms of dietary safety cannot be expressed as a single fibre fraction. Furthermore, recommendations of dietary fibre are age dependent. Young rabbits require higher minimum levels than fattening or breeding does, probably because of their lower daily intake to reduce enteritis. An excess of dietary fibre is also not desirable because digestible energy (DE) content decreases and a too high protein- to- energy ratio is commonly the result. Such a situation is favourable for the proteolytic flora that produces ammonia with an increasing risk of digestive disorders (De Blas, 1981; Lebas, 1989).

Besides dietary fibre, starch also plays a key role in the nutrition-enteritis interaction. Young rabbits have an immature pancreatic enzyme system that can lead to significant amount of starch reaching the caecum when using high-starch diets. Especially dietary starch with higher resistance (corn) against hydrolysis could lead to starch overload. The risk of destabilization of the caecal flora is higher if the increased ileal starch flow is not accompanied with a similar increase of fibre intake (Gidenne and Perez, 1996).

Rabbits use crude fibre less efficiently due to a faster rate of passage of digesta and smaller holding capacity, compared to grazing ruminants. Rabbits are therefore more selective in their diets than ruminants (Jarvis, 1976).

Optimal fibre balance also includes a dietary recommendation for particle size. A sufficient amount of large-size particles is required for optimal performance and to reduce the risk of digestive disorders. According to De Blas *et al*. (1999) a minimum proportion of 25 % of large particles (> 0.315 mm) is required.

Chemical composition and form of fibre not only affect its susceptibility to digestion but can also influence feeding habits. Spreadbury and Davidson (1978), in an experiment, compared oat husk with barley straw and pure cellulose in rabbit diets, and concluded that daily feed intake increased as the crude fibre content of the diet was increased from 3.9 to 27.0%. The optimum level of crude fibre for growing rabbits is 13-14% (Lebas *et al*., 1986).

2.11.4 Minerals and vitamins

Pond *et al.* (1995) stated that the major mineral elements of concern in rabbit diet formulation are calcium and phosphorus (Ca and P), and that the other minerals are usually provided in adequate amounts by the ingredients used plus the addition of trace-mineralized salt. Studies on the calcium and phosphorus requirements of growing rabbits have shown that they need these minerals much less than lactating does. The amounts excreted through the milk are significant. However, excesses of calcium (> 40 g/kg) or phosphorus (> 19 g/kg) induce significant alteration of fertility and prolificacy or higher proportions of stillbirths. Total dietary phosphorus intake ranging from 0.45 to 0.76% did not affect any of the does' reproduction performances (Lebas and Jouglar, 1990). Aduku *et al*. (1988) fed weaner rabbits peanut meal, sunflower meal and palm kernel meal diets containing 14.84, 23.24 and 38.89% crude fibre respectively and observed thatfeed consumption was significantly ($p<0.05$) higher with the palm kernel and sunflower meal diets than with the pea nut diet. This was however, attributed to the rabbits having to compensate for their energy requirement. In the same experiment they found feed to gain ratios to be significantly ($p<0.05$) poorer on the palm kernel and sunflower meal diets than on the pea nut meal diet.

Differences in weight gain and final body weight for the three diets were however, not significant ($p>0.05$) though the diet with lower fibre content had higher weight gains than the one with higher crude fibre content.

The performances of the progeny were independent of their mothers' diet. The lack of response to low-dietary phosphorus levels has been confirmed with fatteners (Lebas *et al*., 1998). The Ca:P ratio does not seem to be critical for rabbits (Lebas *et al*., 1998) and is usually 2:1, however, rabbits can tolerate much higher ratios.

Copper sulphatewhich is often used as a non-nutritive feed additive aids in preventing enteritis (Pond *et al*., 1995). Fielding (1991) stated that rabbits are born with high levels of iron in their livers, sufficient for their preweaning growth. Rabbits require water-soluble (B group and C) as well as fat-soluble vitamins (A, D, E, and K). According to Lukefahr and Cheeke (1991) the major vitamins needed in rabbit diets are vitamins A, D and E and that protein and carbohydrate dietary sources, fed in good variety, may largely meet the mineral and vitamin requirements. Micro-organisms in the digestive flora synthesize sizeable amounts of water-soluble vitamins which are utilized by the rabbits through caecotrophy.

Vitamin K and the B vitamins are not required in the diet, since they are synthesized through coprophagy and fermentation in the caecum or hindgut; likewise vitamin C (Lukefahr and Cheeke, 1991). Under practical conditions, the B-complex vitamins are not dietary essentials for rabbits; however, under stress situations and at high performance levels deficiencies can occur (Ismael, 1992).

Gillespie (1998) has indicated that the use of iodized salt at the rate of 0.5% of the diet will supply the needed sodium, chlorine and iodine for rabbits.

The vitamin A requirement of rabbits has not been adequately determined and a level of 10,000 IU/kg of diet is adequate while levels in excess of 40,000 IU/kg diet may adversely affect reproduction (Pond *et al*., 1995). They further stated that vitamin A-deficient rabbits exhibit poor growth, leg deformities, increased susceptibility and a high incidence of enteritis. Vitamin C supplementation is recommended for rabbits under stress (Verde and Piquer, 1986).

2.11.5 Water as a nutrient for rabbits

Water is normally considered a nutrient, although its properties and functions are quite different from those of other nutrients found in feeds. Water is the major component of the rabbit body, making up 70% of the lean body mass (Maertens, 1992). Maertens (1992) further indicated that rabbits will die more rapidly from water deprivation than from food deprivation.

Restricted drinking water or limited drinking time leads to reduced feed intake that is directly proportional to the amount of water being consumed (Szendro *et al*., 1988). They further reported that water and feed consumption varies with changes in environmental temperature and humidity.As the temperature rises above 20^0C day and night, feed intake tends to drop while water consumption increases. At high temperatures, (30^0C and over) feed and water intakes decline, affecting the performance of growing and lactating animals (Femandez-Carmona *et al.*, 1996). According to Pond *et al*. (1995) water plays an essential role in a number of functions vital to an animal such as digestion, nutrient transport, waste excretion and temperature regulation.

One of the most important properties of water in nutrition is its remarkable ability to dissolve substances. It is said that this property is due to its dielectric constant, which inturn is due to its hydrogen bonding (Lassiter and Edwards, 1982).

2.12 The digestive tract of rabbits

Domestic rabbits (*Oryctolagus cuniculus*) are herbivores, concentrate selectors, and are classified as hindgut (caecum and colon) fermentors (Cheeke, 1987;McNitt *et al*., 1996). Since there are no mammalian enzymes to break down the cellulose components of their plant-based diets, rabbits as well as other herbivores have a symbiotic microbe population (primarily Bacteroides).

Due to smaller body size and higher metabolic rate than horses, rabbits rely on other adaptations for forage utilization (Cheeke, 1987). In rabbits, the microbial population is found in the caecum.The rabbit caecum is very large, compared with the rest of the gut (Stevens and Hume, 1995) and forms a spiral that fills the abdominal cavity. The caecum (Jenkins, 1999) has a capacity 10 times that of the rabbit's stomach, about 40% of the gastrointestinal tract.

Instead of completely fermenting fibre, rabbits utilize a mechanism to sort out indigestible fibre and expel it from the body, a process that is a specialized feeding strategy that overcomes poor-quality protein (Pond *et al*., 1995). This sorting mechanism occurs as digesta enter the rabbit's large intestine and muscular contractions facilitate the separation of fibre and non-fibre (protein, soluble carbohydrates, etc) fractions.

A series of peristaltic (move fibre through colon) and anti-peristaltic waves (move fluid and non-fibre components to caecum for fermentation) separate out non-fibre fractions for further fermentation in the caecum (Cheeke, 1987; Carabano and Piquer, 1998); particle size and density aid separation (Cheeke, 1994). The fibre components are voided from the body (day, or hard, faeces) about 4 hours after consumption of the diet (Cheeke, 1994). After fermentation of the non-fibre components in the caecum, a pellet is formed (called a cecotrope, also soft, or night, faeces) that is voided from the body approximately 8 hours after consumption of the diet

(Pond *et al*., 1995). A neural response (Jenkins, 1999) or the strong odour of VFA (Stevens and Hume, 1995) in the cecotrope seems to stimulate its consumption directly form the anus.

This practice of consuming cecotropes is called coprophagy (Gillespie, 1998). In natural settings, coprophagy usually occurs during the night, opposite of feed intake and the voiding of hard faeces, in a circadian rhythmic pattern (Carabano and Piquer, 1998; Jenkins, 1999), and is an integral part of the rabbit's digestion process (Cheeke, 1994). Due to their small body size, if allowed to consume a diet ad libitum, rabbits will daily eat an amount that approximates 5% of their body weight in dry matter and drink about 10% of their body weight in water (Okerman, 1994). Even at this intake, if a rabbit was to consume only low-quality forages, there would be insufficient energy and nutrients to meet its metabolic requirements. However, if rabbits at maintenance are fed a high-quality pelleted diet for ad libitum consumption, they will become obese (Brooks, 1997).

When allowed to select their own diet in a natural habitat, rabbits select the most tender, succulent plant parts or the plant parts that are most nutrient-dense and lowest in available cell walls.

Some researchers refer to animals that practice this type of eating behaviour *concentrate selectors*, a practice that allows the animal to meet the dietary requirements for their high metabolic rate (Cheeke, 1994). Rabbits have high feed intake (65-80 g/kg BW) and fast feed transit time (19 hours), which enable them to consume lower-quality forages and still meet nutritional requirements (Gidenne, 1992). Most problems seen in rabbit production involve the gastrointestinal tract. Enteritis is the primary gastrointestinal disorder, and it often results in diarrheoa (Milon, 1996).

2.13 Gut microbes and utilization of fibre in rabbits

When compared with other herbivores, actual fibre digestion capability for rabbits is relatively low (14% for alfalfa hay in rabbits compared with 44% in cattle, 41% in horses, and 22% in hogs (McNitt *et al*., 1996).

The actual crude fibre component of most forages fed is only 20-25% (McNitt *et al*., 1996), depending on forage maturity. Obviously, the more mature the forage, the higher the crude fibre. Other non-fibre fractions of forage, protein, and soluble carbohydrates are easily digested by rabbits. In rabbits, dietary fibre has a critical role in maintaining gut health, stimulating gut motility (insoluble fibre only), reducing fur chewing and preventing enteritis (Brooks, 1997). The composition of the hard faeces and the cecotrope is influenced by the diet. If dietary fibre concentration increases, the fibre composition of the faecal pellets also increases. Fibre fermentation in rabbits does not seem to be enhanced by coprophagy (Cheeke, 1994).

Microbes in rabbit gut produce VFA, as do microbes in the rumen of a cow. In rabbits fed a traditional alfalfa/corn diets, acetate is the primary volatile fatty acid produced by microbes, with more butyrate than propionate being formed. Butyrate is the preferred energy source for the hind gut (Stevens and Hume, 1995; Gidenne *et al*., 1998; Jenkins, 1999). Microbes in rabbits produce more VFA on starch-based diets than on forage diets (Cheeke, 1994). Stevens and Hume (1995) indicated that VFA provide a major energy source in rabbit colon. Gut microflora of rabbits are sensitive to most antibiotics (McNitt *et al*., 1996). If antibiotics are fed, the microbe population is altered, favouring *E. Coli*and *Clostridia* organisms that produce toxins harming the gut lining, causing diarrhoea and enterotoxemia (Stein and Walshaw, 1996).

2.14 Utilization of protein in rabbits

In ruminants, microbial protein satisfies the major amino acid requirements for the animal, but this is not true for rabbits. Even though amino acids produced by bacteria may be available via coprophagy (especially lysine, surphur amino acids, and threonine; Carabano and Piquer, 1998), research has shown that microbial protein plays only a minor role in meeting a rabbit's protein and amino acids needs (McNitt, 1996). The majority of microbial protein utilized by the animal is digested in the colon (Stevens and Hume, 1995). As a result, synthetic amino acids are often added to commercial rabbit diets to fully meet amino acids needs, particularly lysine and methionine, which may be limiting amino acids in traditional alfalfa-corn diets (McNitt *et al*., 1996).

Cecotropes do, however, contain approximately 28% crude protein (Stevens and Hume, 1995).

Urea is recycled by the rabbit large intestine in a manner similar to that occurring in the rumen (Stevens and Hume, 1995). However, when dietary urea is fed to rabbits, it is not well utilized by microbes.

Prolonged feeding of 0.5% urea in the diet of rabbits will result in liver or kidney lesions (Cheeke, 1994). Urea is converted to ammonia in rabbit gut, and when absorbed, it results in toxicity. Ingestion of cecotropes is influenced by dietary protein and energy. When an animal is fed a lower energy diet, cecotrope ingestion is maximized (Jenkins, 1999).

When an animal is fed a diet for ad libitum consumption, dietary protein and fibre concentration affect cecotrope consumption which seems to be a protein-sparing mechanism (Cheeke, 1994). Coprophagy has been found to increase protein digestibility (50 vs 75 to 80% for alfalfa) of forages in rabbits. Care should be taken when feeding high levels of dietary protein because

excess protein may increase caecal ammonia levels, causing an increase in caecal pH (Cheeke, 1994). This rise in pH may allow pathogens to flourish and may increase the potential for enteritis.

2.15Utilization of starch in rabbits

High-starch diets are often incompletely digested in the small intestine of the rabbit due to rapid transit times (McNitt *et al*., 1996). Incomplete chemical digestion of the starch results in the availability of starch for microbial fermentation (Stevens and Hume, 1995). Excess starch in the gut results in an extremely rapid growth of microbes. If toxin-producing microbes (primarily *Clostridium spiroforme*) are in residence, high levels of starch may lead to enteritis and possible death (Tisch, 2006). As a result of potential incomplete starch digestion, low-energy grains such as oats are preferred over corn or wheat (Cheeke, 1994).

Grains processed too finely can lead to rapid bacterial fermentation of the starch and cause enterotoxemia. Thus, a coarse grind is recommended.

2.16Calcium metabolism in rabbits

Rabbits have an unusual calcium metabolism, absorbing calcium without vitamin D facilitation and activation of calcium-binding proteins in the gut (McNitt *et al*., 1996; Jenkins, 1999), resulting in excess calcium being excreted in the urine.

In most mammals, less than 2% of dietary calcium is excreted in the urine, but in rabbits it is much higher. In one study cited by Jenkins (1999), the fractional excretion of calcium was 44% when animals were fed a “typical” commercial diet. Since rabbits can absorb calcium without the facilitation of vitamin D, a mechanism is needed to regulate serum calcium levels. Parathyroid hormone and calcitonin are thought to prevent serum Ca levels from becoming dangerously high

due to dietary influence. Diets high in calcium (alfalfa-based) may result in kidney damage for animals at maintenance levels (Cheeke, 1994) because homeostatic mechanisms are not as effective as in other species. Prolonged high dietary calcium will result in calcification of soft tissues such as aorta and kidney (Cheeke, 1994) and formation of kidney stones.

2.17Rabbit meat composition

Rabbit meat is very nutritious and a rich source of protein, energy, minerals and vitamins. Relative to other common meats, rabbit meat is low in fat, sodium and cholesterol (Lebas and Matheron, 1982). Fielding (1991) stated that rabbit meat is especially high in protein and low in fat and that, the fat in the meat is mainly unsaturated which is believed to be a more healthy type of fat than saturated fat which is common in other meats.

Rao *et al*. (1987) reported that rabbit meat mainly composed of 18.8-19.4% protein, 9.9-10.9% fat and 68.5-72.0% moisture.

In an experiment using New Zealand White rabbit, Mohamed (1989) reported the meat composition as 77.34% moisture, 21.55% protein, 2.73% ether extract and 1.63% ash. Table 9.0 shows rabbit meat composition relative to other common meats.

Table 9.0: The chemical composition of rabbit meat as compared to other common meats

Meat composition		Moisture (%)	Dry matter (%)	Protein (%)	Fat (%)	Energy (1 MJ/kg and 2cal/kg)
Rabbit	1	-	20-23	20-22	10-12	7-8
	2	67.9	-	20.8	10.2	1749
Chicken	1	-	20-23	19-21	11-13	7-8
	2	67.6	-	20.0	11.0	1782
Turkey	1	-	38-42	19-21	20-22	10-12
	2	58.3	-	20.1	20.2	2618
Beef	1	-	40-50	15-17	27-29	11-14
	2	55.0	-	16.3	28.0	3168
Lamb	1	-	40-50	14-18	26-30	11-14
	2	55.8	-	15.7	27.7	3124
Pork	1	-	50-55	10-12	42-48	17-20
	2	42.0	-	11.9	45.0	4510

Sources: 1= Fielding (1991)
2=USDA (1963)

2.18 Review of findings on rabbits under tropical conditions

2.18.1 Feed intake, weight gain, FCE and mortality of rabbits fed concentrates in the tropics

Eshiet *et al*. (1979) under tropical conditions evaluated the effects of feeding graded levels of cassava root meal on the performance of fryer rabbits. The experiment showed that rabbits could tolerate up to 30% cassava root meal diet without adverse effects on feed intake and rate of growth. The 45% cassava root level, however, gave poor growth and utilization efficiency and this was blamed on the hydrogen cyanide level in the diet. The results are shown in Table 10.0.

Table 10.0: The effect of feeding graded levels of cassava root meal (CRM) on the life performance of fryer rabbits.

Parameter	Level of CRM inclusion (%)			
	0 (concentrate)	15	30	45
Daily Feed Intake (g)	24.02^{c}	56.43^{a}	60.54^{ab}	79.92^{b}
Daily Weight Gain (g)	18.25	18.53	18.52	16.72
FCE	2.63^{a}	3.06^{b}	3.26^{b}	4.78^{c}
Mortality (%)	25.00	12.50	12.50	25.00

Source: Eshiet *et al*. (1979)

Farinu *et al*. (2008) evaluated the nutritive potential of pigeon pea grain and leaf meals on growth performance of pre-pubertal rabbits in the tropics. Eighteen weaner rabbits were randomly allocated to experimental diets 1, 2 and 3, containing 0% pigeon pea, 15% pigeon grain meal and 15% pigeon pea leaf meal respectively, in replacement of maize offal as the main energy source. The final liveweight (1375.1 g for diet 1, 1487.5 g for diet 2 and 1347.38 g for diet 3); daily weight gain (11.6 g for diet 1, 13.00 g for diet 2 and 11.21 g for diet 3); and FCE values of 6.50, 5.20 and 5.31 for diets 1, 2 and 3, respectively were not significantly ($p>0.05$) affected by the dietary treatments. It was concluded that 15% pigeon pea grain meal inclusion in rabbit diet with maize offal rather than maize, as the main energy base, resulted in better performance of weaner rabbits.

A feeding trial was conducted using weaner rabbits by Ayers *et al*. (1996) to evaluate hybrid poplar (HP) (*Populus spp*.) leaves as animal feed under tropical conditions. Ten New Zealand white weaner rabbits were each assigned to treatment 0%, 10%, 20%, or 40% HP foliage. A diet with 40% Alfalfa Meal (AM) was the control. There was no difference in growth rates of rabbits on the various diets, even though digestibilities were lower in those on diets with HP than those in the AM control. Greater gut fillin rabbits on the HP-containing diets associated with the

higher feed intakes with these diets (Table 11.0), may compromise accuracy of the weight gain data. Table 11.0 shows the performance of the rabbits fed the diets containing hybrid poplar leaf meal.

Table 11.0: Performance of rabbits fed diets containing Poplar leaf meal.

Treatment (Level of inclusion)	Average Daily gain (g)	Daily feed intake (g)	FCE
I (40% alfalfa)	35.5	105.6	3.4
II (10% hybrid poplar)	39.7	117.3	3.3
III (20% hybrid poplar)	36.7	122.3	3.8
IV (40% hybrid poplar)	37.9	133.9	4.0

Source: Ayers *et al*. (1996)

Eustace *et al*. (2003) used 24 weaner rabbits to assess theirperformance using varying dietary cyanide levels. Daily weight gain, daily feed intake and feed efficiency significantly ($p<0.05$) reduced as the cyanide level increased. The results showed that dietary cyanide had negative impact on growth performance (Table 12.0).

Table 12.0: Performance of weaner rabbits fed varying dietary cyanide levels.

	Dietary cyanide Levels			
Parameters	0mg	250mg	500mg	750mg
Initial Live weight (g)	769.17	779.17	777.50	766.67
Final live weight (g)	1630.00	1425.00	1371.67	1329.17
Daily feed intake (g)	68.08^{a}	60.33^{c}	58.12^{c}	54.56^{b}
Daily weight gain (g)	16.64^{a}	11.53^{b}	10.46^{b}	9.74^{b}
FCE	4.85	5.32	5.77	5.63

a,b,c = means in the same row having different superscripts are significantly different ($p<0.05$)
Source: Eustace *et al*. (2003)

In a study by Eustace *et al*. (2003) in which weaner rabbits were fed with dietary cyanide levels; 0 mg, 250 mg, 500 mg, and 750 mg, the resulting cholesterol level values reported were 74.33

mg/dl, 106.75mg/dl, 53.67mg/dl and 104.00mg/dl, respectively, showing that dietary cyanide had negative impact on blood cholesterol level.

Okorie (2003) carried out a six-week experiment to determine the effect of palmitic acid fortified maize wet milling by-product on the performance of weaner rabbits. Forty-eight (48) weaner New Zealand white and Dutch breed of rabbits were assigned to four dietary treatments of 0%, 25%, 30% and 50% levels of the palmitic acid fortified maize wet milling by-product. The growth rate of rabbit on the 25% diet was higher followed by the 0% and 30% diets. Nevertheless, those on 50% showed a depressed growth rate, which could be due to the unpalatability of the by-product at the 50% level. The animals showed a higher feed intake at the 25% level and 0% level ($p>0.05$) and the feed intake decreased from the 30% level to the 50% level of inclusion. The data obtained in the experiment showed a strong promise for the palmitic acid fortified maize wet-milling by-product as a good source of feedstuff for rabbits.Data on the performance of weaner rabbits for the various diets are shown in Table 13.0.

Table 13.0: Effect of palmitic acid fortified maize wet-milling by-products on the performance of weaner rabbits.

	Level of Inclusion			
Parameters	0% (control)	25%	30%	50%
Average initial weight (g)	466	468	470	469
Average final weight (g)	1462^{b}	1479^{a}	1482^{a}	1470^{b}
Growth rate (g/d)	21.84^{a}	22.06^{a}	21.54^{b}	21.03^{b}
Feed intake (g/d)	65.12^{a}	68.81^{a}	63.84^{b}	61.08^{b}
FCE	2.98^{a}	3.12^{a}	2.96^{a}	2.90^{b}
Mortality	-	-	-	-

^{a,b} = within row with different superscripts are significantly different ($p<0.05$)
Source: Okorie (2003)

Hasanat *et al*. (2006) used cross-bred New Zealand white meat type rabbits in a 128- day trial to study the effect of concentrate supplementation on growth of rabbits under rural conditions. Dietary treatment 1 was a conventional diet, while treatment 2 was conventional diet plus concentrate. All animals had free access to locally available green grasses. The results obtained were: initial weight (g), T_1 = 1055.83 and T_2 = 994.98; final weight (g), T_1 = 1426.66^b and T_2 = 1911.66^a; weight gain (g/d) T_1 = 5.30^b and T_2 = 13.02^a. The results showed that, average daily live weight and final weight gain were significantly ($p<0.01$) higher in T_2 than in T_1 group. It could therefore be inferred that supplementation of concentrates in addition to conventional feeding may improve growth performance of rabbits under rural conditions.

Omole and Onwudike (1982) investigated the effects of palm oil in cassava peel diet for weaner rabbits and the results are shown in Table 14.0. The inference drawn showed that dietary cassava peel meal supplemented with palm oil improved live performances of weaner rabbits in all the treatments, including the cassava peel meal. The inclusion of up to 30% cassava peel meal seemed to cause no significant depression in growth or feed utilization.

Table 14.0: Effect of different levels of cassava meal and supplementary palm oil on weaner rabbits.

	Parameter			
	Av. initial weight (g)	Av. final weight (g)	Daily weight gain (g)	FCE
Level of Cassava peel Meal (%)				
0	617.5	1942.5	23.66[c]	3.09[a]
10	615.8	1969.3	24.17[c]	3.11[a]
20	620.1	1955.7	23.85[c]	3.04[a]
30	622.4	1933.9	23.42[c]	3.21[a]
40	624.5	1663.9	18.56[b]	3.87[b]
50	621.7	1470.7	15.16[a]	4.59[c]

Means within a row not followed by the same letter differ significantly ($p<0.05$)
Source: Omole and Onwudike (1982)

Omole and Sonaiya (1981) evaluated the utilization of cassava peel meal by rabbits in two separate studies. The results showed that cassava peel meal could make up to 40% of the ration of growing rabbits without any deleterious effects on live performance, especially when fish meal (FM) diets were consistently superior to groundnut cake (GNC) diets at all levels of cassava peel meal.The data on performance of the rabbits are presented in Table 15.0.

Table 15.0: Effect of unsupplemented cassava peel meal and protein sources on the performance of growing rabbits.

	Cassava peel meal (%)					
Parameters	0%		20%		40%	
Protein sources[a]	*FM*	*GNC*	*FM*	*GNC*	*FM*	*GNC*
Average initial weight (g)	575.6	578.2	580.2	584.7	579.4	582.1
Average final weight (g)	1994.2	1659.7	1936.5	1635.5	1840.5	1453.5
Daily feed intake (g)	76.27[a]	70.68[a]	77.26[a]	71.66[a]	77.47[a]	63.02[b]
Daily gain (g)	25.34[c]	19.31[ab]	24.22[c]	18.76[ab]	22.52[b]	15.56[a]
FCE	3.01[a]	4.66[abc]	3.19[ab]	3.82[abc]	3.44[abc]	4.05[c]

A = protein source, FM = Fish meal, GNC = Groundnut cake values in each row with different superscripts are significantly different ($p<0.05$)

Source: Omole and Sonaiya (1981).

Amata and Bratte (2008) conducted an experiment to determine the effect of feeding graded levels of *Gliricidia sepium* leaf meal (GLM) on the performance of weaner rabbits for an 8 week period in the tropics.Although body weight gains and feed intake tended to decline as the level of GLM in the diets was increased, which is a reflection of the increasing levels of fibre in the diets, the differences were non-significant. FCE though numerically higher for the 10, 15 and 20% GLM diets when compared to the control treatment, was not significantly affected by dietary treatments. This implies that inclusion of GLM at moderate levels of up to 20% cannot significantly reduce feed intake, FCE and growth in rabbits. The results of the experiment are shown in (Table 16.0).

Table 16.0: Performance of weaner rabbits fed graded levels of gliricidia leaf meal diets.

	Level of gliricidia leaf meal inclusion (%)				
Parameter (g)	0	5	10	15	20
Initial body weight	571.00	725.00	712.50	727.50	757.47
Final body weight	1533.25	1612.50	1703.40	1700.00	1676.04
Weight gain	958.25	887.31	991.90	972.50	919.37
Feed intake	7160	6830	7120	6780	6590
FCE	0.13 (13%)	0.13 (13%)	0.14(14%)	0.15(15%)	0.14(14%)

Source: Amata and Bratte (2008)

2.18.2 Haematological and biochemical values of rabbits

In an experiment to determine the haematological indices of weaner rabbits as affected by stocking density in Nigeria, Yakubu *et al*. (2008) reported values which are shown in Table 17.0.

Table 17.0: Mean leucocytic and erythrocytic values for rabbits reared at different stocking densities.

Parameter	Stocking density (rabbits/ m^2) 10	14.3	20	25
Packed cell volume PCV (%)	34.50	32.90	28.40	28.20
Haemoglobin (g/dl)	10.20	9.47	8.93	8.80
Red blood cell ($\times 10^6$/µl)	6.23	6.17	5.37	5.30
White blood cell ($\times 10^9$/dl)	5.50	5.60	5.27	5.13
Neutrophils (%)	45.60	45.90	48.33	49.70
Lymphocytes (%)	52.80	50.80	47.50	47.60
Eosinophils (%)	0.33	0.83	1.10	1.00

Source: Yakubu *et al*. (2008)

The conclusion drawn from the study was that group-housing of rabbits at a density of 14.30 rabbits per m^2 could guarantee and promote an improved welfare in a tropical environment.

Ahamefule *et al*. (2008) carried out a research to assess the haematological and biochemical profile of weaner rabbits fed raw or a processed pigeon pea seed (PSM) meal based diets at 20% inclusion level in the tropics. The summary of the haematological and biochemical components of the rabbits fed the various diets are presented in Table 18.0.

Table 18.0: Haematological and biochemical components of rabbits fed diets containing raw, boiled, toasted or soaked pigeon pea seed.

Parameter	Raw PSM Diet	Boiled PSM Diet	Toasted PSM Diet	Soaked PSM Diet
Haemoglobin (g/dl)	5.53	6.93	8.40	8.40
PCV (%)	28.5^a	19.6^c	24.6^b	25.3^b
WBC ($\times 10^3$)	6.80^a	6.03^{ab}	5.00^b	6.30^a
Neutrophils (%)	72.6	55.3	56.30	56.00
Eosinophils (%)	10.30	10.00	8.33	11.00
Lymphocytes (%)	37.00^a	33.60^b	33.60^b	33.00^b
Total Protein (g/dl)	5.30	4.73	3.93	2.90
Globulin (g/dl)	1.10^b	2.70^a	1.76^{ab}	1.26^b
Albumin (g/dl)	4.20	2.03	2.17	1.64

^{a,b} = means on the same row not followed by the same letter are significantly different ($p<0.05$)
Source: Ahamefule *et al*. (2008)

The conclusion drawn from the study was that most haematological and biochemical values obtained were out of the normal physiological range for rabbits. Raw or processed pea generally caused remarkable changes in the haematological and biochemical profile ofthe weaner rabbits when incorporated at 20% level in the feed.

A 12-week feeding trial to evaluate the blood biochemistry and haematology of rabbits fed sun-dried, ensiled and fermented cassava peel based diet was conducted by Ahamefule *et al*.(2006) in Nigeria. It was observed that the haematological values obtained for rabbits fed sun-dried, ensiled and fermented cassava peel based diets, except PCV and WBC, fell within normal stipulated ranges. This is a good indication that sun-drying, ensiling and fermentation could be used to reduce hydrogen cyanide (HCN) to a non-lethal level in cassava peels for rabbit nutrition.Table 19.0 shows a summary of the results of the trial.

Table 19.0: Summary of blood haematological components of rabbits fed various processed forms of cassava based diets.

Parameter	Control	Sun-dried	Ensiled	Fermented
Packed cell volume PCV (%)	42.75^{c}	45.75^{ab}	43.25^{bc}	46.50^{a}
White blood cell (10^{3}/dl)	6.00^{b}	5.80^{b}	6.30^{b}	7.30^{a}
Neutrophils (%)	41.50^{a}	37.50^{b}	43.25^{a}	40.25^{ab}
Lymphocytes (%)	59.00^{ab}	60.75^{a}	56.50^{b}	57.50^{ab}
Eosinophils (%)	1.50	2.00	1.25	1.75

a,b,c = means on the same row not followed by the same letter are significantly different ($p<0.05$)

Source: Ahamefule *et al*. (2006)

Ogbuewu *et al*. (2008) carried out a 16-week feeding trial to determine the effect of dietary neem leaf meal (NLM) on serum biochemical constituents of buck rabbits. The results of the trial suggested that buck rabbits could tolerate 5-15% dietary levels of NLM without deleterious

effects. Table 20.0 shows the serum biochemical characteristics of the buck rabbits fed graded levels of neem leaf meal (NLM).

Table 20.0: Serum biochemical characteristics of buck rabbits fed graded levels of neem leaf meal (NLM).

Parameter	Inclusion levels of Neem Leaf Meal (NLM) T_0 (0%)	T_1 (5%)	T_2 (10%)	T_3 (15%)
Total protein (g/dl)	6.10	3.00	3.20	6.90
Globulin (g/dl)	4.70^{a}	2.10^{a}	1.50^{b}	5.10^{a}
Albumin (g/dl)	1.40^{ab}	0.90^{b}	1.70^{a}	1.80^{a}
Cholesterol (mg/dl)	174.60^{a}	115.20^{b}	95.40^{c}	56.50^{d}

Source: Ogbuewu *et al*. (2008).

2.18.3 Carcass characteristics of rabbits under tropical conditions

Eustace *et al*. (2003) assessedthe response of carcass characteristics of 24 growing rabbits to varying dietary cyanide levels. The results indicated that increase in dietary cyanide levels caused a significant *($p<0.05$)* reduction in the liveweight, slaughter weight and the lungs weight. This observation may be due to the effect of the cyanide levels interfering in the digestion of the nutrients. The carcass characteristics of the growing rabbits fed the different levels of dietary cyanide are shown in Table 21.0.

Table 21.0: Carcass characteristics of rabbits fed varying levels of dietary cyanide.

Parameter	Dietary cyanide levels 0 mg	250 mg	500 mg	750mg
Liveweight (g)	1650.00^{a}	1500.00^{c}	1375.00^{b}	1355.00^{b}
Slaughter weight (g)	1600.00^{a}	1425.00^{c}	1315.00^{b}	1305.00^{b}
Carcass weight (g)	1335.00	1075.00	1,000.00	975.00
Liver weight (g)	48.35	45.94	40.40	40.65
Kidney weight (g)	9.45	9.86	9.80	9.40
Heart Weight (g)	3.90	3.75	2.95	3.45
Lungs weight (g)	9.70^{a}	7.01^{b}	6.95^{b}	6.80^{b}

a,b and c means in the same row having different superscripts are significantly different (*$p<0.05$*)
Source: Eustace *et al*. (2003)

Amata and Bratte (2008) carried out an experiment to determine the effect of feeding graded levels of *Gliricidia sepium* leaf meal (GLM) on organ weights of 25 weaner rabbits allotted to five dietary treatments containing 0% (control), 5%, 10% 15% and 20% GLM.

The conclusion from the experiment indicated that beyond 10% GLM in rabbit diets, there would be probably increases in detoxification activities in the liver and kidneys of the rabbits (Table 22.0).

Table 22.0: Organ weights of rabbits fed graded levels of gliricidia leaf meal.

	Levels of GLM inclusion (%)				
Organ weights (g)	0	5	10	15	20
Heart	4.75	4.87	5.64	5.99	5.02
Kidney	6.52[b]	7.65[b]	10.54[a]	10.95[a]	10.25
Liver	32.24[b]	30.36[b]	32.69[b]	40.62[a]	42.84
Lungs	5.24	5.48	5.18	5.44	6.36

Within each row, means with the same superscripts are not significantly different.
Source: Amata and Bratte (2008)

Okorie (2003) conducted an experiment to assess the effect of palmitic acid fortified maize wet-milling by-product on the performance of weaner rabbits and reported the following carcass yield in Table 23.0. Dressing percentage and breast weight were lower ($p<0.05$) for the 50% inclusion of the palmitic acid fortified maize wet-milling by-product, while the inclusion of the by-product increased ($p>0.05$) the viscera weight. The results of the experiment showed that palmitic acid fortified maize wet-milling by-product could improve carcass yield of rabbits.

Table 23.0: Carcass yield (% liveweight) of rabbits fed different levels of palmitic acid fortified maize wet milling by-product.

	Inclusion levels of fortified by-product			
Parameter	0%	25%	30%	50%
Weight of animals (g)	1200	1290	1311	1205
Dressing %	73.01[b]	76.2[a]	75.4	72.6[b]
Liver weight (g)	3.28[a]	3.1[a]	3.01[a]	2.79[a]
Kidneys weight (g)	0.80	0.75	0.73	0.70
Heart weight (g)	1.05	0.98	0.92	0.88

a,b = means on the same row not followed by the same letter are significantly different ($p<0.05$)
Source: Okorie (2003)

In an experiment to study the effect of different feeding systems on the carcass characteristics of New Zealand white rabbits, Biya *et al*. (2008) reported carcass characteristic values as shown in Table 24.0.T_1 represented rabbits which were fed with concentrate alone.T_2rabbits had 25% replacement of concentrate.T_3 had 50 vegetable cuttings on DM basis.T_4 had 25%concentrate and 75% vegetable cuttings on DM basis and T_5 had 100% vegetable cuttings on DM basis.The results showed that T_2, which had 25% replacement of concentrate with vegetable cuttings produced the highest dressing percentage compared to the other treatment groups.

Table 24.0: Carcass characteristics of New Zealand white rabbits.

Parameters	T_1	T_2	T_3	T_4	T_5
Slaughtered weight (g)	1972.50^{b}	2290.00^{a}	1959.17^{c}	1595.83^{d}	261.67^{c}
Carcass weight (g)	1015.55^{b}	1197.36^{a}	988.24^{c}	742.21^{d}	571.66^{c}
Dressing percentage	51.48	52.27	50.44	46.51	45.31
Pelt (%)	11.58^{b}	11.20^{b}	11.00^{b}	10.13^{c}	10.08^{c}
Head (%)	8.77^{a}	8.58^{ab}	8.50^{b}	8.05^{c}	7.75^{d}
Liver (%)	2.66^{c}	3.63^{a}	2.92^{b}	2.51^{c}	2.33^{d}
Kidney (%)	0.89^{b}	1.26^{a}	1.04^{ab}	0.94^{b}	0.84^{b}
Heart + Lungs + Spleen (%)	1.16^{a}	1.14^{ab}	1.13^{b}	1.10^{c}	1.07^{d}

Body components expressed as percentage of slaughter weight. Means bearing different superscripts in a row differ significantly ($p<0.05$)
Source: Biya *et al*. (2008)

2.18.4 Digestibility values of rabbits fed concentrates in the tropics

Iyeghe-Erakpotobor *et al*. (2005) evaluated concentrate, grass and legume combinations on performance and nutrient digestibility of grower rabbits under tropical conditions. The results showed a high digestibility of dry matter, crude protein, crude fibre and ether extract indicating

that the rabbits were able to utilize nutrients in the high forage and low concentrate combinations used for growth.

It could be concluded from this study that any of the combinations of concentrate, grass and forage would be adequate for grower rabbits.The reported results of apparent digestibility, dry matter (DM), ether extract (EE), crude fibre (CF) and crude protein (CP) are presented in Table 25.0.

Table 25.0: Apparent digestibility of rabbits fed concentrate, grass and legume combinations.

Treatment	Dry Matter (%)	Ether extract (%)	Crude Fibre (%)	Crude protein (%)
RR	0.66 (66)^{bc}	0.69 (69)	0.51 (51)	0.70 (70)^{a}
RRG	0.66 (66)^{bc}	0.71 (71)	0.50 (50)	0.69 (69)^{ab}
RRP	0.59 (59)^{c}	0.68 (68)	0.43 (43)	0.59 (59)^{b}
RRS	0.67 (67)^{bc}	0.68 (68)	0.51 (51)	0.71 (71)^{a}
SRG	0.70 (70)^{ab}	0.71 (71)	0.53 (53)	0.69 (69)^{ab}
SRP	0.72 (72)^{a}	0.77 (77)	0.55 (55)	0.68 (68)^{ab}
SRS	0.71 (71)^{a}	0.80 (80)	0.51 (51)	0.74 (74)^{a}

Data

RRP = Rabbit meal and Rhodes grass; RRG = Rabbit meal, Rhodes grass and Groundnut haulms; RRP = Rabbit meal, Rhodes grass and sweet potato vines; RRS = Rabbit meal, Rhodes grass and soyabean forage; SRG = Soyabean cheese waste meal, Rhodes grass and Groundnut haulms; SRP = Soyabean cheese waste meal, Rhodes grass and sweet potato vines; SRS = Soyabean cheese waste meal, Rhodes grass and soyabean forage.

Source: Iyeghe-Erakpotobor *et al*. (2005)

Eustace *et al*. (2003) assessed the response of rabbits fed varying levels of dietary cyanide and reported the apparent digestibility of rabbits as shown in (Table 26.0). The results showed a low nutrient digestibility with a consequent reduction in growth rate and feed conversion as cyanide concentration increased beyond 250 mg. Based on the results of this study, diets formulated for rabbits should contain not more than 250 mg cyanide per kg in diet.

Table 26.0:Apparent nutrient digestibility of rabbits fed varying levels of dietary cyanide.

Parameter	Dietary cyanide levels			
	0 mg	250 mg	500 mg	750 mg
Dry matter	74.94	69.99	69.34	67.55
Crude protein	66.26	62.48	59.43	57.66
Crude fibre	48.53	35.80	33.65	33.37
Ether extract	90.66	88.03	88.46	83.07

Source: Eustace *et al*. (2003)

A study was carried out to determine the digestibility of weaner rabbits fed graded levels of soyabean cheese waste/maize offal diet and brachiaria grass hay by Iyeghe-Erakpotobor *et al*. (2006) and reported digestibility coefficients as shown in Table 27.0. Dry matter and ether extract digestibility values were similar for the control, and significantly higher than 100 and 50% SBW treatments. Crude protein digestibility was similar for the control and all the experimental groups. This could indicate a high efficiency in crude protein utilization. It is concluded from this study that soybean cheese waste/maize offal diet compared favourably with the standard rabbit meal fed to rabbits in nutrient digestibility.

Table 27.0: Nutrient digestibility coefficients of weaner rabbits fed graded levels of soyabean cheese waste/maize offal meal and brachiaria hay

Parameter	Control (100% RBM)	100% SBW	75% SBW	50% SBW	25%SBW
Dry matter	0.76^{a} (76)	0.63^{b} (63)	0.74^{a} (74)	0.63^{b} (63)	0.76^{a} (76)
Ether extract	0.75^{a} (75)	0.67^{b} (67)	0.75^{a} (75)	0.65^{b} (65)	0.77^{a} (77)
Crude protein	0.78 (78)	0.74 (74)	0.79 (79)	0.69 (69)	0.75 (75)
Crude fibre	0.58^{ab} (58)	0.45^{b} (45)	0.64^{a} (64)	0.52^{b} (52)	0.71^{a} (71)

Means with different superscripts along rows are significantly different ($p<0.05$).

RBM = Rabbit meal, and SBW = Soyabean cheese waste meal.

Source: Iyeghe-Erakpotobor *et al*. (2006)

Bamikole *et al*. (2005) investigated the potential of mulberry leaves in rabbit production where the nutrient digestibility of the rabbits was monitored.

The percentage of concentrate in the rations was incrementally replaced with mulberry leaves: 100:0, 75:25, 50:50, 25:75, 0:100. The results obtained for nutrient digestibility are shown in Table 28.0. The results indicated that the levels of DM, CP and CF were not significantly different among the diets, except for EE. The values of EE significantly declined as the percentage of concentrate offered decreased. It could be concluded that the high levels of nutrients intake and digestibility confirm the high nutritive value of mulberry leaves and their potential as forage that can support rabbit production.

Table 28.0 Dry matter and nutrient digestibility of diets containing different percentages of concentrate and mulberry leaves fed to rabbits.

	Diets (%) (concentrate: mulberry leaves)				
Parameter	100:0	75:25	50:50	25:75	0:100
Dry matter	82.33	75.67	75.67	77.00	79.67
Crude protein	84.00	77.67	76.33	80.33	83.67
Crude fibre	81.67	86.67	79.67	83.67	88.67
Ether extract	86.00[a]	68.67[b]	65.67[b]	74.33[b]	55.65[c]

Means in a row followed by the same letter are not significantly different at 0.05%.
Source: Bamikole *et al*. (2005).

Ayers *et al*. (1996) conducted a feeding trial using weaner rabbits to evaluate black locust and hybrid poplar (HP) leaves as animal feed under tropical conditions and reported nutrient digestibility values as indicated in Table 29.0. Nutrients digestibility values were lower in diets with hybrid poplar leaf meal than in the alfalfa (control). The reduced crude protein digestibility with increasing dietary hybrid poplar leaf meal is likely due to effects of antinutritional factors.

Table 29.0: Nutrient digestibility values of rabbits fed diets containing poplar leaf meal.

		Digestibility %	
Treatment	Crude protein	Acid Detergent Fibre	Dry matter
I (40% alfalfa)	78.75[a]	26.28[a]	64.35
II (10% hybrid polar)	68.71[b]	19.04[b]	59.02
III (20% hybrid poplar)	60.05[b]	8.40[b]	55.72
IV (40% hybrid poplar)	54.76[b]	10.15[b]	57.63

[a] different from[b] ($p<0.05$)

Source: Ayers *et al*. (1996)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site

The study was carried out at the Cattle Research Station, Boadi, of the Kwame Nkrumah University ofScience and Technology, Kumasi. The Station is located in the south-eastern part of Kumasi. The average monthly temperatures of the area vary between 26.1^0C and 28.9^0C. High temperatures occur during the months of November-April with average maximum temperatures occurring in February and March while the lowest are experienced in July. Rainfall in the area is bimodal with an annual mean of 1500 mm. The rainy season covers April-July and September-November. A short dry season separates the two periods in August. The maindry season lasts from November to February (Tuah *et al*., 1990).

3.2 Cultivation of moringa plants

An experimental plot of moringa plants was established at the Cattle Research Station of the Kwame Nkrumah University of Science and Technology, Kumasi, on the 14th of July, 2008, as a source of moringa leaf meal for the experiment. A plot size of 28 × 12.60 m equivalent to 0.035 ha, and a plant spacing of 1.30 m × 1.30 m giving a population of 5,917 plants per ha were adopted. Seedlings were raised in polybags and transplanted three weeks after germination onto the prepared plot. Poultry manure was applied before planting and top-dressed with the same manure type every four weeks interval, until leaves were harvested. Watering and weeding were done continuously during fodder establishment. At the height of 2 m, the apical buds of all plants were cut to facilitate branching.

All plants were first harvested at 90 days of growth. To avoid border effects,only the central plants were harvested to determine the total fresh weight of forage.

Dry matter (DM) weight was determined mathematically from the fresh matter weight. Both the fresh and dry matter weights were then extrapolated to hectare basis. Representative samples of the air-dried leaves were taken to the laboratory for chemical analysis to determine crude protein, crude fibre, ether extract, nitrogen free extractives, calcium, and phosphorus, using the standard procedures of the Association of Official Analytical Chemists (AOAC, 1990).

3.3 Sources of feed ingredients and experimental animals

Millet mash residue was obtained from local porridge makers in Kumasi while soyabean meal (SBM) was purchased from a commercial feed supplier in Kumasi. The weaned rabbits were obtained from the Cattle Research Station of the Kwame Nkrumah University of Science and Technology, Kumasi, and some individual rabbit keepers in and around Kumasi. Moringa leaf meal was obtained from the established moringa plot at the Research Station.

3.4 Processing of moringa leaves

The harvested moringa leaves were air dried in shade under a shed until they were crispy to touch, while retaining their greenish colouration. The leaves were then milled using a hammer mill of sieve size 3 mm, to obtain a product herein referred to as moringa leaf meal (MOLM) which was stored in sacs until needed.

3.5 Experimental animals and management

Thirty (30) weaner rabbits of mixed breeds and sexes were used for the experiment. The rabbits were between 6-7 weeks of age and weighed between 641.7 g and 643.3 g.

They were randomly divided into five groups of six animals per treatment, after balancing for body weight. Two animals constituted a replicate and each replicate was housed in a separate hutch raised from the ground.

The animals were provided with a feeder and a drinker in each hutch. Prior to the experiment, each animal was dewormed using Piperazine (Dorpharma B.V. Ltd., The Netherlands) and given acaricide bathe using Amirazzo (Arab Pesticides and Veterinary Drugs Manufacturing Company, Jordan). Coccidiosis was routinely controlled using Amprocox (Maridav Ltd., Ghana) or cocciplus (Polichem; S.L. Ltd., Spain).

3.6 Experimental diet

Five experimental diets were formulated. Diet 1, which was designated as T_O served as the control diet and contained soyabean meal as the main protein source with no moringa leaf meal. Diet 2 designated as T_1; Diet 3 as T_2; Diet 4 as T_3 and Diet 5 as T_4 contained moringa leaf meal at the rate of 5, 10, 15 and 20%, respectively.

3.7 Experimental design and duration of experiment

The five treatment groups were assigned the five experimental diets in a completely randomized design (CRD). Each treatment was replicated three times and there were two rabbits per replicate. Each rabbit was fed an assigned diet which started on 29 November, 2008 and lasted for twelve (12) weeks after one week of adjustment period.

3.8 Growth study

The experimental diets were offered *ad libitum* in separate wooden feeders in the morning (08.00h), so the rabbits determined their intake of the feed. The daily supply was about 5% the body weight of the rabbit concerned.

The diets were offered daily and the feed leftover and/or wastage were weighed daily before feeding. Water was also provided *ad libitum* in plastic containers. All animals were weighed at the start of the experiment before allocating them to the treatments. Parameters determined included average feed intake, average body weight gain, feed conversion ratio, feed cost, feed cost per kg gain, and mortality.

3.9 Blood sample collection and analysis

At the end of the feeding period, the animals were starved of feed for 24 hours before blood samples were collected from one rabbit per replicate for haematological and biochemical analysis. The blood samples were collected from each rabbit from the external ear vein using a sterilized disposable syringe and needle between 6.30 and 7.30 am.Prior to bleeding, a cotton swab soaked in 70% ethanol was used to dilate the vein and to prevent infection. An initial 1.0 ml blood was collected into labeled sterile universal bottles containing Ethylene- Diamine-Tetra-Acetic acid (EDTA) as anticoagulant. This was used to determine the haematological components within an hour of sample collection. Another 1.0 ml of blood was collected into labeled sterile sample bottles without anticoagulant and used to determine the biochemical components. The blood samples were centrifuged at 500 rpm (revolution per minute) for 3 minutes in a microcentrifuge to obtain serum that was free from cell debris for the biochemical analysis using a spectrophotometer (Available Commercial Kits produced by Sentinel, Italy) at a wavelength of 500 nm.

The serum obtained was analysed colorimetrically for total protein (TP) by the Biuret method with kits (PLASMATEC) supplied by Plasmatec Laboratory Products Ltd., U.K.

Colorimetric determination of TP is based on the principle of Biuret reaction (copper salts in alkaline medium) in which cupric ions form a blue complex, in alkaline solution, with $NH_2$of two or more peptide bonds. The intensityof the blue colour formed is proportional to the protein concentration in the plasma or serum. Albumin concentration was determined by the Bromocresol Green (BCG) method (Peters *et al*., 1982); albumins (Ab) bind with BCG to form a green compound. The concentration of Ab is directly proportional to the intensity of the green colour formed. Globulin (Gb) concentration was computed as the difference between total protein and albumin concentrations. Cholesterol was determined as described by Coles (1986).

The red blood cell (RBC) counts, total white blood cell (WBC) counts, haemoglobin (Hb) concentration and Packed cell volume (PCV) parameters were determined following standard procedures described by Davice and Lewis (1991).

3.10 Digestibility study

Digestibility study was carried out during the last week of the feeding trial. It involved feeding the rabbit with known quantity of feed which lasted for seven days. Total faeces voided was collected daily and oven dried to determine moisture content. Representative samples of dried faeces were taken for proximate analysis using AOAC (1990) methods.

The digestibility values for dry matter (DM), crude protein (CP), ether extract (EE), and crude fibre (CF) were calculated as nutrient intake minus nutrient excreted divided by nutrient intake multiplied by hundred.

3.11 Carcass yield evaluation

At the end of the experimental period, one rabbit per replicate (15 rabbits in all) was randomly selected, starved of feed for 24 hours and slaughtered by cutting the jugular vein to allow proper

bleeding. Determination of blood weight was by the difference between slaughter weight and hotcarcassweight. The slaughtered rabbits were defurred using flame and eviscerated to evaluate their carcasses.Dressing percentage was determined by dividing the hot carcass weight by the slaughter weight and multiplied by hundred.The meat composition of the carcasses was determined by removing the right thighs and peeling off the skins of each animal. The muscle of each rabbit was separated from the bone and ground separately for three times in an electric grinder (Hong Teng Co. Ltd, China). After thorough mixing, aliquots were obtained for moisture; protein and ether extract analysis using the procedures outlined by AOAC (1990).

3.12 Economics of production

The prevailing market prices of ingredients used during the period of the study were used for the economic appraisal of the feeds. Economics of production was based on the feed cost per kg diet and feed cost per kg weight gain. Feed cost per kg liveweight gain was calculated as a product of the feed cost per kg diet and feed conversion ratio for individual dietary treatments. Table 30.0 below shows the feed ingredients and their prices per kilogramme.

Table: 30.0 Feed Ingredients and their Prices per kilogramme.

Ingredients	Price per kilogramme (GH¢/kg)
Millet mash residue	0.13
Soya bean meal	0.78
Premix	1.60
Dicalcium phosphate	1.60
Salt	0.20
Moringa leaf meal	1.20

3.13 Statistical analysis

Analysis of variance (ANOVA) for Completely Randomized Design (CRD) was carried out using GenStat(Release 4.24)statistical package (Genstat, 2005).Differences between means were separated by the Duncan's Multiple Range Test (DMRT).

CHAPTER FOUR

4.0 RESULTS

4.1.0 Moringa cultivation

The leaf yield of the moringa trees at the first harvest is presented in Table 31.0.

Table 31.0 Moringa leaf production at 90 days of planting

Plant part	Weight in kg/ha
Fresh leaves	2500.61
Dry leaves (DM)	616.40

4.1.1 Chemical composition of moringa leaf meal

The results of the chemical composition analyses of the moringa leaf meal (MOLM) are presented in Table 32.0. The MOLM was found to be rich in crude protein (29.25%), ash (7.13%), phosphorus (0.33%) and calcium (8.64%).

Table 32.0:Chemical composition of Moringa leaf meal (MOLM) (%DM basis).

Fraction	Composition
Dry matter	24.65
Crude protein (CP)	29.25
Ether Extract (EE)	2.23
Crude Fibre (CF)	19.25
Ash	7.13
Nitrogen Free Extract (NFE)	41.98
Phosphorus	0.33
Calcium	8.64

4.2 Percentage inclusion levels and chemical contents of experimental diets

The percentage inclusion levels and chemical contents of the experimental diets fed the weaner rabbits are shown in Table 33.0.

Table 33.0: Percentage inclusion levels and chemical contents of experimental diets fed to weaner rabbits.

	Dietary Treatments				
Ingredient (%)	T_0 0%MOLM	T_1 5%MOLM	T_2 10%MOLM	T_3 15%MOLM	T_4 20%MOLM
Milletmash residue	78.00	78.00	78.00	78.00	78.00
Soyabean meal	20.00	15.00	10.00	5.00	-
Moringa leaf meal	-	5.00	10.00	15.00	20.00
Dicalcium Phosphate	1.00	1.00	1.00	1.00	1.00
Vitamin-mineral premix[1]	0.50	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00	100.00
Calculated composition %					
Crude protein (CP)	18.16	17.32	16.46	15.63	14.78
Crude fibre (CF)	8.45	9.11	9.77	10.43	11.09
Ether Extract (EE)	3.51	3.59	3.66	3.74	3.81
Lysine	0.78	7.26	13.70	20.22	26.70
Methionine	0.35	2.07	3.79	5.51	7.23
Digestible energy (kcal/kg)	2952.70	2883.42	2814.14	2744.86	2675.59
Analyzed composition %					
Dry matter (DM)	88.01	88.74	89.40	88.10	88.76
Crude protein (CP)	17.44	17.31	16.66	15.91	15.50
Crude fibre (CF)	7.75	9.01	9.11	10.12	10.84
Ether extract (EE)	1.97	1.20	1.41	1.49	1.52
Calcium (Ca)	1.20	1.04	1.20	1.28	1.36
Phosphorus (P)	0.31	0.25	0.34	0.37	0.38

[1]Vitamin-mineral premix = Inclusion rate: 2.5 g/kg to supply the following/kg diet: vitamin A-8000IU; vitamin D – 3000IU; vitamin E – 8IU; vitamin K- 2mg; vitamin B_1- 1mg; vitamin B_2– 2.5mg; vitamin B_{12}–15mcg; niacin – 10mg; panthothenic – 5mg; antioxidant –6mg; folic acid – 0.5mg; choline –150mg; iron -20mg; manganese – 80 mg; copper – 8mg; zinc – 50mg; cobalt – 0.225mg;iodine – 2mg; selenium –0.1mg.

The calculated and analyzed nutrient compositions of the five experimental diets fed to the rabbits during the period of the experiment are also shown in Table 33.0.

The percentage CP of the analyzed diets did not vary considerably from the calculated values. The crude protein in T_0 (0%MOLM) of the analyzed composition, however, reduced while that of diets T_1 (5% MOLM), T_2 (10%MOLM), T_3 (15%MOLM) and T_4 (20%MOLM) appreciated slightly. The CF and EE compositions in the analyzed diets showed a considerable reduction in value as compared to the calculated compositions. The lysine and methionine values in the calculated composition showed relative increase as the inclusion level of MOLM increased from T_0 to T_4. It was observed from the analyzed composition of the diets that, as the level of MOLM inclusion increased, the values of the CF also increased, unlike the CP which showed a decreasing trend.

4.3 Productive performance of rabbits fed moringa diets

The productive performance of the weaner rabbits fed the various diets is indicated in Table 34.0. The rabbits had similar body weights at the start of the experiment. The final body weight and the total weight gain increased with increasing levels of MOLM, but the treatment mean differences were not statistically significant ($P>0.05$). The daily weight gain also increased with increasing level of MOLM, and the control animals (T_0) performed poorer ($p<0.05$) than those fed the MOLM inclusive diets. The daily feed intake and the FCR values similarly improved with increasing level of MOLM, but the treatment differences were not statistically significant. The MOLM increased the unit cost of the concentrate feed used. No animal died in the course of the experiment.

Table 34.0:Productiveperformance of weaner rabbits fed moringa diets

PARAMETERS	DIETARY TREATMENTS						
	T_0 0% MOLM	T_1 5%MOLM	T_2 10%MOLM	T_3 15%MOLM	T_4 20%MOLM	SEM	SIG.
Initial weight (g)	641.67	641.67	641.67	643.33	641.67	38.81	NS
SD	(76.38)	(87.80)	(52.04)	(60.28)	(52.04)		
Final weight (g)	1625.31	1774.83	1791.63	1821.85	1902.51	86.12	NS
SD	(5.00)	(5.10)	(2.08)	(2.00)	(2.52)		
Total weight gain (g)	983.64	1133.16	1149.96	1178.52	1260.84	61.05	NS
SD	(0.61)	(30.20)	(31.04)	(41.00)	(50.10)		
Daily weight gain (g)	11.71^{b}	13.49^{a}	13.69^{a}	14.03^{a}	15.01^{a}	0.55	*
SD	(1.41)	(0.86)	(1.36)	(0.15)	(0.02)		
Daily weight gain per body weight (g/kg)	7.20^{b}	7.60^{a}	7.66^{a}	7.77^{a}	7.90^{a}	0.31	*
SD	(0.87)	(0.06)	(0.50)	(0.91)	(0.38)		
Daily(DM) feed intake (g)	60.10	61.13	61.20	62.15	63.40	1.36	NS
SD	(0.56)	(1.13)	(2.91)	(2.15)	(3.61)		
Daily (DM) feed intake per body weight (g/kg)	36.98	34.53	34.31	34.42	33.32	1.28	NS
SD	(0.34)	(1.88)	(2.27)	(3.92)	(0.48)		
F.C.R.(feed/gain)	5.13	4.53	4.47	4.43	4.22	0.16	NS
SD	(0.23)	(0.47)	(0.26)	(0.23)	(0.11)		
Feed Cost/kg (GH¢)	0.28	0.30	0.32	0.35	0.37	-	-
Feed Cost/kg gain (GH¢)	1.44	1.36	1.43	1.55	1.56	0.05	NS
SD	(0.06)	(0.14)	(0.09)	(0.08)	(0.04)		
Mortality	0.00	0.00	0.00	0.00	0.00	-	-

SEM = Standard Error of means; NS = Not significantly different ($p>0.05$); * = significantly different ($p<0.05$)

SIG = Significance level; ^{a,b} = Values in the same row with different superscripts differ significantly ($p<0.05$)

F.C.R. = Feed Conversion Ratio; SD = Standard deviation

4.4 Apparent nutrient digestibility of rabbits fed moringa diets

The apparent nutrient digestibility values are shown in Table 35.0.

Table 35.0: Apparent nutrient digestibility of rabbits fed moringa leaf meal diets

	Treatments						
Parameters	T_0 0%MOLM	T_1 5%MOLM	T_2 10%MOLM	T_3 15%MOLM	T_4 20%MOLM	SEM	SIG.
Dry matter (DM)	65.02^b	75.50^a	76.00^a	77.02^a	78.40^a	2.59	*
SD	(2.98)	(2.00)	(6.00)	(4.00)	(6.41)		
Crude protein (CP)	65.10^b	74.50^a	76.32^a	80.75^a	87.80^a	2.67	*
SD	(2.90)	(6.81)	(3.68)	(5.72)	(2.35)		
Crude Fibre (CF)	50.01	50.20	51.00	53.00	55.00	0.97	NS
SD	(1.00)	(2.00)	(1.00)	(2.74)	(0.80)		
Ether Extract (EE)	70.00	71.00	72.00	75.12	77.50	9.81	NS
SD	(17.09)	(3.00)	(18.00)	(10.06)	(7.00)		

SEM = Standard Error of Means; * = significantly different ($p<0.05$); NS = Not significantly different ($p>0.05$)
SIG. = Significance level; SD = Standard deviation

The apparent digestibility values for dry matter (DM), crude protein (CP), crude fibre (CF) and ether extract (EE) were generally higher for rabbits on dietary treatments 1, 2, 3 and 4 than for those on T_0. The general trend observed was that as the level of MOLM inclusion increased from T_0 to T_4, the values obtained for the various nutrients increased accordingly. No significant ($p>0.05$) differences were observed for the CF and EE values. The DM and CP digestibility values were, however, higher ($p<0.05$) for rabbits on dietary treatments 1, 2, 3, and 4 than for those on T_0.

4.5Carcass measurements and meat composition of rabbits fed moringa diets

The carcass measurements and meat composition are indicated in Table 36.0. The slaughter weight, hot carcass weight, dressed weight and dressing percentage increased numerically as the MOLM level was increased in the diet.

There was a significant positive correlation between slaughter weight and dressed weight (r=0.9306, *P<0.05*).Similarly, the slaughter weight correlated positively with dressing percentage (r=0.5365, *P<0.05*). The MOLM improved meat quality by increasing (*p<0.01*) protein content and reducing (*p<0.01*) fat level in the meat.

Table 36.0: Carcass measurements (g) and meat composition (%) of rabbits fed moringa diets

	Treatments						
Carcass characteristics	T_0 0%MOLM	T_1 5%MOLM	T_2 10%MOLM	T_3 15%MOLM	T_4 20%MOLM	SEM	SIG.
Slaughter weight	1290.33	1428.67	1430.00	1487.67	1530.33	163.72	NS
SD	(128.70)	(78.82)	(78.80)	(114.72)	(133.46)		
Hot carcass weight	1258.33	1383.33	1390.00	1431.00	1484.67	161.73	NS
SD	(75.34)	(82.92)	(71.36)	(67.62)	(98.08)		
Blood weight	32.00	45.34	40.00	56.67	45.66	6.54	NS
SD	(10.58)	(6.11)	(12.50)	(14.22)	(11.59)		
Dressed weight	801.67	862.67	885.67	927.00	1019.67	68.27	NS
SD	(114.41)	(112.82)	(41.20)	(132.64)	(157.47)		
Dressing percentage	62.13	60.38	61.93	62.31	66.63	1.26	NS
SD	(1.94)	(3.68)	(1.43)	(2.00)	(0.63)		
Full GIT Weight	212.00	275.67	249.67	251.67	250.00	31.01	NS
SD	(70.16)	(53.90)	(30.83)	(68.63)	(60.30)		
Empty GIT Weight	127.00	128.33	126.00	113.67	132.00	26.80	NS
SD	(76.27)	(31.53)	(30.01)	(38.66)	(19.35)		
Liver Weight	44.00	42.33	42.13	37.33	32.33	3.22	NS
SD	(4.00)	(2.30)	(2.21)	(4.45)	(7.47)		
Kidney Weight	9.33	9.20	8.47	7.41	7.20	0.98	NS
SD	(1.15)	(1.09)	(1.25)	(0.58)	(0.59)		
Lung Weight	13.00	9.00	10.33	13.10	12.67	1.52	NS
SD	(1.73)	(1.00)	(1.15)	(3.46)	(4.16)		
Heart Weight	4.00	3.00	4.33	3.33	4.20	0.89	NS
SD	(2.00)	(1.00)	(1.15)	(1.15)	(2.08)		
Caecum + content weight	65.67	75.00	80.00	77.00	76.90	7.46	NS
SD	(12.66)	(5.57)	(13.80)	(14.00)	(14.10)		
Empty Caecum weight	17.33	19.67	20.33	24.67	21.00	1.83	NS
SD	(2.52)	(1.53)	(4.73)	(2.52)	(3.61)		
Meat composition (%)							
Moisture	73.80	74.04	74.20	75.30	77.10	0.07	NS
SD	(5.00)	(4.11)	(4.12)	(7.10)	(8.10)		
Crude protein	20.02^b	20.60^a	20.70^a	21.00^a	21.30^a	0.16	**
SD	(0.03)	(0.35)	(0.50)	(0.10)	(0.10)		
Ether Extract	10.30^a	9.45^a	9.30^a	8.96^a	8.56^b	0.13	**
SD	(0.37)	(0.20)	(0.09)	(0.13)	(0.03)		

SEM = Standard Error of Means; ** = significantly different (*p<0.01*); NS = Not significantly different (*p>0.05*)
SIG. = Significance level; SD = Standard deviation

4.6 Blood components of rabbits fed moringa diets

The blood haematological and biochemical components of the rabbits are shown in Table 37.0. The MOLM did not vary the blood characteristics studied. However, the MOLM tended to reduce the cholesterol level in the blood.

Table 37.0: Haematological and biochemical components of weaner rabbits fed moringa diets

	Treatments						
	T_0 0%MOLM	T_1 5%MOLM	T_2 10%MOLM	T_3 15%MOLM	T_4 20%MOLM	SEM	SIG.
Haematological components							
Haemoglobin (g/dl)	14.50	14.45	14.26	14.90	15.95	0.35	NS
SD	(0.45)	(0.97)	(0.77)	(0.39)	(0.06)		
Packed cell volume (%)	45.40	43.30	46.17	44.40	46.77	1.69	NS
SD	(3.33)	(2.72)	(4.36)	(0.44)	(2.32)		
Red Blood cell ($\times10^6$/µl)	7.35	7.90	7.40	7.66	7.73	0.28	NS
SD	(0.84)	(0.85)	(0.90)	(0.75)	(0.76)		
White blood cell ($\times10^3$/dl)	8.30	8.90	8.20	8.60	8.53	0.28	NS
SD	(0.84)	(0.56)	(0.35)	(0.30)	(0.59)		
Neutrophils (%)	43.00	41.20	39.50	34.50	35.20	5.22	NS
SD	(16.10)	(1.59)	(1.32)	(9.86)	(5.30)		
Lymphocytes (%)	56.00	57.50	46.50	43.00	41.00	7.17	NS
SD	(4.36)	(26.43)	(6.84)	(2.65)	(1.00)		
Eosinophils (%)	1.04	1.01	1.02	1.03	1.00	0.10	NS
SD	(0.03)	(0.03)	(0.01)	(0.20)	(0.02)		
Biochemical components							
Cholesterol (mg/dl)	40.70	38.80	36.90	35.50	35.02	2.21	NS
SD	(1.39)	(6.64)	(0.95)	(1.04)	(5.01)		
Total protein (g/dl)	5.80	6.00	6.90	5.90	5.10	0.38	NS
SD	(7.59)	(6.55)	(1.73)	(4.36)	(4.62)		
Albumin (g/dl)	3.40	3.70	4.10	3.80	3.20	0.35	NS
SD	(8.30)	(1.00)	(1.73)	(3.12)	(9.85)		
Globulin (g/dl)	2.40	2.30	2.80	2.10	1.90	0.96	NS
SD	(3.22)	(6.25)	(3.46)	(5.30)	(7.21)		

SEM = Standard Error of Means; NS = Not significantly different ($p>0.05$); SIG. = Significance level
SD = Standard deviation

CHAPTER FIVE

5.0 DISCUSSION

The leaf yield obtained for the cultivatedmoringa plants after the first cut using a planting distance of 1.30m × 1.30 m on the plot size of 28 m × 12.60 m were extrapolated to2,500.61 and 616.40 kg /ha on fresh and dry matter bases, respectively (Table 31.0). These values were, however, lower than 97400 kg/haon fresh matter and 16560 kg/ha dry matter basis reported by Makker and Becker (1997) after their first cut of moringa plants. The differences may partly be attributed to the higher planting densities used by the earlier researchers. Other factors such as edaphic, climatic and varietal differences may also have contributed tothe observed differences.

The crude protein (CP) content of the MOLM used was 29.25% (Table 32.0). This was higher than the CP values of 27.1% and 27.51% MOLM reported by Booth and Wickens (1988) and Oduro *et al*. (2008), respectively. The values obtained for the crude fibre (CF), ether extract (EE), calcium (Ca) and Phosphorus (P) for the MOLM in the present study were, however, similar to those reported by Oduro *et al*. (2008), but the CF value of 19.25% was slightly higher than the 19.20% reported by Booth and Wickens (1988). The variations in the nutrients could be attributed to the age of cuttingor harvesting, climatic conditions, edaphic factors, agronomic practices as well as methods of processing and analysis (Fuglie, 1999). The CP of MOLM as observed was lower than that of soyabean meal (44%) or fish meal (60%) used conventionally as sources of protein in rabbit rations.

From Table 33.0 differences were observed between calculated and analyzed crude protein, ether extract and crude fibre contents of the experimental diets. While analyzed CP values were slightly higher for T_1 (5%MOLM), T_2 (10%MOLM), T_3 (15%MOLM) and T_4 (20%MOLM) the reverse was true for that of treatment T_0(0%MOLM). The CF and EE values for the analyzed composition for all the treatments were, however, below those of the calculated ones. The differences might be due to the variations between tabulated nutrient content values used in the calculation and actual nutrient content of the ingredients used in formulating the diets. Perhaps, if all the ingredients had been analyzed before the formulation and compounding of the diets, this situation might not have arisen. The nutrients met the minimum nutrient requirements for rabbits (Maertens, 1992). The differences observed with the calculated lysine and methionine levels as the level of MOLM inclusion increased was to be expectedsince MOLM is reported to have higher levels of these amino acids (Booth and Wickens, 1988) than soyabean meal (NRC, 1994).

High weight gain of animals normally results from increased feed intake. This situation was observed in the present experiment. Weight gain increased with the level ofMOLM inclusion in the diet. The average daily weight gain was significantly ($p<0.05$) higher for the rabbits on the MOLM diets(T_1 toT_4)than for those on the control diet (T_0).This result agrees with the finding of Bamikole *et al*. (2005) when they reported an increase in daily weight gain after feeding rabbits with mulberry leaves based diets, but conflicts with that of Famounyan and Meffega (1986) who reported low body weight gain in rabbits fed sun-dried cassava leaves diets in the tropics. In the present study, feed intake did not vary between treatment groups.

The poorer average daily gains in the control animals (T_0), therefore, suggests that the control (T_0) diet may be poorer in quality than the MOLM diets ($T_1$to T_4).

Normally an increase in CP in diets should result in higher daily weight gain. However, protein increases should be matched with increased amino acids like methionine and lysine that are normally deficient in rabbit diets for growth to increase, otherwise growth may be depressed. The CP values (Table33.0) for the experimental diets reduced slightly as the inclusion level of MOLM increased.The higher weight gains in the rabbits fed the MOLM diets may, therefore, be partly due to a better protein quality, possibly arising from a higher methionine and lysine supply (Booth and Wickens, 1988).

According to McDonald *et al*. (1988) the protein in soyabean meal contains all the essential amino acids but the concentration of methionine and cysteine are sub-optimal, and that methionine is the first limiting amino acid and may be particularly important in high energy diets. Gillespie (1998) also reported that methionine and lysine are usually the amino acids that are found to be deficient in rabbit rations.

Vitamin A is important in rabbit growth. MOLM is reported to have a high vitamin A (Booth and Wickens, 1988; Grubben and Denton, 2004; Fuglie, 2005). The control diet T_0 (0%MOLM) might have provided insufficient vitamin A for the rabbits, hence resulting in poor growth, since vitamin A aids in promoting growth in rabbits. Pond *et al*. (1995) stated that vitamin A deficiency in the diets of rabbits makes the rabbits to exhibit poor growth.

The superior feed conversion ratios for the MOLMdiets might have also contributed to the superior growth rate and weight gain by the rabbits on the MOLMdiets as compared to the control. The average daily weight gain (ADG) values recorded in this study were higher than those reported by Farinu *et al*. (2008).However, the present ADG values of 11.7 - 15.0 g/dwere lower than the 15.16 – 39.70 g/d reported by Okorie (2003),Omole and Onwudike (1982), Eshiet *et al*. (1979); Ayers *et al*. (1996) and Omole and Sonaiya (1981).

The generally low growth rates observed in this study could be explained by the fact that the rabbits did not consume a lot of the feeds to ensure higher growth. It might also be possible that subclinical infections may have adversely affected their growth rate. Another possible reason may be linked to poor genetic constitution of the rabbits used.

The average daily feed intake (ADFI) did not show any significant ($p>0.05$) difference between the dietary treatments, however,the rabbits showed systematic increase in daily feed intake from treatment T_0 to T_4.This trend in feed intake by the rabbits is understandable, since leaf meals contain relatively high fibre which tends to increase the total fibre content of the diet and dilute other nutrients. Rabbits must eat to meet their energy requirement to sustain rapid growth and development, hence the increased feed intake. This assertion generally agrees with the findings by other researchers (Spreadbury and Davidson, 1978; Aduku *et al*., 1988) who reported higher feed intake with increasing level of crude fibre (CF) in the diets of rabbits. The results, however, contrast the findings by Nworgu *et al*. (1999) who reported a reduction in feed intake by rabbits on increased forage meal in the diet. Another associated factor for the increased feed intake might also be due to greater palatability of the MOLM diets as compared to the control diet. The depressed feed intake of rabbits on the control diet may also be related to variation in the amino

acid profiles of the feeds. Forbes (1995) reported that if the amino acid content in the feed differed widely from the animal's requirement for amino acids, feed intake would be depressed and that if the deficient amino acid was supplemented, intake would be increased.The present study produced daily feed intake values of 60.1- 63.4 g (Table34.0), which were generally lower than concentrate feed intake of 61.08 – 133.9 g earlier reported for rabbits(Ayers *et al*., 1996; Omole and Sonaiya *et al*., 1981; Okorie, 2003). The values reported in this study however, were generally higher than the 24.02 – 60.54 g reported by Eshiet *et al*. (1979) in the tropics.

The feed conversion ratio valuesof 5.13, 4.53, 4.47, 4.43 and 4.22 (Table34.0) obtained in this study were higher than the 2.63- 4.00reported by earlier researchers in the tropics (Ayers *et al*., 1996; Okorie, 2003); but were generallylower than that of 5.32 – 5.63 reported by Eustace *et al*. (2003). The generally poor FCRs obtained were probably due to the relatively low growth rates. Genetic differences might have also contributed to the lower FCRs recorded.

The feed cost increased as the level of MOLM inclusion increased from T_0 (0%MOLM) to T_4 (20%MOLM). This was to be expected, since the higher MOLM diets contained more of the expensive MOLM and lesser amounts of the cheaper soyabean meal (SBM). At the time of the experiment, the prevailing market prices for SBM and MOLM were GH ¢ 0.78 and GH ¢ 1.20 per kg, respectively (Table30.0).The high price of MOLM was due to the high demand for the product because of the promotion of MOLM as food supplement for humans at the time of the experiment.The difference in feed cost per kg live weight was not significant ($p>0.05$), although the values obtained for 0% MOLM, 15% MOLM and 20% MOLM were comparatively higher than those for 5% and 10% MOLM diets. This might be due to the low FCR and high feed

cost/kg values. Based on the present results, it could be concluded that the rabbits fed the various dietary treatments produced similar economic efficiency in feed cost per kg weight gain.

The apparent digestibility values recorded for rabbits on the various dietary treatments are shown in Table 35.0. The lower apparent digestibility values recorded for rabbits on diet T_0 (0%MOLM) was somehow unexpected due to its relatively lower crude fibre content as compared to those of T_1 (5%MOLM), T_2 (10%MOLM), T_3 (15%MOLM) and T_4 (20%MOLM). This may suggest that the CF contents in all the dietary treatments were similar and therefore, did not affect the digestion of the various nutrients investigated. The probable reason might be due to the fact that MOLM was more digestible than the SBM used for the formulation of the treatment diets. Fahey *et al.* (2001) reported that moringa is an outstanding indigenous source of highly digestible protein. The fact that digestibility values increased as the level of MOLM increased may attest to this assumption. The present digestibility values of 65.02-78.40% forDM, 65.10-87.80% forCP, 50.01-55.00% for CF and 70.00-75.50% forEE (Table 35.0) are generally higher thanthe 55.72-64.35% for DM, 26.28-62.48% for CP, 8.40-48.53% for CF and 65.0-69.00% for EE reported earlier (Eustace *et al*., 2003; Iyeghe-Erakpotobor *et al*., 2006; Ayers *et al*., 1996; Iyeghe-Erakpotobor, 2005) in the tropics.This observation may be as a result of the highly digestible nature of moringa.

The various dietary treatments imposed on the rabbits produced no significant ($p>0.05$) impact on the full GIT, empty GIT, lung, heart and empty caecum weights (Table36.0). Although slaughter weight, hot carcass weight, dressed weight, and dressing percentage did not show any significant ($p>0.05$) difference in their average values, it was observed that the values tended to

increase with increasing levels of MOLM in the diets.This observation may be a reflection of the relatively higher feed intake by rabbits on the MOLM diets resulting in higher daily weight gain. The positive correlation observed between slaughter weight and dressed weight,and between slaughter weight and dressing percentage were significant ($p<0.05$), suggesting that as slaughter weight increased, dressed weight and dressing percentage also increased with increasing inclusion levels ofMOLM in the diets.This is in line with the observation that the diets containing the MOLM resulted in better feed: gain ratios and hence the heavier weights of the rabbits fed those diets.The slaughter weight values of 1428.67 g-1530.33 g obtained in this study were generally higher than the 1305.00 g - 1425.00 g reported by Eustace *et al*. (2003). However, the values were lower thanthe 1595.83 g - 2290.00 g reported by Biya *et al*.(2008). The dressing percentage values from the present study were greater than those reported by Biya *et al*. (2008), butlower than those reported by Okorie (2003). The dressed weight values of 801.67 g -1019.67 g obtained in this study were generallylowerprobably because of the lower feed intake by the rabbits when compared with 988.24 g – 1335.00 g reported byother researchers in the tropics (Biya *et al*.,2008; Eustace *et al*., 2003).

The liver and kidney weights differences did not show any significance ($p>0.05$), however, it was observed that as the inclusion level of MOLM increased, the corresponding mean values decreased marginally. This situation may be blamed on the presence of some antinutritional factors possibly present in the soyabean meal (SBM) used in the formulation of the diets forT_0 (0%MOLM), T_1 (5%MOLM), T_2 (10% MOLM) andT_3 (15%MOLM), since rabbits on these diets had higher liver and kidney weights than treatment four (4) without SBM. According to

Bone (1979) increased metabolic rate of the organs in an attempt to reduce toxic or antinutritional factors in livestock feeds to non-toxic metabolites may cause abnormalities (increase) in their weights. Ahamefule *et al*. (2006) reported that the weights of some internal organs like kidney and liver of animals may be used in animal feeding experiments as evidence of toxicity. The quality of protein in SBM is dependent on the cultivar and processing method.Under-processing may lead to deleterious level of antinutritional factors, which may impact negatively on the growth and performance in young animals (Parkhurst and Mountney, 1988). The SBM used for the study might have been under-processed thereby retaining some antinutritional factors which could have accounted for the higher weights of the kidney and liver in an attempt to detoxify them in the rabbits that received the T_0, T_1, T_2 and T_3 diets.

The values obtained in this study for the liver and kidney weights were generally lower, but the heart (3.00 - 4.33 g) and lung (9.00 – 13.10 g) weights were higher indicating a higher physiological activity of these organs than in thecase of the 2.95 – 3.90 gheart weight and 6.80 – 9.40 g lung weight reported in the tropics by Eustace *et al*. (2003), when they fed weaner rabbits varying levels of dietary cyanide.The weights of the liver (32.33 g – 44.00 g) and kidney(7.20 g – 9.33 g)were higher than the liver (30.36 g – 42.84 g) and kidney (5.18 g – 6.36 g)weights reported by Amata and Bratte (2008) who studied the effect of partial replacement of SBM with gliricidia leaf meal (GLM) on the performance and organ weights of weaner rabbits in the tropics.

The chemical analysis of the meat of the rabbits (Table: 36.0) indicated that the various dietary treatments did not significantly ($p>0.05$) influence the moisture content. However, there was an increase in moisture content in the MOLMdiets T_1 (5%MOLM), T_2 (10%MOLM), T_3

(15%MOLM) and T_4 (20%MOLM) over the control diet T_0 (0%MOLM). The crude protein content of the meat showed higher (*p<0.01*) values for rabbits fed diets containing MOLM over those fed the control diet (T_0). The ether extract content of the meat showed higher (*p<0.01*) values for rabbits fed diets T_0 (0%MOLM), T_1 (5%MOLM), T_2 (10%MOLM) and T_3 (15%MOLM) which had varying amounts of soyabean meal over the T_4 (20%MOLM) diet which did not have any SBM (Table36.0). The differences observed in the chemical composition of the meat could possibly be attributed to the fact that the protein or amino acid profile of the SBM was deficient in certain amino acids as compared to that of MOLM. Protein or amino acid content of a diet is directly related to the moisture level of the carcass, which is inversely related to the ether extract (fat) level (Noblet and Henry, 1977). Therefore, when a diet is deficient in certain amino acids or a low protein diet is fed to animals, carcass moisture level declines resulting in a concomitant increase in carcass fat or lipid levels.

Previous research reports have shown that a reduction of the level of protein and essential amino acids in the diet, from an optimum level for growth, is associated with a decreased growth rate and efficiency of feed utilization and a concomitant increase in body fat (Wahlstrom and Libal, 1974; Noblet and Henry, 1977; Russell *et al*., 1983). Wang *et al*. (1991) and Marks (1990) also reported that dietary protein level is one of the several non-genetic factors that influence the amount of body fat. The results of the analyzed rabbit meat composition values in this study, 20.02 – 21.30% CP and 8.56 – 10.30% EE(Table36.0) compare favourably with the 20.00 - 22.00%CP and 10.00 – 12.00%EE reported by Fielding (1991) but contrast values of 21.55% CP and 2.73% EE reported by Mohammed (1989) in the tropics.

All the haematological parameters measured in the present experiment were within the normal physiological rangesreported for rabbits;haemoglobin (8.0 – 17.5g/dl), packed cell volume (30.0 – 50.0%), red blood cell (4.0 – 8.0×10^6/µl), white blood cell (5.0 – 12.0 × 10^3/dl), neutrophils (35.0 – 55.0%), lymphocytes (25.0 – 50.0%) and eosinophils (0.0 – 5.0%) (Jenkins, 1993; Hillyer,1994).Madubuike and Ekenyem (2006) indicated that there is evidence in literature that haematological characteristics of livestock suggest their physiological disposition to the plane of nutrition.It may then be suggested that, the different diets imposed on the rabbits were balanced in their formulation to support relatively high performance and maintain the normal haematological profile of the rabbits. The values of haemoglobin (14.26 – 15.95g/dl), packed cell volume (43.30 – 46.77%), red blood cell (7.35 – 7.90 × 10^6/µl)and white blood cell (8.20 – 8.90 × 10^3/dl)reported in this study (Table37.0) were generally higher when compared to haemoglobin (5.53 – 10.20g/dl), packed cell volume (19.60 – 46.50%), red blood cell (5.30 – 6.23 × 10^6/µl) and white blood cell (5.00 – 7.30 ×10^3/dl) values reported by other researchers in the tropics (Ahamefule *et al*., 2006; Yakubu *et al*., 2008; Ahamefule *et al*., 2008).

There were no significant (*p>0.05*) differences in the averages for the various biochemical components studied, and this suggeststhat the diets did not influence the biochemical components studied. However, there was a trend towards a reduction in the cholesterol level as the inclusion level of MOLM in the diets was increased from T_0(0%MOLM) to T_4 (20%MOLM). This observation agreeswith the results of a research by Ghasi *et al*. (1999) where they reported that juice extracted from moringa leaves was found to be a potent hypocholesterolemic agent. In their research using Wister rat, they concluded that even when moringa juice extract was given at the relatively low dose of 1mg/g, co-administered with a high

fat diet daily over a period of 30 days, cholesterol was reduced in serum. This reduction in serum cholesterol level of rabbits fed theMOLMdiets may suggest a general decline in lipid mobilization. It could be that MOLM has some indirect inhibitory effects exerted at the levels of HMG-COA reductase, a key enzyme in cholesterol biosynthesis. It may be suggested then that, moringa leaf meal diets were capable of reducing serum cholesterol, hence assisting in the reduction and deposition of cholesterol in the muscles.

This fall in serum cholesterol level of rabbits on MOLM diets suggest that MOLM could be used to produce animal products with reduced cholesterol content.The reduction in the cholesterol level of rabbits fed MOLM diets is in agreement with earlier findings (Upadhyay, 1990; Oforjindu, 2006) which indicated that neem leaf meal in the diets of broiler birds and rats resulted in a decrease in the cholesterol and liver lipid levels. Although the values for total protein, albumin and globulin did not show any trend, the values obtained and that of cholesterol were found to be within the normal physiological range for rabbits; total protein (5.4 – 7.5 g/dl), albumin (2.5 – 4.5 g/dl), globulin (1.9 – 3.5 g/dl) and cholesterol (35.0 – 60.0 mg/dl) (Jenkins, 1993; Hillyer, 1994). The biochemical values of total protein (5.10 – 6.90 g/dl), globulin (1.90 – 2.80 g/dl) and albumin (3.20 – 4.10 g/dl) reported in this study (Table37.0) were generally higher while cholesterol level (35.02 – 40.70 mg/dl) were lower than cholesterol (56.50 – 174.60 mg/dl) reported (Ogbuewu *et al*., 2008; Ahamefule *et al*., 2008) in other tropical areas. The generally higher biochemical values in this study could be due to the high nutritional value of the moringa.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATION

6.1 Conclusions

The present experiment has shown that:

- Moringa plants are fast-growing and produce high biomass within a short time period when cultivated. A yield of 616.40 kg/ha dry matter (DM) could be obtained at first cut using a planting distance of 1.30 m × 1.30 m.
- Moringa leaf meal (MOLM) could be used to improve daily weight gain, and dry matter (DM) and crude protein (CP) digestibility of rabbits.
- Moringa leaf meal (MOLM) diets produced similar economic benefits as soya bean meal (SBM) diet.
- Moringa leaf meal (MOLM) is non-toxic to rabbits at least at the 20% diet inclusionlevel.
- Moringa leaf meal (MOLM) has the potential to reduce cholesterol level in blood and the meat of rabbits.
- Moringa leaf meal (MOLM) has the potential to produce leaner carcass due to reduced fat deposition in the muscles of rabbits.
- Moringa leaf meal (MOLM)could be used to replace soyabean meal (SBM) partially or completely in rabbit diets as a non-conventional protein source, not withstanding the present high costof themoringa leaf meal.

6.2 Recommendation

Research to support improved production techniques of the moringa plant is, however, needed to enable farmers produce the meal at lower cost for economic use in animal feeding.

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APPENDICES

APPENDIX 1.0: ANOVA FOR WEIGHT GAIN

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	17.293	4.323	4.70	3.48
Error	10	9.191	0.919		
Total	14	26.484			

APPENDIX 2.0: ANOVA FOR CHOLESTEROL

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	67.119	16.780	1.15	3.48
Error	10	146.141	14.614		
Total	14	213.260			

APPENDDIX 3.0: ANOVA FOR FEED INTAKE

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	18.520	4.630	0.84	3.48
Error	10	55.359	5.536		
Total	14	73.879			

APPENDIX 4.0: ANOVA FOR F.C.R.

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	1.399	0.350	4.32	3.48
Error	10	0.808	0.081		
Total	14	2.207			

APPENDIX 5.0: ANOVA FOR SLAUGHTER WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	98,528.93	24,632.23	0.31	3.48
Error	10	804,110.67	80411.07		
Total	14	902,639.60			

APPENDIX 6.0: ANOVA FOR HOT CARASS WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	84,065.73	21016.43	0.27	3.48
Error	10	784,674.00	78467.40		
Total	14	868,739.73			

APPENDIX 7.0: ANOVA FOR BLOOD WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	1,028.26	257.07	2.00	3.48
Error	10	1,284.67	128.47		
Total	14	2,312.93			

APPENDIX 8.0: ANOVA FOR DRESSED WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	78,946.67	19,736.67	1.41	3.48
Error	10	139,810.66	13,981.07		
Total	14	218,757.33			

APPENDIX 9.0: ANOVA FOR FULL GIT WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	14,138.26	3,534.57	1.23	3.48
Error	10	28,842.67	2,884.27		
Total	14	42,980.93			

APPENDIX 10.0: ANOVA FOR EMPTY GIT WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	1,349.06	337.27	0.16	3.48
Error	10	21,548.67	2,154.87		
Total	14	22,897.73			

APPENDIX 11.0: ANOVA FOR LIVER WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	282.26	70.57	2.27	3.48
Error	10	310.67	31.07		
Total	14	592.93			

APPENDIX 12.0: ANOVA FOR AVERAGE TOTAL WEIGHT GAIN

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	122019.128	30504.782	2.72	3.48
Error	10	111817.204	11181.720		
Total	14	233836.332			

APPENDIX 13.0: ANOVA FOR AVERAGE FINAL WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	122397.204	30599.301	1.38	3.48
Error	10	222475.884	22247.588		
Total	14	344873.088			

APPENDIX 14.0: ANOVA FOR INITIAL ANIMAL WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	6.670	1.6675	0.0003	3.48
Error	10	45183.330	4518.333		
Total	14	45190.000			

APPENDIX 15.0: ANOVA FOR LYMPHOCYTES

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	681.90	170.480	1.10	3.48
Error	10	1544.44	154.440		
Total	14	2226.34			

APPENDIX 16.0: ANOVA FOR HAEMOGLOBIN

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	1.420	0.360	0.34	3.48
Error	10	10.610	1.060		
Total	14	12.030			

APPENDIX 17.0: ANOVA FOR WHITE BLOOD CELLS

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	2.230	0.560	0.58	3.48
Error	10	9.740	0.970		
Total	14	11.970			

APPENDIX 18.0: ANOVA FOR NEUTROPHILS

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	165.80	41.45	0.51	3.48
Error	10	817.28	81.73		
Total	14	983.08			

APPENDIX 19.0: ANOVA FOR ALBUMIN

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	14.960	3.740	1.11	3.48
Error	10	36.733	3.673		
Total	14	51.693			

APPENDIX 20.0; ANOVA FOR EOSINOPHILS

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	0.0009	0.00025	0.89	3.48
Error	10	0.0028	0.00028		
Total	14	0.0037			

APPENDIX 21.0: ANOVA PACKED CELL VOLUME (PCV)

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	10.320	2.58	0.30	3.48
Error	10	86.050	8.61		
Total	14	96.37			

APPENDIX 22.0: ANOVA FOR RED BLOOD CELL

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	0.740	0.185	0.81	3.48
Error	10	2.270	0.227		
Total	14	3.010			

APPENDIX 23.0: ANOVA FOR TOTAL BLOOD PROTEIN

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	47.640	11.910	2.70	3.48
Error	10	44.133	4.413		
Total	14	91.773			

APPENDIX 24.0; ANOVA FOR GLOBULIN

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	13.907	3.477	1.25	3.48
Error	10	27.733	2.773		
Total	14	41.640			

APPENDIX 25.0: ANOVA FOR MEAT MOISTURE

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	0.0178	0.0045	0.24	3.48
Error	10	0.1834	0.0183		
Total	14	0.2012			

APPENDIX 26.0: ANOVA FOR MEAT PROTEIN

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	2.7612	0.6903	8.83	5.99
Error	10	0.7814	0.0781		
Total	14	3.5426			

APPENDIX 27.0: ANOVA FOR ETHER EXTRACT OF MEAT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	1.1336	0.2834	6.79	5.99
Error	10	0.4174	0.0417		
Total	14	1.551			

APPENDIX 28.0: ANOVA FOR KIDNEY WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	16.93	4.23	1.47	3.48
Error	10	28.67	2.87		
Total	14	45.60			

APPENDIX 29.0: ANOVA FOR LUNG WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	40.27	10.07	1.45	3.48
Error	10	69.33	6.93		
Total	14	109.60			

APPENDIX 30.0: ANOVA FOR EMPTY CAECUM WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	84.93	21.23	2.11	3.48
Error	10	100.67	10.07		
Total	14	185.60			

APPENDIX 31.0: ANOVA FOR CAECUM AND CONTENT WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	369.60	92.40	0.55	3.48
Error	10	1,669.33	166.93		
Total	14	2,038.93			

APPENDIX 32.0: ANOVA FOR HEART WEIGHT

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	5.73	1.43	0.60	3.48
Error	10	24.00	2.40		
Total	14	29.73			

APPENDIX 33.0: ANOVA FOR CRUDE PROTEIN (DIGESTIBILITY)

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	933.978	233.495	4.55	3.48
Error	10	513.327	51.333		
Total	14	1,447.30			

APPENDIX 34.0: ANOVA FOR DRY MATTER (DM) DIGESTIBILITY

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	408.942	102.235	5.09	3.48
Error	10	200.881	20.088		
Total	14	609.823			

APPENDIX 35.0: ANOVA FOR CRUDE FIBRE (CF) DIGESTIBILITY

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	249.600	62.40	3.28	3.48
Error	10	190.343	19.03		
Total	14	439.943			

APPENDIX 36.0: ANOVA FOR ETHER EXTRACT DIGESTBILITY

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	163.09	40.7725	0.14	3.48
Error	10	2889.52	288.952		
Total	14	3052.61			

APPENDIX 37.0: ANOVA FOR FEED INTAKE PER BODY WEIGHT (g/kg)

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	22.09	5.523	1.13	3.48
Error	10	48.815	4.882		
Total	14	70.90			

APPENDIX 38.0: ANOVA FOR FEED COST/KG GAIN

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	0.090	0.0225	2.86	3.48
Error	10	0.0786	0.00786		
Total	14	0.1686			

APPENDIX 39.0: ANOVA FOR DAILY BODY WEIGHT GAIN (g)

Source	DF	Sum of Squares	Mean Square	F-value	P
Model	4	4.84	1.21	4.09	3.48
Error	10	2.96	0.296		
Total	14	7.80			