

**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS
TRAINING AND ENTREPRENEURIAL DEVELOPMENT
ASANTE MAMPONG**

**EFFECTS OF DIETARY UREA-TREATED MAIZE HUSK
AND PELLETING ON GROWTH PERFORMANCE,
REPRODUCTION, BLOOD PROFILE, AND CARCASS
CHARACTERISTICS OF FEMALE RABBITS**

(Oryctolagus cuniculus)

**COLLINS OWUSU
(MASTER OF PHILOSOPHY)**

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BY

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**A thesis submitted to the School of Graduate Studies, Akenten Appiah-Menka
University of Skills Training and Entrepreneurial Development in partial fulfilment
of the requirements for the award of a Master of Philosophy degree in Animal
Science**

DECEMBER, 2024

DECLARATION

Student's Declaration

I hereby declare that this thesis, with the exception of quotations and references contained in published works which have been duly acknowledged; is the result of my own original work and that no part of it has been presented for another degree at this university or elsewhere.

CANDIDATE'S NAME: COLLINS OWUSU

DATE

SIGNATURE

Supervisor's Declaration

I hereby declare that the preparation and presentation of this work were supervised in accordance with guidelines for the supervision of theses as laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

SUPERVISOR'S NAME: DR. F. R. K. BONSU

DATE

SIGNATURE

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DEDICATION

This project work is dedicated to God, the Almighty, my ever-loving and hardworking mother; Elizabeth Ama Mansa, my dearest wife; Mrs. Dorcas Owusu Appiah, my dear children; Lawrencina Owusu Anokyewaa, Morris Owusu Berko, Bevelyn Owusu Mansa, Ashbel Owusu Boakyewaa, and Darius Owusu Osei.

LIST OF ABBREVIATIONS

DM	Dry Matter
ACE	Angiotensin -1-Converting Enzyme
NRC	National Research Council
VFAs	Volatile Fatty Acids
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
WHO	World Health Organization
NGOs	Non-Governmental Organizations
SFAs	Saturated Fatty Acids

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ABSTRACT

Thirty-two (32) crossbred (Chinchilla × New Zealand White) weaner rabbits, all female, of averagely 8 weeks old with mean body weight of 950.7 g were used to investigate the effects of dietary urea-treated maize husk meal and pelleting on growth performances, reproduction, blood profile, and carcass characteristics. The rabbits were randomly assigned to eight dietary treatments with four rabbits per each treatment using a 2×4 factorial in a randomized complete block design (RCBD) for four months. Factor one was feed form with two levels: Pelleted and Non-pelleted, and factor two was Urea with four levels: 0 %, 2 %, 4 %, and 6 %. Sun-dried maize husks were treated with four levels of urea: 0 % (no urea), 2 %, 4 %, and 6 %. The respective treated maize husks obtained were used to formulate the experimental diet designated as PU0 % (0 % urea pelleted), NPU0 % (0 % urea non-pelleted), PU2 % (2 % urea pelleted), NPU2 % (2 % urea non-pelleted), PU4 % (4 % urea pelleted), NPU 4% (4 % urea non-pelleted), PU6 % (6 % urea pelleted) and NPU6 % (6 % urea non-pelleted). The data collected were subjected to a two-way analysis of variance (ANOVA) using Statistix Analytical Software Package version 10.0, (2024) and means were separated by using the Tukey's least significant difference at 5 % probability level. The results showed that animals that were fed with the pelleted feed form significantly recorded higher ($p = 0.045$) total feed intake (9095 ± 114.5 g) higher ($p = 0.000$) total weight gain (2226 ± 30.32 g) and lower ($p = 0.000$) average feed conversion ratio (4.000 ± 0.069). The interactions between 0 % urea level and pelleted feed form significantly recorded the highest ($p = 0.014$) total feed intake (9397 ± 229.0). However, the interaction between 4 % urea level and pelleted feed form recorded the lowest ($p = 0.118$) average feed conversion ratio of (3.718 ± 0.137) which indicates efficient feed utilization and better feed quality though, not statistically significant. Feed form and urea levels had no significant effect on gestation length ($p =$

0.729) and liveability of bunnies ($p = 0.842$). Again, non-pelleted feed form significantly had higher ($p = 0.008$) effect on litter size with value (5.750 ± 0.537), litter weight, 238.2 ± 16.27 g ($p = 0.025$) and weaning weight, 3355 ± 217.2 g ($p = 0.033$). Non-pelleted feed form significantly ($p < 0.05$) recorded the higher white blood cells, haematocrit, granulocyte, haemoglobin, and lymphocyte, counts, serum urea, Alkaline Phosphatase Aspartate Aminotransferase and low-density lipoprotein against the pelleted. Total serum cholesterol was significantly higher ($p = 0.001$) with the non-pelleted feed form, (2.804 ± 0.138 mmol/L) as a result of the significant higher ($p = 0.000$) low-density lipoprotein (1.508 ± 0.107 mmol/L). There was a trend of significant increase in low-density lipoprotein with increasing urea levels with 6 % recording the highest ($p = 0.008$) value of (1.417 ± 0.152 mmol/L). Increasing urea levels significantly ($p = 0.000$) tended to decrease caecal pH. There was a trend of significant ($p = 0.018$) increase percentage of visceral content (VC %) with increasing urea levels, with 6 % recording the highest value of (10.65 ± 0.343 %). The results suggest that maize husk could be incorporated into rabbits' diet either treated with 4 % urea level, or untreated without any detrimental effect on growth and reproduction. Urea-treated maize husk meal can be fed to rabbits in the non-pelleted form, and it is likely to increase reproductive performances such as litter size, livability percentage, litter size at weaning, and weaning weight.

Keywords: weaner rabbits, sun-dried maize husk, urea, pelleted feed, non-pelleted feed, growth performance, carcass characteristics, blood profile, reproductive performances.

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

By 2050, the world's population of 7.3 billion is anticipated to increase to 10 billion, doubling the demand for food while increasing demand for meat and milk to 73 % and 58 %, respectively (Bhandari, 2019). According to Ezeh *et al.* (2020), Africa will account for more than 1.52 billion of this increase. Parisi *et al.* (2020) also opined that the production of fish should nearly triple by 2050, while the production of meat from cattle, pigs, poultry, and dairy products should double. To meet this demand, huge quantity of feed resources will be required, but the area under fodder production could be challenged for expansion increased due to increasing human population and urbanization.

Globally, Yitbarek, (2019) asserted that about 30 % of the agricultural GDP in developing countries comes from livestock production, which accounts for roughly 43 % of the agricultural gross domestic product. This provides a clear indication regarding the pressure and competition on the available land space between animal production and human inhabitation. Finding farming systems that enhance biodiversity and agricultural output is a crucial 21st-century challenge that must be met in a sustainable manner.

The competition between humans and livestock has led to the ever-increasing cost of conventional feedstuffs, which has caused significantly limited availability of meat a in animal production (Abdullahi *et al.*, 2023). Protein malnutrition, especially originating from animals, is prevalent in the majority of underdeveloped nations, where it is estimated that, on average, only 4.5 mg of animal protein is consumed per head per compared to the recommended 35 g (FAO, 2008). This has necessitated the need to be

explore, assess, and adopt small domestic animals with short generational cycles and efficient feed and land such as pigs, chickens, and rabbits, as a suitable solutions to the growing demand for food of animal origin. The productivity of these livestock depends largely on their capacity to use feeds that are useless for human nutrition. This is because it is rarely possible to mention surplus since human population is rapidly surpassing the supply of food. The production of pigs and chickens has been very costly in terms of feeding since they compete with human for the similar feed ingredients. Airina *et al.* (2021); Odedire and Onoja *et al.* (2022) posited that rabbits have number of characteristics that might be advantageous to smallholder subsistence-type integrated farming systems. Because of their small body size, quick growth rate, genetic diversity, high reproductive potential, short gestation period, early sexual maturity, low competition with humans for similar feed resources, ability to rebreed multiple times in a year, and short generation interval (Al-Saffar and Almayahi, 2018; Jenckel *et al.*, 2021), make rabbits good choice as small livestock in developing countries.

Despite the many advantages, Ubuia *et al.* (2019); Rahman *et al.* (2020) reported that rabbit farming has not yet achieved its full potential as a low-cost animal protein source in the tropics. Internationally, the production of rabbits has remained in the hands of small-scale farmers consisting of women and children (Ogbonna 2015; Kuka and Onwujiariri 2021; Wongnaa *et al.*, 2023). Osei *et al.* (2012) claimed that the production of rabbits in Ghana is still developing more slowly than the poultry and pig industries. According to Osei *et al.* (2012), Ghana's rabbit production expanded dramatically as a result of a national multimedia communication campaign that backed the National Rabbit Project, which was established in 1972 to promote backyard rabbit breeding. Despite the rising demand for rabbit meat and the numerous advantages enjoyed by the rabbit

farmers, the production decreased significantly when the project ended (Opoku and Lukefahr, 1990). However, Owusu-Ntumy *et al.* (2024) opined that due to the low-cost of production and less religious restrictions on rabbit meat consumption, rabbit farming is gradually gaining acceptance in the nation, and the interest in production has begun to rise again, with people from all educational backgrounds engaging in it, especially in urban dwellings. To sustain and improve rabbit production in Ghana, good management and proper feeding at a cheaper cost are indispensable.

Katoch (2022) recorded that maize husk is one of the potential cereal by-products that can be used in rabbit diets to replace a portion of the high-cost conventional feed sources. According to Odeyinka *et al.* (2007), cereal by-product, such as maize husks, has a high digestible energy content for rabbits. Maize husks are generally considered a potential source of fibre in rabbit feeding because of their abundant availability from maize processing and at a low cost. Ruminants easily consume maize husks, either processed or not (Mafimidiwo *et al.*, 2022). However, non-ruminant herbivores like rabbits can seldom use these husks without processing because of their simple stomach nature. To improve its utilization, strategies that can solubilize the fibre fractions for easy absorption need to be employed. One of the proven methods of processing maize husk is the use of urea and pelleting. Treating maize husk with urea has been a method for raising the nitrogen level of fibrous feed material to improve its quality and to enhance its nutritional status, palatability, and digestibility, making it more suitable for feeding rabbits (Aruwayo, 2018).

1.2 Problem Statement

One of the greatest challenges facing rabbit production in the tropics has been the excruciating rising costs of conventional feed resources combined with a lack of knowledge about potential substitute of less expensive feed ingredients (Okoyere *et al.*, 2024). The cost is aggravated as a result of the selective feeding behaviour of rabbits, which causes a lot of feed wastage (Hagen *et al.*, 2018; Orisaleye *et al.*, 2024), resulting in the production and marketing of livestock and their products at very high and unaffordable prices. Therefore, encouraging the use of less expensive and more nutrient-dense alternative feed supplies that are well suited to tropical climates is the urgent challenge for animal scientists, researchers, and feed mill operators (Quansah and Makkar, 2012).

Maize husk is the fibrous leaf covering the corn ear that farmers often remove, leaving huge amounts for cattle and small ruminants to graze after harvest (Folorunso and Adamu, 2021). The husks, according to Kalio and Amadi (2018); Afolayan (2022), have been identified as an alternative feed resource that can be added to animal diets in terms of availability of roughage, but the residues were limited by their high fibre and low protein content (Enawgaw *et al.*, 2023).

To resolve these nutritional limitations, urea, a non-protein nitrogenous compound treatment, has been incorporated to increase the protein content of the substrates (Aquino *et al.*, 2020). Also, the ammonia produced during urea treatment dissolves the carbohydrates, primarily the hemicelluloses, causing the vegetal matter to expand in an aqueous environment. This facilitates microbial digestion and makes it easier for rumen cellulolytic microorganisms to reach the material (Aruwayo, 2018).

The pelleting process as reported by Molina (2022), is also employed to break down the structural carbohydrates of the husks, making the nutrients more bioavailable to the animals to reduce feed wastage and cost. Raju *et al.* (2021) stressed that pelletizing animal feed is an effective method for enhancing their feed intake, digestibility, feed conversion, and growth performance. The pressure and heat generated during pelleting increase the gelatinization of starch, which raises the possibility of fermentation (Ran *et al.*, 2021) and decrease the danger of acidosis (Singer, 2024).

There is a wealth of research on using maize crop residues in animal nutrition, such as maize offal (Ajimohun *et al.*, 2021), maize cob (Mafimidiwo *et al.*, 2022) and maize bran (Abubakar *et al.*, 2023). However, the application of urea-treated corn husk in rabbit feeding has not been extensively studied. The impact of this non-conventional feed source, maize husk treated with varying levels of urea and pelleting, on rabbit production must therefore be examined in order to assess its acceptability as a substitute feed source.

1.3 Objectives of the Study

1.3.1 Main objective

The primary objective of this study was to determine the effects of dietary urea-treated maize husk and pelleting on the general performance of female rabbits.

1.3.2 Specific objectives

Specific objectives of the study were to determine the effects of dietary urea-treated maize husk and pelleting on:

- i. growth performance of female rabbits
- ii. reproductive performance of female rabbits

- iii. haematological and serum biochemical characteristics of female rabbits and
- iv. carcass characteristics of female rabbits

1.4 Justification and Significance of the Study

By studying the impact of maize husk when treated with urea and pelleted, the research seeks to determine its potential as a viable feed component that could contribute to the sustainability of rabbit production systems. Understanding how these treatments affect the performance of female rabbits can inform farmers about the practicality of incorporating it into rabbit nutrition. Furthermore, examining how rabbits performance is affected by urea-treated maize husk can advance the scientific understanding of animal nutrition and guide future studies on sustainable animal feeding methods.

CHAPTER TWO: LITERATURE REVIEW

2.1 History and Domestication of the Rabbit

Rabbits are classified under the Kingdom Animalia, Superphylum Chordata, Phylum Vertebrata, Class Mammalia, Order Lagomorpha, Family Leporidae, and eight distinct genera, including *Pentalagus* (Amami rabbit), *Bunolagus* (Riverine rabbit), *Nesolagus*, *Romerolagus*, *Brachylagus*, *Sylvilagus* (cottontail rabbit), *Oryctolagus*, and *Poelagus* (Owuor, 2021). Currently, the genus *Oryctolagus* is represented by only one species, *Oryctolagus cuniculus*, the European rabbit, which is thought to have descended from *Oryctolagus laynesis* (Alves *et al.*, 2008).

Because rabbits' bones are thin, delicate and are easily broken by predators, it is difficult to trace the origins and evolutionary history of rabbits (Lukefahr *et al.*, 2022). According to fossil evidence, the order Lagomorpha dates to the late Eocene, around 45 million years ago (Smith *et al.*, 2018). It seems that southern France and the Iberian Peninsula (Spain and Portugal) are the origins of leporids (rabbits and hares). As noted by Fontanesi *et al.* (2021), because they have two more incisor teeth than rodents (six instead of four), and digestive system adaptations, rabbits are currently categorized as belonging to a different order called Lagomorpha.

They have a specialized dental structure known as aradicular hypsodont, which enables continuous tooth growth to compensate for the wear and tear caused by their diet of fibrous plants. Ibrahim *et al.* (2017) recorded that rabbits have large, powerful hind legs, and each foot has five toes, rabbits are hindgut digesters with a caecum that digests fibre. They are reared in cages/hutches or deep litter for the source of meat and wool. Rabbits are classified as monogastric herbivores or pseudo-ruminants because they can eat and

digest forage. They do not possess four stomach compartments and do not chew the cud nor regurgitate as ruminants, but also do what is known as coprophagy. All breeds of domestic rabbits, according to Owuor *et al.* (2019), are descended from *Oryctolagus cuniculus*, the European wild rabbit. Historically, Romans started raising rabbits in captivity for their meat and used them for hunting and entertainment purposes (DeMello, 2016). This early domestication process laid the foundation for the diverse breeds of rabbit we see today (Riley, 2019).

2.2 Breeds of Rabbits

Around the world, there are around 350 different breeds of domesticated rabbits (Claudy, 2021). The domestic rabbit belongs to the Lagomorph family and is a subspecies of the European rabbit (Jenckel *et al.*, 2021). Breeds are produced through unique selective breeding and, in rare cases, by natural selection for exceptionally unique characteristics. Some of the common breeds of rabbit reared in Africa are the New Zealand white; known for their pink eye and white coats, the California; a medium-sized breed with white coat and black markings, the Chinchilla; noted for their thick, soft fur and larger body size, the Dutch, the French lop, the African Giant, Lion head; a medium-size breed with a distinctive mane of hair around their head, English spot, English Angora; known for their long, soft hair, the Satin; a medium-sized breed with shiny, smooth coat, and the Crossbreds of varied genetic variations. California, Chinchilla, New Zealand White, and Flemish Giant rabbits are among the exotic and local breeds of rabbits that are currently kept in Ghana (Osei *et al.*, 2019). According to Sergon (2022), the New Zealand White rabbit is the commonest breed kept for commercial meat production all over the world, more so in China, the United States, and Africa.



Plate 2.1: Some common breeds of rabbits reared in Ghana

Sources: (Sengupta and Dutta, 2020)

2.3 Rabbit Meat and Its Nutritional Compositions

The rabbit can utilize cellulose-rich feed (forages), and are able to convert roughly 20 % of the protein they eat into muscle mass, which is comparable to chicken at 22 % (Jiang *et al.*, 2020; Siddiqui *et al.*, 2023). The effectiveness of protein conversion to meat is higher in rabbits than in other livestock, such as beef, where it varies between 8 % and 12 %, and in swine, it ranges between 16 % and 18 % (Mariezcurrena-Berasain *et al.*, 2020). Animals' ability to turn feed into meat is a crucial factor in predicting the

economic success and environmental sustainability of the farming system. In contrast to other domestic meat sources such as beef, pig, or chicken, Nina *et al.* (2019) reported that one of the most nutritious white meats is rabbit meat. It is said to be healthier than other meats since it contains less cholesterol and saturated fat. Despite the low amount of fat, Adeyemi *et al.* (2022) asserted that beneficial fats like oleic and linoleic unsaturated fatty acids are abundant in rabbit meat. Zubiri-Gaitán *et al.* (2022) indicated that rabbit meat has reduced levels of intramuscular fat, cholesterol, and sodium and higher amounts of omega 3 (n-3) fatty acids, but high in potassium, essential vitamin such as vitamin B -12 and E, selenium, calcium, phosphorus, copper, iron, and zinc indicating potential health benefits for consumers.

Rabbit meat has between 48 and 60 mg of total cholesterol per 100 g according to Zamaratskaia *et al.* (2023), and has the highest percentage of digestible proteins 20 – 21 %, low fat 10 – 11 %, low calories 1749 Kcal/Kg. Bharathy *et al.* (2022) reported that the meat of rabbits has a lower fat content (9.2 g/100 g) and higher levels of calcium (21.4 mg/100 g) and phosphorus (347 mg/100 g) than other meats. It is also high in niacin, which helps to convert carbohydrates to energy. According to a chemical examination of meat observed by Sarfo (2018) on chicken, beef, and pork; pork was high in fat, 28.2 g per 100 g, whereas the highest cholesterol concentration was found in beef, which had 114.5 mg per 100 g, nearly twice as much as rabbit meat. Again, rabbit meat does not form uric acid during metabolism and hence, its recommendation for diabetics, hypertensive, people with heart-related diseases, young children, pregnant women, and the middle-aged (Ataxodjayeva and Akramova, 2023)

Due to its low fat and cholesterol content, Ataxodjayeva and Akramova (2023), asserted that nutritionists recommend rabbit meat in diets for various diseases of the gastrointestinal tract, stomach, biliary tract, liver, allergies and others. According to Zamaratskaia *et al.* (2023), rabbit meat is also a potential source of bioactive peptides with antioxidant and anti-hypertensive qualities. The meat contains a number of bioactive peptides that have been chemically characterized and found to have potent angiotensin-I-converting enzyme (ACE) inhibitory effects (Takeda *et al.*, 2020). As the popularity of rabbit meat grows, the dietary fortification increases, making the nutritional aspects of the meat even better. Therefore, rabbit production is considered a good source of meat in developing countries where there is an abundance of agro-industrial by-product feedstuffs.

2.4 Nutritional Requirements of Rabbits

The primary advantage of rabbit's production in developing nations with chronic protein deficits is their ability to consume primarily forage-based diets without competing with humans. Jiya (2021) recorded that the rabbit is a monogastric herbivore with simple stomach that can survive on forage only. However, for better growth, there is the need for their forage to be supplemented with concentrates that can be fed in meal or balanced pelleted rabbit's feed that contains 3 – 35 g dry matter per kg of live weight per day. They can digest cellulose anaerobically with the help of micro-organisms present in their enlarged caecum, similar to the action that takes place in the rumen of ruminants. It is impossible to overstate the importance of nutrients for rabbits since they are necessary for their bodily development maintenance, and reproduction (Martinez-Paredes *et al.*, 2018).

2.4.1 Protein requirements

Protein is regarded as the most important of all nutrients. It is required throughout an animal's life for growth, building up of new cells, repair of worn-out tissues, and proper functioning of the body (Cedar, 2022). Compared to other nutrients, it is critically limiting in the diet of animals. According to study, lowering the amount of protein and essential amino acids in the diet from what is ideal for animal growth is linked to a slower growth rate and less effective use of feed, as well as a corresponding rise in body fat (Olatubosun and Tech, 2014). According to Ozung *et al.* (2017), because of coprophagy, rabbits have been shown to adapt to low-protein diets more successfully than chickens, though production may not be optimal. Varga (2014) revealed that while rabbits have a need for critical amino acids, caecotrophy complicates matters. Amino acids produced by micro-organisms in the caecum are taken up from the caecotroph during digestion.

Jiya (2021) reported that lysine, methionine, arginine, phenylalanine, histidine, valine, threonine, tryptophan, leucine, and isoleucine are the 10 essential amino acids that rabbits need in their meals in order to live and develop. Akande (2015) experimented with diets containing 10 - 22 % crude protein and reported that 18 - 22 % was an optimum range for the production of tropical rabbits, whereas 15 % crude protein was adequate for rabbits in the temperate. Ingestion of caecotroph is influenced by dietary protein and energy.

According to Moxon *et al.* (2023), when rabbits are fed with a lower energy diet, caecotroph ingestion is maximized. Coprophagy has been found to increase protein digestibility of forages in rabbits (Irlbeck, 2001). According to Thompson (2013), the

rabbit's demand for caecotroph is decreased by a high protein diet. Therefore, Elling-Staats *et al.* (2022) indicated that giving excessive amounts of dietary protein should be done with caution since too much protein can raise the ammonia levels in the caecum, which raises the caecal pH and may encourage the growth of pathogens and increase the risk of enteritis. However, poor tissue regeneration and reduced protein synthesis are caused by inadequate dietary protein or an essential amino acid deficit.

2.4.2 Energy requirement

Energy, as opined by Maharjan *et al.* (2021) is the primary nutrient required to maintain optimum performance in all farm animals. Although, energy can be supplied by all nutrients in the feed through different metabolic pathways, carbohydrates and fats are the primary sources (Olatubosun and Tech, 2014). The energy needed by rabbits for organic synthesis is usually supplied by carbohydrates and, to a lesser extent, by fats. Where there is an excess of protein, it also helps to supply energy after deamination. Also, van der Hee and Wells (2021) recorded that the volatile fatty acids such as acetate, butyrate, and propionate that are produced by bacteria present in the caecum are absorbed into the bloodstream and also used as a source of energy. Carbohydrates can be obtained from grains such as maize, which is included in the concentrate of the rabbit's diet (Mutwedu *et al.*, 2020).

The amount of energy that rabbits need depends on a number of factors. These include reproductive functions (age, body size, growth, breastfeeding, maintenance, and sex) and environmental factors (temperature, humidity, and air movement) (Nuhu, 2010). Thus, it is hard to set a strict energy requirement for different categories of rabbits. According to

Cherwon (2020), in 1977, the National Research Council (NRC) recommended that growing rabbits should have a diet of 2500 kcal/kg of digestible energy. Osman *et al.* (2020) found that typical rabbit diets had relatively low digestible energy levels, ranging from 2400 to 2800 kcal/kg weight diet. Higher energy levels, according to the authors, lead to lower energy intake and worse performance. Moreover, Jiya (2021) reported that it is recommended to provide rabbits with feed that contains between 2600-2700 kcal/kg metabolizable energy. They require between 2100-2200 kcal/kg for maintenance, whereas reproduction and growth require between 300-500 kcal/kg more than maintenance requirements.

2.4.3 Fibre in rabbit nutrition

The importance of fibre in rabbit nutrition cannot be over-emphasized due to its significant role in gut motility in rabbits (Miller, 2022). Rabbits are hindgut fermenters, with the caecum and colon being the primary sites of fibre fermentation. Dietary fibre, as opined by Eslami *et al.* (2021), is essentially in maintaining mucosa functionality and serves as a substrate for micro-biota that relates to performance and digestive health. According to Yang *et al.* (2019), dietary fibre accounts for 40 - 50 % of the feed for the growing rabbit. Adewale *et al.* (2021) indicated that high-fibre diets help to regulate the pH balance in the rabbit's gastrointestinal tract, reducing the risk of digestive problems.

Diets deficient in indigestible fibre increase the risk of trichobezoars, or hairballs, which are caused by the retention of food and hair in the stomach and gastrointestinal hypo motility Oglesbee and Lord (2020), a common issue in rabbits that can lead to digestive blockages (Angliss *et al.*, 2021). Farías-Kovac *et al.* (2020) confirmed that the rabbit has

a relatively limited ability to digest dietary fibre. Nonetheless, rabbits' performance and general health are frequently negatively impacted when on low-fibre diets. Because of its poor digestion, fibre is not regarded as a true nutrient in rabbits; instead, it is regarded as a food that helps to sustain gut motility. Ibrahim *et al.* (2017) opined that rabbits ate more feed to make up for the loss of endogenous protein when dietary fibre levels were raised.

Ogana *et al.* (2020) recorded dietary fibre level of 15 - 20 %, while crude fibre level of between 10 - 17 % was found to support optimum growth rate. It was discovered that consuming more than 17 % crude fibre limits energy intake, which lowers performance. A low fibre level below 10 % leads to hypo-motility, which predisposes the animal to diarrhoea. Agunbiade *et al.* (2001) reported that the dietary fibre level for rabbits should be in the range of 150 - 200 g / kg, as a high dietary fibre level in excess of 200 g /kg may lead to caecal impaction and energy intake limitation. Ayandiran *et al.* (2021) also concluded that rabbits can use up to 30 % of crude fibre, compared to 10 % for most poultry species, and are shown to be effective at converting feed into meat.

In rabbits, Chen (2023) observed that certain enzymes like pectinases and xylanases can aid in the partial digestion of fibre in the stomach and small intestine. Though, digestibility within the caecum relies on the kind of plant material and, to a lesser extent, processing methods, the majority of fibre digestion occurs by the microbial flora within the caecum (Blas and Gidenne, 2020). Ocasio-Vega *et al.* (2018) reported that dietary fibre aids in maintaining a high passage rate, preventing digesta build-up in the caecum, which lowers feed intake and hinders growth. Moreover, according to Liu *et al.* (2022), fibre serves as a substrate for caecal micro-organisms, which produce volatile fatty acids

(VFAs) as their primary fermentation products. This may reduce the prevalence of digestive problems and mortality. Bakr *et al.* (2019) asserted that fibre also serves to maintain the gut's micro-ecological balances, encourage the growth of the digestive system, and ultimately enhance productivity.

2.5 Maize husk in rabbit nutrition

One significant benefit of rabbits over other monogastric animals is their capacity to use inexpensive and non-conventional feed resources. Van der Sluis *et al.* (2024) noticed that rabbits can sufficiently degrade substantial amounts of fibre, making dietary fibre the main constituent of rabbit feed. Rabbits can digest 65-78 % fibre consumed (Kurtong, 2014). The digestive tract of rabbits is set up to digest cellulose in the form of tough, woody stems and fibrous vegetation due to the long digestive tracts that slowly break down cellulose and process it. This inherent quality of the rabbit makes maize husk inclusion in their diet a potential non-conventional feedstuff.

2.5.1 Nutritional composition of maize husk as a feed component for rabbits

Maize husk is the most common and least valued by-product of modern corn processing. Maize husk, is made up of 10 % - 14 % of the grain's total fibre content (Jiao *et al.*, 2022). According to Santoso *et al.* (2024), for every kilogram of dry matter, maize husks contain 382 g of cellulose, 445 g of hemicellulose, 66 g of lignin, 19 g of protein, and 28 g of ash. Furthermore, Jiao *et al.* (2022) emphasized that maize husks are abundant in phenolic acids, with ferulic acid accounting for 90 % of these acids. Ferulic acid is mostly found in the pericarp layers and aleurone cell walls. There are three types of ferulic acid found in maize husks: free, soluble, and insoluble. Because of its potent

antioxidant properties, ferulic acid can control the oxidation status of cells and shield biological macromolecules like proteins and DNA from oxidative damage. El-Beltagi *et al.* (2023) claimed that phenolic substances are potent antioxidants that prevent pro-oxidative effects on proteins, DNA, and lipids by producing stable radicals. In a study by Duru (2020), the mineral elements and phytochemicals found in maize husk were identified and measured using gas chromatography coupled to a flame ionization detector (GC-FID) and energy dispersive X-ray fluorescence (EDXRF). The most prevalent mineral elements identified were calcium, sulphuric acid, and potassium, which are crucial for both human and animal nutrition. Their respective concentrations were 61.74 mg/g, 38.02 mg/g, and 31.14 mg/g.

Phenols, flavan-3-ol, steroids, flavanones, proanthocyanins, and resveratrol were the main phytochemicals in the ethanolic extract; their respective amounts were 12.35 mg/g, 10.74 mg/g, 10.03 mg/g, 9.19 mg/g, 5.40 mg/g, and 3.36 mg/g. According to Pandey *et al.* (2023), dietary fibre can help avoid a range of gastrointestinal disorders, including constipation and haemorrhoids, by enhancing gut flora and boosting probiotic bacteria like *Lactobacillus* and *Bifidobacterium*. Somchart *et al.* (2019) emphasized that maize residues (husk, stalk, and stover) without grain could be prepared and used as traditional animal feed; however, the residues' high fibre content limited their use and could turn them into rotten plants when contaminated by spoilage microorganisms.



Plate 2.2: Maize Husk

2.5.2 Challenges in the use of maize husk as a feed component for rabbits

Although, crop leftovers are widely used in animal feed, several limiting constraints affect how completely these residues may be turned into valuable animal products. Bhandari (2019) asserted that cell walls, which contain neutral-detergent fibre and make up to 80 % of the dry matter, are significant source of energy for ruminants, but cereal crop leftovers are low in protein. Because crop leftovers are low in nitrogen, low in digestibility, and low in intake, animals fed them perform poorly. Phenolic and other aromatic compounds, commonly known as lignin, prevent rumen micro-organisms from breaking down cell wall polysaccharides (cellulose and hemicellulose) (Aruwayo, 2018; Bhandari, 2019). Despite their nutritional potential and low cost, these non-conventional feedstuffs of plant origin are limited in their use due to the presence of alkaloids, glycosides, oxalic acids, phytates, protease inhibitors, saponins, momosine, cyanoglycosides, and linamarin (Phenya, 2018). At higher inclusion levels, these anti-nutritional substances inhibit animals' growth and other physiological functions. Phenya

(2018) stated that interactions with other components of anti-nutritional factors (ANTFs) can deactivate nutrients, disrupt the digestive tract, and affect how feed is utilized metabolically.

As posited by Adem (2019), crop residues such as maize husks are potentially rich sources of energy, as about 60 - 80 % of their DM consists of polysaccharides. It can effectively be fed to small ruminants with low requirements as the primary component of a diet with little supplementation. However, because of its poor digestion and nutritional value, only a small percentage of this quantity of maize stover is fed to ruminants. These limitations stem from their unique cell wall structure, chemical makeup, and nutrient shortages, including those in nitrogen, sulphur, and phosphorus, all of which are critical for rumen microbes. Zhou *et al.* (2023) stated that the high fibre contents, which are primarily composed of 40 - 50 % cellulose, 25 - 35 % hemicelluloses, and other substances, are typically the cause of the low digestibility and 15-20 % of lignin on DM basis.

Thus, to increase the digestibility of maize husk, it is important to release the linkage between cellulose, hemicellulose, and lignin or alter the compact structure of these tissues in order improve the digestibility and biodegradability of animals by allowing lignified tissues to be separated from non-lignified ones.

2.5.3 Improving the quality of maize husk as a feed component for rabbits

Strategies that can solubilize the fibre fractions for absorption by non-ruminants must be used to increase the use of maize husk. By making agricultural leftovers more palatable and separating cellulose and hemicellulose from silica and lignin, the treatment increases

voluntary consumption. Dissociation promotes microbial activity, which makes organic nutrients more digestible and increases energy availability by decreasing losses during digestion. It also increases surface area, which gives micro-organisms and their enzymes more exposed surface area, which increases digestibility. Densification decreases feed bulkiness, improving quality and extending storage time, and neutralizes the feed's toxic components to cut down on feed waste and refusal during feeding. Animal production tends to be cost-effective and economical, ensuring balanced intake of nutrients and reducing the slope of feed sorting (Bolaji, 2019).

2.6 Urea and Its Chemical Compositions

Urea, commonly known as carbamide, is a white crystalline material and an organic nitrogenous compound with the chemical formula $\text{CO}(\text{NH}_2)_2$. A carbonyl functional group connects the two amino groups ($-\text{NH}_2$) in this amide. Thus, it is the most basic carbamic acid amide. As the primary nitrogen-containing material in mammal urine, urea plays a significant role in the metabolism of nitrogen-containing substances in animals (Rasool, 2024). It is a common organic chemical used as a nitrogen fertilizer since it has no smell, dissolves well in water, and is essentially non-toxic. Protein only contains 16.6 % nitrogen; hence, a crude protein content of 290 grams per 100 grams of urea is equal to the 46.6 % nitrogen concentration of pure urea (Mutayoba, 2010). The urease enzyme breaks down the nitrogen content of urea at room temperature into ammonia (NH_3) and carbon dioxide (CO_2).

2.7 Effect of treating maize husk with urea

To improve the nutritional value of straw, several pre-processing techniques have been investigated in practice, including physical, chemical, and biological treatment (Ma *et*

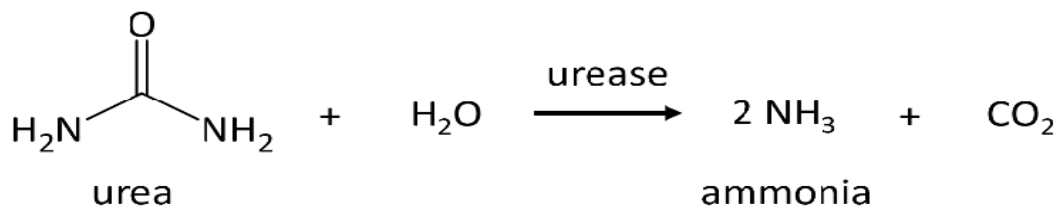
al., 2020). Chemicals have been employed to increase the nutritional content of agricultural residues since the 1920s, when German scientist Beckman treated stacks of crop wastes with sodium hydroxide, improving their digestibility in the process (Kumssa, 2017)

According to Attia *et al.* (2021), upon undergoing physical and biological processing, highly lignified cereal crop residue may become more appealing and easier to be consumed. However, the physico-chemical method, as a proven method of processing maize husk, is the use of urea. Traditionally, urea treatment and pelleting have been used to enhance the quality of fibrous feed materials by raising its nitrogen content through the actions of ammonia ions on the cell wall. Urea treatment is a technique where ammonia from urea is used to treat straw. This is called ammoniation.

Straw is mostly composed of fibre, which includes cellulose and hemicellulose. Some cellulose and hemicellulose, according to Lobo *et al.* (2021) are bonded to lignin and are impervious to microbial attack. This link is broken by ammoniation, allowing the animal to use these fractions. Ammoniation often raises crude protein content by 1-2 times and digestibility by 20 % (Katoch 2023). Patel and Katole (2023) confirmed that the positive benefits of urea treatment include improved animal fattening, higher nitrogen content, increased digestibility by 8 - 12 %, and increased voluntary intake by 25 - 50 %. The protein content rose from 11.1 % to 16 %, and the *in vitro* digestibility from 47 % - 53 %. A study by Nimoniche *et al.* (2023) found that adding urea to straw improved the dry and organic matter of the roughages' apparent digestibility. According to Paengkoum *et al.* (2019), applying urea treatment usually results in a 10 - 15 % increase in dry matter digestibility and a 25 - 35 % increase in feed intake. Concerning the performance of

animals, Aliyi (2021) compared animals fed untreated straw with those fed urea-treated straw and observed that those fed urea-treated straw gained 0.21 kg daily, while animals fed untreated straw lost 0.13 kg. According to Aruwayo (2018), urea treatment is an easy technique that involves spraying a urea solution onto the dry mass of fodder and keeping it airtight to produce an anaerobic environment for the urease enzyme, using locally accessible materials to establish a hermetic seal. When water, urea, and the ideal ambient temperature are present, urea hydrolyzes to produce gaseous ammonia and carbonic dioxide, starting a process that spreads the forages over time.

According to Llopis-Lorente *et al.* (2023), the urease that the rumen microbes produce also readily converts urea to ammonia in the manner described below;



The ammonia released from urea weakens the lignified outer walls of the husk, allowing better penetration by rumen micro-organisms to produce more effective fermentation and liberation of nutrients (Emmanuel *et al.*, 2015). However, the authors stressed that urea should only be added to animal diets in limited amounts to reduce the risk of hyperammonemia.

Chen *et al.* (2021) verified that one mole of urea produces two moles of ammonia after the hydrolysis process is finished. Devidas (2023) concluded that the basis for urea treatment is the direct production of ammonia and fixation in straw, as well as the chemical modification of straw, which Kumar and Deshmukh (2022) has also proven. Kumar and Deshmukh (2022) stated that the ideal urea application rate is between 3 and

5 kg (3-5 %) of urea per 100 kg of fodder, with 4 % being the optimum. According to Aruwayo (2018), the urea application rate ranges from 4 to 6 kg of urea per 100 kg of straw matter, which is equivalent to 2.27 to 3.4 kg of ammonia treatment. According to Kumssa (2017), the amount of urea used varies but typically falls between 4 % and 5 % of the air-dried mass of the straw/stover, while the amount of water used ranges from as low as 0.2 litres per kilogram of straw to as high as 1 litre per kilogram of straw. Kumar and Deshmukh (2022) opined that when there is a significant build-up of free ammonia in the feed, the hydrolysis of the urea may halt or falter. This suggests that the likelihood of obtaining the greatest benefit is decreased when urea therapy is administered at a rate higher than that which is advised. Water is necessary because it facilitates urea breakdown.

According to Kumar and Deshmukh (2022), because ammonia is hygroscopic, larger water content may trap it and prevent it from fixing in the straw's cell walls. For successful ureolysis and ammoniation of straws, Kumssa (2017) indicated that the moisture content needed to breakdown the urea should be between 30 % and 60 %. Inadequate ureolysis results in insufficient ammonia, which, when combined with excessive oxygen in damp environments, causes mold growth and poor treatment. According to Kumssa (2017), the optimal temperature range for ureolysis is between 30 and 60 °C and the rate of ureolysis doubles or decreases by a factor of two for every 10 °C rise or decrease in temperature. At temperatures ranging from 20 - 45 °C, ureolysis can be completed in one to seven days. During the process, about 70 % of the given urea is hydrolyzed to ammonia gas, albeit most of the ammonia gas is expelled during ventilation prior to feeding (Kumssa, 2017). In the caecum, remaining ammonia that

adhered to the dry food during treatment provides nitrogen for the microbial protein synthesis.

2.8 Feed Forms for Feeding Rabbits.

The amount of meat that pigs, rabbits, and poultry produce is greatly influenced by the physical form of their meal. There are three ways to present livestock feeds: pellets, crumbs, and mash. According to Assefa *et al.* (2022), more than 25 % more agricultural residue is consumed by animals after it has been chopped and ground. It has also been demonstrated that these actions increase the feed transit rate and total feed consumption efficiency. According to Khdr *et al.* (2019), mash is a type of complete feed that has been blended and coarsely crushed to make it difficult for animals to separate the contents. Pelleting is the technique of turning finely powdered mash feed into dense, freely flowing capsules using mechanical pressure and steam injection (moisture and heat) (Lobo, 2022).

In addition to enhancing nutrient use efficiency, changing the physical properties of feed by combining roughage and concentrates to create complete feed also lowers feed waste, feed costs, and labour expenses. Zhang *et al.* (2019) reported that while pelleting may strengthen this effect by reducing particle size, the size and hardness of the pellet may also have an impact on microbial accessibility to fermentable nutrients. Raju *et al.* (2021) opined that pelleting causes a more gradual release of oil in the rumen and a greater rumen escape of dietary crude protein (CP), which may increase the bioavailability of dietary protein. Better pellet feeding performance can be achieved by pathogen eradication, reduced feed waste, less selective feeding, and greater palatability (Nabi *et al.*, 2017; Uys, 2022; Vakili, 2023). According to Malik *et al.* (2023), animals fed

pelleted meals generally grow more quickly than those on non-pelleted diets. In terms of the feed conversion ratio, Salih (2019) reported that pelleted diets resulted in less waste and improved feed conversion ratios compared to mashed diets. Lancheros *et al.* (2020) also recounted that pelleting enhances palatability, decreases feed waste, and improves nutrient digestibility, all of which can result in increased feed intake and ultimately higher weight gains. According to Rodríguez-Fontes *et al.* (2023), the diameter of the pellets ranges between 3.0 and 4.5 mm to increase feed consumption. The length of the pellets should be between 2 and 2.5 times the diameter to give the granule more solidity.

2.9 Growth Performance of Rabbits

The growth performance of a rabbit is the daily weight gain from birth to slaughter age or the maturity stage. According to Isaac and Oriaku (2023), for an animal to be profitable to produce, it should have maximal growth and a comparable body size. The effects of dietary treatments on growth performance depend on the nutritional value of the diet. Animal with higher growth rate genotypes has the ability to convert little feed taken into productive purpose.

2.9.1 Daily feed intake of rabbits

In addition to meeting animal welfare regulations, proper feeding practices can help raise rabbits in a healthy and productive manner without incurring additional costs (Huang *et al.*, 2023). Rothacher (2023) concluded that one of the factors that could influence how much an animal eats a specific feed is its palatability. According to Adeyemi *et al.* (2011), increased body weight gain is typically the outcome of increased feed intake. Age in rabbits can significantly affect feed intake in rabbits. Feed intake rapidly increases with age until it reaches a peak, where it decreases due to declining health,

dental issues, or reduced activities (Tag-El Din, 2019). In a research conducted by Tag-El Din (2019), daily feed intake of rabbit was recorded in the range of weeks and reported 6 - 8 weeks: (75.0 0±2.2 g), 8 – 10 weeks: (117.0±5.6 g), 10 – 12 weeks: (124.0±5.3 g) for the rabbits that were fed with the control diet.

According to Legendre *et al.* (2018), feed intake of young rabbits averaged 112 g DM/day/rabbit. Houndonougbo *et al.* (2012), in a study using palm-press fibres-based diet to feed rabbits recorded an average daily feed intake of 78.7 g which was lower than what was recorded by Legendre *et al.* (2018). However, Kpehe *et al.* (2020) recorded significantly daily feed intake ranges of 81.63 - 93.88 g when feeding rabbits with rice offal meal. In a related study, Nuhu (2010) after feeding rabbits with moringa leaf meal (MOLM) recorded an average daily feed intake value of 60.1- 63.4 g, which was relatively lower than what was reported by Kpehe *et al.* (2020). Mafimidiwo *et al.* (2022) conducted research by feeding rabbits with varying levels of urea-molasses treated maize cob as a replacement for wheat offal and significantly reported an average daily feed intake of 36.87- 42.40 g/day. With these discrepancies in average daily feed intake values reported in earlier studies, there is a need to undertake further studies to ascertain the validity.

2.9.2 Body weight gain of rabbits

Onoja and Mallam (2022) reported that rabbits in the tropics increase 8 –13 g of body weight every day, while those in temperate areas gain 42 g. The authors further stressed that the breeds, age, and type of forage or concentrate that rabbits raised in the tropics are fed determine how much weight they gain. In contrast to the 35 - 40 g per day often seen in temperate settings, research from tropical nations has shown that rabbits normally

grow between 10 and 20 g per day (Onoja and Mallam, 2022). The average daily weight gain of rabbits, according to Gasco *et al.* (2019) is 44.5 g/d when rabbits were fed with dietary supplementation with insect fats. In a related study, Kpehe *et al.* (2020) fed rabbits with diets containing varied levels of fermented rice and recorded significantly lower average body weight gain values, 10.20 – 20.54 g/day as compared to what was reported by Gasco *et al.* (2019) but corroborates with the findings of Onoja and Mallam (2022).

Shuaibu *et al.* (2021) conducted research by feeding rabbit diets with varying amounts of roasted date palm (*Phoenix dactylifera*) seed meal with an inclusion level of 0 %, 5 %, 10 %, 15 % and 20 % for 12 weeks and significantly recorded average daily weight gain values between treatments of 13.15 g, 13.21 g, 11.90 g, 12.18 g and 11.95 g respectively. Another study was conducted by Anya *et al.* (2018) who fed rabbits with cocoa bean shell meal-based diets for 60 days did not observe any significant difference in weight gain between dietary treatments. However, an average body weight gain value of 14.04 g/day was recorded.

Mohammed and Jamala (2013) fed rabbits with urea-treated cowpea husk meal and reported that average daily weight gain is increased in the rabbits fed with urea-treated cowpea husk (16.97 g, 16.67 g and 17.84 g) for 40 %, 50 % and 60 % inclusion levels of urea-treated cowpea husk respectively as compared to the control group (16.61 g/day). Rabbits were fed with a diet supplemented with a urea-bentonite combination with an inclusion level of control, urea-supplemented (containing 1% urea), bentonite-supplemented (containing 2.5% sodium bentonite), and urea-bentonite co-supplemented (containing 1% urea and 2.5% sodium bentonite). At the end of the feeding trial, the

following were recorded as average daily weight gain 15.70 ± 1.12 g, 12.92 ± 1.06 g, 18.81 ± 2.46 g, 20.88 ± 1.45 g (Saleh *et al.*, 2011).

2.9.3 Feed conversion ratio of rabbits

The efficiency with which an animal transforms feed into more body mass is measured by the feed conversion ratio (FCR) (Fry *et al.*, 2018). Thus, it indicates how efficiently an animal is converting feed into a desired output, which could be milk, meat, eggs, etc. According to Fry *et al.* (2018), feed conversion ratio is calculated by dividing the kilogram of feed consumed by the kilogram of body weight gain. According to Gidenne *et al.* (2020), one important indicator for assessing a farming system's effectiveness and profitability is feed efficiency, which is typically represented as FCR.

According to Shaikh *et al.* (2024), rabbits have a high feed conversion efficiency, with feed/ gain ratios of 2 - 2.3 on high-grain diets and 3 - 3.8 on high-forage, grain-free diets. Moreover, research conducted by Adeyemi *et al.* (2008) reported feed conversion ratio of 2.87 - 3.54 when rabbits were fed with Cassava peels and leaves in diets. Okorie (2003) used palmitic acid-fortified maize wet milling by-product recorded a range of FCR as 2.63 to 4.0. However, Mafimidiwo *et al.* (2022) recorded higher values of FCR of 5.23 – 7.22, although not statistically significant, when rabbits were fed with varying levels of urea-molasses treated maize cob as replacement for wheat offal.

In a related study, Jadori *et al.* (2024) also reported significantly higher FCR ranges of 4.90 – 5.59 when rabbits were fed with varying levels of millet offal as a replacement for maize offal. Anya *et al.* (2018) fed rabbits with cocoa bean shell meal-based diets for 60 days and recorded an average FCR value of 4.75, which was lower than what was

reported by Jadori *et al.* (2024). Ruknuzzaman (2016), in an experiment using dietary urea molasses multi-nutrient cake (UMMC) on rabbits, reported a significant difference in FCR between the rabbits of control group (6.06) and rabbits fed 6 % (4.63) and 8 % (4.85) urea-containing UMMC. Although rabbits fed 4 % urea containing UMMC showed slightly lower FCR (5.44), but did not significantly differ ($P > 0.05$) from the control group (6.06).

2.10 Reproductive Performance of Rabbits

The ability of rabbits to reproduce is a crucial component in assessing the economic feasibility and profitability of production (Sam *et al.*, 2020). Smith and Akinbamijo (2000) stated that genetics, the physical environment, and more importantly, nutrition, influence farm animals' ability to reproduce. According to the authors, an adequate diet may even mitigate the adverse impacts of adverse physical environment and help mediocre biological types realize their genetic potential. Bhutia *et al.* (2017) opined that good productivity in livestock requires dietary balance to get a high reproductive and productive quotient.

2.10.1 Gestation length

It is the length of time between successful conception and birth. According to Wambai (2023), the gestation period in rabbits lasts 28 - 32 days, and if properly managed, the doe can produce four or five litters per year. Ruknuzzaman (2016) fed rabbits with different inclusive levels (0 %, 4 %, 6 %, and 8 %) of urea molasses multi-nutrient cake (UMMC) and reported that the different levels of UMMC showed no significant effect on gestation length. The author recorded values that ranged from 31.40 to 32.00 days. In a related study, Salma *et al.* (2002) reported a gestation period of 31.60 - 32.30 days in

rabbits supplied with different levels of protein. Rashwan *et al.* (2003) indicated that a rabbits typically kindle between 31 and 33 days following either artificial insemination or natural mating.

2.10.2 Litter size at birth

Meky *et al.* (2023) asserted that the most crucial economic factor in rabbit production is litter size. Litter size refers to the live birth of multiple offspring at one time in animals from the same mother. According to Silvestris *et al.* (2019), insufficient calories, protein, vitamins, and micro- and macro-minerals were associated with poor reproductive success in rabbits. Inadequate nutrition reduces the number of ova and spermatozoa produced, leading to conception failure or the birth of fewer and weaker offspring (Evans *et al.*, 2022). The doe is characterized as polytochous, and the number of kits that are born and successfully weaned is a measure of the doe's performance (Mambiri, 2013). The number of offspring born is closely related to the rate of ovulation, the capacity of the uterus, and the survival rates of embryos or fetuses in the doe (Szendr\Ho *et al.*, 2019; Garca *et al.*, 2021).

Omar *et al.* (2022) opined that larger litter sizes in rabbits are associated with lower birth weight and increased mortality. Fadare and Fatoba, (2018) recorded that the litter size, averaging 9.5 kits from temperate regions, has failed to materialise in the tropics. Adeyemi (2014) reported that the average litter size is about 6 in the tropics, but it can range from 4 to 12, as an average doe is equipped to nurse up to 8 kits. Moreki *et al.* (2019) also substantiated that litter size per doe ranged from 6 to 10 kits with 5 to 6 litres per year. Brahmantiyo *et al.* (2018) recorded an average litter size of 8.5 kits and, life litter size of 8.0 kits. Hasanat *et al.* (2006) in a study found that with the exception of the

inclusion of urea, rabbits given the identical concentrate supplement at birth had an average litter size of 2.50 to 3.25.

2.10.3 Average litter weight at birth

Various environmental factors, including parity, lactation status, season of farrowing, nest quality, cannibalism among the kits, and sex, influence the weight of the kits after birth (Belabbas *et al.*, 2022). Konan *et al.* (2021) fed local rabbits does with *Desmodium tortuosum*, *Euphorbia heterophylla* and *Moringa oleifera* recorded an average litter weight of 52.45 g. Olateju and Chineke (2022) in a study on how genotype affects crossbred kits' reproductive performance found that the kits that were born with the lowest birth weight ($66.75 \text{ g} \pm 0.51$) were those that were bred within a short time (29) days, pre-weaning kits weight ($379.60 \text{ g} \pm 21.85$), that is, body weight at 21 days ($207.20 \text{ g} \pm 5.00$) and post-weaning weight (body weight at 35 days: $319.40 \text{ g} \pm 12.43$). The one with the maximum body weight at 21 days ($395.50 \text{ g} \pm 1.50$), body weight at 35 days ($564.00 \text{ g} \pm 1.00$), and birth weight ($217.00 \text{ g} \pm 3.00$) were all at 34 days of gestation.

2.10.4 Litter size and litter weight at weaning

Fadare and Fatoba (2018), the weight of the kit at weaning is determined by the size of the litter; a larger litter results in a lower weight. According to the authors, the average size of litter at weaning was 5.68 kits with weaning weight of 423.7 g. Brahmantiyo *et al.* (2018) found that the average litter size was 8.5 kits, the live litter size was 8.0 kits, and the weaned litter size was 6.5 kits at the first mating age of 144 days. The litter size at birth was 8.15, and the number live kits decreased from 7.37 at birth to 6.05 kits at weaning was also reported by Belabbas *et al.* (2023).

2.10.5 Percentage livability

It refers to the percentage of kits that survived at weaning per the litter size at birth. Concerns about animal welfare are raised by decreased kit survivorship, which also increases the cost of producing rabbit meat. Pinto-Pinho *et al.* (2023) reported that mortality percentages during the suckling period were found to increase significantly with the increase in litter size at birth; the mortality rate was 10 – 15 % for litters of less than 8 kits, 20 % for those of 10 kits during the suckling period. This seems to be a result of a decrease in the average individual weight per litter at birth. In addition, with increased litter size, the competition for teats is greater, and consequently, the smaller rabbit obtains less milk (Vidjannagni *et al.*, 2018; Zepeda *et al.*, 2019). Rabbit kits depend completely on their feeding on doe milk during the first 20 days lactation period, and an increase in total milk yield during the lactation period leads to an increase in the livability of the kits (Rashwan and Marai, 2000). Belabbas *et al.* (2023) reported that 26 % of born rabbit kits perished before weaning. Rashwan and Marai (2000) indicated that pre-weaning loss was estimated to be 70 % - 78 % in the first week and 16.63 % in the second week of life.

2.11 Haematological Characteristics of Rabbit

Rabbits are fed a variety of feed items with little consideration for their physiological impacts or overall health. The most often utilized parameter for assessing these effects is animal haematology (Ayo-Ajasa *et al.*, 2022). According to Garba *et al.* (2022), haematological measurements, including haemoglobin concentration, white blood cell count, red blood cell count, and haematocrit value, are frequently used to check the physiological state and general health of both humans and animals. Ibezute *et al.* (2023)

also posited that since blood serves as the body's main transport system, haematological investigations are important. Evaluations of the haematological profile usually offer vital information on how the body responds to various types of injury, including toxic injury. Anaemia is indicated when the rabbits' haematological values are below the normal range, however when they are within the normal range, it indicates that the diets had no negative effects on their haematological parameters during an experimental period (Ayo-Ajasa *et al.*, 2022).

Ogbuewu *et al.* (2019), indicated that the haematological variables that are most frequently impacted by pathological and nutritional factors are red blood cells (RBCs), haemoglobin concentration (HGB), packed cell volume (PCV) or haematocrit (HCT), white blood cells (WBCs), mean corpuscular haemoglobin (MCH) mean corpuscular haemoglobin concentration (MCHC), lymphocyte count (LYM), platelet count (PLT), and granulocyte count (GRA). Ayo-Ajasa *et al.* (2022) conducted research using different feed types on male and female weaned rabbits and reported the ranges of some blood parameters for rabbits as follows: HCT: 30 – 35 %, HGB: 9.3 – 19.3 g/dl, and RBC: 4.00 – 8.60 ($\times 10^6 / \text{mm}^3$). Amao *et al.* (2023) also reported a normal range of HCT (33.50 - 50 %) in adult rabbits. Packed Cell Volume, according to Ikyume *et al.* (2018) is involved in the transport of oxygen and food nutrients. Onoja and Mallam (2022) shown that a rabbit's WBC count between 5 - 13 ($\times 10^9 / \text{l}$) is regarded as being within the normal range.

Martins *et al.* (2020); Oluwafemi *et al.* (2020); Emerue *et al.* (2022) in their respective studies indicated that rabbits with WBC levels within the usual range are healthy, whereas those with WBC levels below the normal range are indicative of allergic reactions, anaphylactic shock, and certain parasites. Etim *et al.* (2014) reported a RBC

range in rabbits to be 4.8 – 6.3 ($\times 10^6$ /mm³). Makanjuola *et al.* (2014) asserted that healthy animals and high-quality dietary protein are linked to elevated RBC levels. Akintunde *et al.* (2019) recorded a normal range of HGB's to be 8 - 17 g/dl and it shows that the essential physiological link between haemoglobin and oxygen in the transportation of gases (oxygen and carbon dioxide) to and from the body's tissues has been maintained and was normal. Amaza *et al.* (2020) in a study, fed rabbits with varying amounts of yam peel meal to replace maize, significantly reported the following ranges of haematological indices: WBCs: 6.97 – 19.73($\times 10^3$ uL), HGB: 9.60 – 15.97 g/dL, HCT: 30.33 – 50.90 %, PLT: 169 – 299.30($\times 10^3$ uL), and MCHC: 30.70 – 32.73 pg.

Table 2.1: Normal physiological range of some haematological indices of the rabbit

	Male		Female	
	Mean \pm SEM	Range	Mean \pm SEM	Range
WBC ($\times 10^9$ /L)	11.40 \pm 0.61	5.90-18.30	10.44 \pm 1.05	5.80-20.10
HCT (%)	48.91 \pm 0.83	41.70-57.00	42.18 \pm 1.09	33.10-47.70
HGB (g/L)	175.2 \pm 3.5	41.70-57.00	148.1 \pm 5.4	108.0-175.0
GRA ($\times 10^9$ /L)	6.04 \pm 0.45	1.70-12.10	6.61 \pm 0.85	1.70-14.70
GRA (%)	51.91 \pm 2.20	27.00-73.00	61.87 \pm 3.58	24.00-79.00
LYM ($\times 10^9$ /L)	5.37 \pm 0.30	2.90-8.90	4.15 \pm 0.46	1.40-8.20
LYM (%)	48.08 \pm 2.20	27.00-73.00	38.12 \pm 3.58	21.00-76.00
PLT ($\times 10^9$ /L)	496.3 \pm 36.5	135.0-1005.0	589.4 \pm 72.0	62.0-1188.0
MCHC (g/dl)	357.9 \pm 2.3	317.0-368.0	349.7 \pm 4.6	315.0-368.0
RBC ($\times 10^{12}$ /L)	5.69 \pm 0.24	3.87 – 6.46	9.35 \pm 1.04	4.78 - 6.53

HCT, haematocrit value; *HGB*, haemoglobin concentration; *WBC*, white blood cell count; *MCHC*, mean erythrocyte haemoglobin concentration; *LYM*, lymphocyte *PLT*, thrombocyte count. *SEM*: Standard error of the mean.

Sources: (Özkan *et al.*, 2012; Argente *et al.*, 2019).

2.12 Serum Biochemical Characteristics of Rabbit

Serum biochemistry refers to the chemical analysis of serum, the liquid components of blood that remain after the cells and clotting factors have been removed (Lima-Oliveira *et al.*, 2018). Blood serum components include glucose, proteins, electrolytes, enzymes, lipids, and other metabolites. Understanding blood biochemistry is crucial for assessing the health status of rabbits and diagnosing diseases. According to Özkan *et al.* (2012), the following are some of the serum biochemical indices that are normally used to assess the health status of rabbits: alanine aminotransferase, aspartate amino transferase, alkaline phosphatase, glucose, serum urea concentration, Creatinine, total bilirubin, triglyceride, total cholesterol, serum proteins including albumin and globulin and some electrolytes like sodium, potassium, chloride, and calcium.

Serum biochemistry analyses provide useful details about the overall health and operation of numerous organ systems, which can reveal details about the rabbit's internal health. According to Adeyemi *et al.* (2015), liver function is indicated by certain enzymes, including alkaline phosphatase (ALP), aspartate aminotransferase (AST), and alanine aminotransferase (ALT). Elevated levels of these enzymes may suggest liver disease or injury in rabbits. Kidney function is measured using blood urea nitrogen (BUN) and Creatinine levels. Elevated levels may indicate kidney disease or dehydration. Amaza *et al.* (2020) in a study, fed rabbits with graded levels of yam peel meal as replacement for maize significantly reported the following ranges of serum biochemical indices; total protein (TP): 54.67 – 66.33, albumin (ALB): 33.33 – 41.00 g/L, serum urea: 9.63 – 19.00 g/dL, total bilirubin (T.BIL): 0.83 – 6.97 mmol/l, AST: 43.33 – 47.33 U/L, and ALT: 46.33 – 60.67 U/L. In a related study, Jimoh *et al.* (2023) compared three plants protein cakes; groundnut cake, cottonseed cake and palm kernel

cake meal on rabbits and recorded the following range of serum biochemical indices; serum urea: 7.43 – 9.00 mmol/L, Creatinine: 0.83 – 8.70 g/dL, ALP: 56.67 – 60.00 U/L, ALT: 8.00 – 11.00 U/L, AST: 5.33 – 6.67 U/L, total protein (TP): 57.00 – 60.33 g/L and albumin (ALB): 33.00 – 34.00 g/L. Iwegbu *et al.* (2023) fed weaned rabbits with different inclusive levels of *Carica papaya* aqueous leaf extract and significantly recorded varied range of values of the following; total protein: 5.31- 6. 85 g/dL, globulin: 2.04 – 3.83 g/dL, albumin: 1.97 – 3.20 g/dL, total cholesterol: 1.03 – 2.56 mmol/L, AST: 33.88 – 35.91 UL, ALT: 25.34 – 29.04 UL and Creatinine: 0.89 – 1.23 g/L.

Saleh *et al.* (2011) researched the impact of urea and/or bentonite supplementation on a few associated metabolic parameters with a control, bentonite-supplemented (with 2.5% sodium bentonite), urea-supplemented (with 1% urea), and urea-bentonite co-supplemented (1 % urea + 2.5% sodium bentonite) inclusion level. At the end of the feeding trial, the following values were significantly recorded on biochemical indices; (urea concentration: 2.19±0.01, 4.78b±0.08, 2.12 ±0.07, 2.17±0.08 mmol/l), (Creatinine: 85.3±0.9, 209.5±6.0, 84.1±3.2, and 90.9±2.8 mmol/l), (total protein: 68.14±1.18, 54.66±0.75, 68.07±1.40, and 75.36±0.99) to represent the treatments respectively.

Table 2.2: Normal reference range of some serum biochemical indices of the rabbit

Parameters	Mean	SEM	Range
Albumin (g/L)	48.66	0.77	25.0 -40.0
Total Protein (g/L)	71.37	0.83	50.0 – 75.0
AST (U/L)	33.27	2.78	5.0 -98.0
ALP (U/L)	98.98	10.79	10 - 96
ALT (U/L)	28.18	3.32	5 – 260
Creatinine (g/dL)	1.00	0.07	0.5 – 2.6
Total bilirubin (g/dL)	0.28	0.02	0 – 0.7

Total cholesterol (mmol/L)	37.35	2.21	10 - 80
Triglycerides (g/dL)	91.67	6.77	15 - 160

AST: aspartate aminotransferase, ALP: alkaline phosphatase, ALT: alanine aminotransferase, and, AST: aspartate aminotransferase, ALP: alkaline phosphatase, ALT: alanine aminotransferase, and SEM: standard error of means.

2.13 Carcass Traits of Rabbit

Carcass quality must meet financial goals like marketable meat output and attraction to consumers (Okanlawon *et al.*, 2020). According to Sam *et al.* (2020), the adult rabbit's weight and maturity at the time of slaughter have an impact on carcass characteristics. Depending on local eating habits, the dress-out rate may be significantly higher if the skin is also consumed. Therefore, a single doe can yield up to 70 kg of high-quality meat annually (Handlos, 2018).

2.13.1 Live body weight of the rabbit

Live weight is the whole-body weight of a live animal. It is the weight of the animal taken immediately before slaughter. Tag-El Din (2019) conducted research on rabbits by feeding them with dietary nano-zinc and nano-selenium addition for 12 weeks and recorded the following values for live body weights at the end of the feeding trial: 2146.0 g±52.3, 2202.0 g±62.2, 2299.0 g±54.1 to represent the control (30 and 60 mg Nano-Zn/kg, respectively) and other treatments supplemented with 0.1 and 0.3 mg Nano-Se/kg respectively. In a related study on rabbits, Dorra *et al.* (2013) used stocking density and added dietary organic acids to determine growth performance in a 12-week feeding trial, and recorded a non-significant range of values of live body weight, 2072 – 2158 g±50.0, between treatments.

Moreover, Imbabi *et al.* (2021) conducted research on the effects of using fennel essential oil in place of antibiotics in rabbit diets on levels of antioxidant enzymes, growth, and meat quality for 12 weeks. At the end of the research, average live body weights between treatments were significantly recorded as 1443, 1684, and 1700 ± 36.28 g. Also, North *et al.* (2019) had 12 weeks of research on dietary quercetin supplementation and sex thereupon rabbit caecal micro biota. At the end of the research, varied, non-significant live body weights of 2039, 2032, and 2046 ± 166 g were recorded between treatments. These differences in live body weight recorded in a previous study need to be researched to prove the validity.

2.13.2 Slaughter weight of rabbit

The slaughter weight of an animal is the carcass's gross weight, which includes the internal organs, head, feet, and hide or skin, but does not include the portion of blood that is not recovered after slaughter (Africa, 2012). Yaranoğlu *et al.* (2023) in a study found that the average slaughter weight for New Zealand was 2.3 kg. Kaidi *et al.* (2010), studied both the impact of slaughter weight (2.2, 2.4, and 2.6 kg) and slaughter age (70 to 77 days). North *et al.* (2018) conducted research work on investigating how quercetin supplementation affects the carcass and meat quality of New Zealand white rabbits in 12-week duration and recorded an average slaughter of 3200 ± 101 g, 3234 ± 87.9 g in response to the control and the diet 2 kg quercetin dihydrate, respectively. Pałka *et al.* (2023) experimented to evaluate New Zealand white rabbits (NZW), Grey Flemish Giant (GFG) rabbits, and their crossbreds in terms of growth, slaughter performance, and specific meat quality characteristics (meat texture and basic chemical make-up). The authors recorded a significant average slaughter weight of 2511 g for NZW, 2896 g for the cross NZW \times GFG, and 3057 g for GFG.

2.13.3 Dressed carcass weight of rabbits

The term "dressed carcass weight" describes the weight of an animal following partial slaughter, which includes the removal of all internal organs, often the head, and inedible (or undesirable) parts of the tail and legs. It consists of the body parts that were left behind after this first slaughter, such as bones and cartilage. Oko *et al.* (2018) embarked on a 12-week feeding trial by feeding rabbits with dietary cocoa (*Theobroma cacao*) pod husk meal and significantly recorded the following values of dressed carcass weights 1500 g, 1283 g, 1283 g, 1217 g, 1483 g, 1333 g, 1300 g, 1033 g, 1183 g, 1183 g, 1017 g, 966.7 ± 106.9 g in respect to the different levels of treatments. In a study to determine how *Moringa oleifera* leaf meal affected growth, nutrient digestibility, blood composition, and carcass characteristics of New Zealand white rabbits, Rahmy *et al.* (2023) reported varied but non-significant dressed carcass weights of 1270.3 g, 1362.8 g, 1389 g, and 1390 g for 0 % MOLM, 10 % MOLM, 20 % MOLM, and 30 % MOLM inclusion levels, respectively. Pałka *et al.* (2023) also recorded dressed carcass weights of 1205 g, 1496 g, and 1432 g for New Zealand White rabbits (NZW), crossbreds (NZW \times GFG) Grey Flemish Giant (GFG) rabbits, respectively.

2.13.4 Dressing percentage of rabbit

Dressing percentage is the fraction of dressed carcass weight to the live weight of the animal, expressed as a percentage. Thus, it is calculated as: (dressed carcass weight \div the live weight) \times 100. A higher dressing percentage is an indication of more meat yield, better muscle-to-bone ratio, and less waste. It means that a larger proportion of the animal's live weight is converted into usable carcass weight. According Jiwuba *et al.* (2020), dressing percentage of rabbits normally ranges from 50 to 56 % and tends to be

greater if the rabbits are fully grown and have some fat. However, in a study, Oko *et al.* (2018) embarked on a 16-week feeding trial by feeding rabbits with dietary cocoa (*Theobroma cacao*) pod husk meal and reported dressing percentage values of 60.40, 63.64, 61.60, 62.39, 62.24 62.99, 60.47, 61.39, 62.28, 61.21, 59.80, 59.79±1.13 % in respect to the different levels of treatments although, the values were not significant.

Mafimidiwo *et al.* (2022) conducted research by feeding rabbits with different levels of urea-molasses-treated maize cob in place of wheat offal and significantly reported dressing percentage of 61.16, 63.55, 58.64, 50.65, 56.34±3.04 % with respect to the level of treatment. These values were higher than 45.30 % to 50.18 % reported by Njidda and Isidahomen (2010), when rabbits were fed with grasshopper meal as a substitute for fishmeal. In a related study, Olatubosun and Tech (2014) conducted research by feeding growing rabbits with two feed forms of different particle sizes. At the end of the experiment, the following values of dressing percentages were significantly recorded: 64.36, 63.73, 66.86, 62.54±1.41 % for the treatment levels. Rabbits were fed with dietary supplementation with *Moringa oleifera* leaves in response to the inclusion levels, 0.5 %, 1 %, and 1.5 % by Selim *et al.* (2021). At the end of the feeding trial, dressing percentages of 58.23, 58.61, 59.15, and 61.74±0.56 % were observed for the treatment levels.

2.13.5 Caecal pH level of rabbits

Studies have shown that feeding rabbits with urea-treated diets can lead to changes in the pH levels of their gastrointestinal tract. Geiger (2019) reported that when urea is metabolized in the rabbit's digestive system, it results in the production of ammonia, which can affect the pH of the digestive tract. Studies investigating the effects of urea-

treated diets on rabbit physiology have reported varying pH levels in different parts of the digestive tract. Ruknuzzaman (2016) posited that adding urea to rabbit diets increases the pH of the digestive contents, particularly in the caecum. Miranda *et al.* (2024) reported that urea-treated diets may lead to an increase in pH levels, particularly in the caecum, where fermentation of fibrous material occurs. The increase in pH in the caecum creates a more alkaline environment, which can influence the microbial populations responsible for fibre digestion. Varga (2014) was of the view that caecal pH is most acidic in the middle of the day and most alkaline in the morning, exhibiting a daily rhythm resembling feeding behaviour. Fluctuations in caecal pH affect the population of caecal micro-organisms. However, a study by El-Deep *et al.* (2020) observed that rabbits fed a diet supplemented with urea exhibited a significant decrease in caecal pH compared to those fed a control diet. The authors attributed this reduction in pH to increased microbial fermentation of urea in the caecum, resulting in the production of volatile fatty acids (VFAs) and other acidic metabolites. The addition of urea to the diet can alter microbial fermentation patterns, leading to an accumulation of acidic metabolites and a subsequent decrease in caecal pH. According to Maklad *et al.* (2023), the pH level in the caecum of the rabbit is typically higher, ranging from 6.5 to 7.5 or even higher, creating an ideal environment for the growth of beneficial bacteria that aid in the digestion of fibre. This range of pH levels may differ when measured in other parts of the rabbit's system.

Selim *et al.* (2021) recorded caecal pH values of 7.17, 7.16, 7.18, 7.11 ± 0.09 when rabbits were fed with dietary supplementation with *Moringa oleifera* leaves in response to the inclusion levels, control, 0.5 %, 1 %, and 1.5 %, respectively. Tripathi *et al.* (2008) conducted research by feeding rabbits with varying amounts of high-glucosinolate

mustard (*Brassica juncea*) meal to replace soya-bean meal (SBM) in the diets of broiler rabbits and reported caecal pH values of 6.19, 6.03, 5.95, and 5.85 in response to the inclusion levels of 0, 80 g, 160 g and 245 g of the mustard meal respectively. Another research was carried out by Rodríguez-Romero *et al.* (2013) who raised rabbits on diets with different amounts of neutral detergent soluble and insoluble fibre and recorded a caecal pH of 6.2. In a related study, Alvarenga *et al.* (2017) conducted research by looking at the impact of feed form on rabbits' caecal characteristics and diet digestibility and reported 7.02, 6.38, and 6.42 ± 0.083 in response to the difference in the feed form as muesli, pelleted, or extruded. The feed had a significant effect ($p = 0.002$) on the pH values recorded.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Location and Duration of Study

The experiment was carried out at the Akenten Appiah-Menka University of Skill Training and Entrepreneurial Development (AAMUSTED), Asante Mampong campus, at the Rabbitry Unit of the Department of Animal Science Education, from 3rd November, 2023 to 12th March, 2024. Asante Mampong is located 60 km North-East of Kumasi on the Kumasi-Ejura Road. Asante Mampong is typically characterized as a hot, humid forest-savannah transitional zone, and it is located between latitudes 07° 04'N and longitude 010° 24'W (Jnr *et al.*, 2013). According to the Meteorological Service Department (2019), the lowest and highest yearly temperatures observed throughout the study period were 22 - 33°C, respectively.

3.2 Research Design

The experiment was carried out by using a 2 × 4 factorial in the Randomized Complete Block Design with eight treatments. Each treatment comprised four (4) female rabbits. The factors are;

1. First factor: Feed form at two (2) levels (Pelleted and Non-pelleted)
2. Second factor: Urea at four (4) levels (0 %, 2 %, 4 %, and 6 %)

3.3 Experimental Animals and Management

Thirty-two (32) weaned crossbred rabbits (Chinchilla × New Zealand White), all females of averagely 8 weeks old, were obtained from the Ministry of Food and Agriculture, Kumasi, in the Ashanti region of Ghana for the research. The animals were allotted randomly into eight dietary treatments, with four rabbits per treatment, and each rabbit served as a replicate. The experimental animals were maintained in rabbit hutches, 3-tier

wooden cages with a metal-wire bottom to allow easy faeces collection were used for keeping the experimental rabbits. Each of the rabbits was kept in a separate cage which measured 60 cm × 75 cm. The three-tier wooden cages were placed in an open environment with a shed (out-door unit) and a natural lighting regime for the animals.

Before the commencement of the experiment, 1 ml of Sulphadimidine Sodium (333 mg/ml) injection was given to each rabbit subcutaneously as a prophylaxis for coccidiosis. Each of them was again treated with Ivermectin 2 % injection, also subcutaneously, against internal and external parasites. Other management practices, like cleaning and disinfecting the hutch to avoid the accumulation of urine and faeces, were done daily for all treatment groups. Drinking and feeding troughs were made available to the rabbits. The animals were fed with the experimental diets twice daily (morning and evening) with a quantity depending on the weight of the animals, and portable drinking water was offered *ad-libitum* for the experimental duration.

3.4 Preparation of Experimental Diets

Dried maize husks of 'Asontem' maize variety were collected from a farmland in Asante Mampong, further sun-dried for 3 days until the husk became crispy. The husks were chopped into a smaller size of about 3 to 5 cm with a pair of scissors. The chopped maize husks were treated at room temperature with four different levels of urea (0 %, 2 %, 4 %, and 6 %). The husks were treated by dissolving 2 kg, 4 kg, and 6 kg of urea in 100 litres of water to make urea-water solution and were used to treat 100 kg of dried and chopped maize husk, respectively. The treated husks were kept air-tight in a polythene sheet and kept in a room for 72 hours. After treatment duration of 72 hours, the treated husks were sun-dried to remove the moisture content before milling using the hammer mill with a

sieve diameter of 2 mm. In all cases, 30 % of the urea-treated maize husks were used with the basal diet to formulate and compound a 100 kg feed for each group of the experimental animals. In addition to the 30 % treated maize husk, the following feed ingredients were used to compound the basal diet for the experimental animals: soyabean, wheat bran, cassava flour as a binder, vitamin premix, dicalcium phosphate, and salt. Part of each compounded feed was pelleted (diameter: 3.5 mm; length: 11 mm, and a steam temperature of 80 °C) according to the procedure outlined by Birolo *et al.* (2022).



Plate 3.1: Spraying urea solution on maize husk with knapsack machine

Treatments were given based on the factors indicated with the basal diet.

1. Basal diet + 0 %, urea treated maize pelleted (PU0 %)
2. Basal diet + 0 % urea treated maize non-pelleted (NPU0 %)
3. Basal diet + 2 %, urea treated maize pelleted (PU2 %)
4. Basal diet + 2 %, urea treated maize non-pelleted (NPU2 %)
5. Basal diet + 4 %, urea treated maize pelleted (PU4 %)
6. Basal diet + 4 %, urea treated maize non-pelleted (NPU4 %)

7. Basal diet + 6 %, urea treated maize pelleted (PU6 %)
8. Basal diet + 6 %, urea treated maize non-pelleted (NPU6 %)

Table 3.1: Percentage Compositions of Experimental Diets

Feed ingredients	0 % urea	2 % urea	4 % urea	6 % urea
Soya bean	15.80	15.00	13.00	11.72
Wheat bran	43.00	41.00	44.00	44.00
Maize husk	30.00	30.00	30.00	30.00
Cassava flour	10.00	12.80	11.80	13.08
Dicalcium phosphate	0.200	0.200	0.200	0.200
Vitamin Premix	0.500	0.500	0.500	0.500
Salt	0.500	0.500	0.500	0.500
Total (%)	100.0	100.0	100.0	100.0
Calculated nutrient compositions				
Crude protein (%)	16.85	16.71	16.80	16.75
Crude fibre (%)	16.85	15.95	16.77	16.17
Ash (%)	5.039	5.128	5.051	5.098
Ether Extract (%)	7.190	8.341	8.988	10.16
Nitrogen Free Extract	45.15	44.70	43.77	43.06

3.5 Data Collection and Handling

3.5.1 Growth performance evaluation

The animals were weighed at the commencement of the experiment to ascertain their initial weight and to balance the weights to have similar weight for all treatments. The data collected were daily feed intake, weekly body weight, body weight gain and feed conversion ratio.

3.5.2 Feed intake

Each replicate was fed with the respective experimental diets twice daily (morning and evening). The quantity of the feed provided daily and the leftover of the previous day's feed were weighed for each replicate to determine the daily feed intake. All measurements were done in grams (g/day)

Daily feed intake (g) = daily feed given (g) – daily feed left over (g).

The total daily feed intake for each replicate during the week was added as the weekly feed intake (WFI). Total feed intake (TFI) per replicate was calculated by adding all the weekly feed intakes within the feeding trial period.

3.5.3 Weekly body weight

To monitor the growth pattern of the animals in response to the experimental treatments, the weight of each replicate was taken on a weekly basis before feeding in the morning. Feed intake and body weights were measured using a Weighing EK-6000i electronic balance (A and D Co. Ltd, USA.) (Kyere *et al.*, 2020). Weekly body weight gain (WTG) per replicate was calculated as:

Weekly body weight gain (WTG (g)) = Final weekly weight - Initial weekly weight.

Total weight gain (TWTG) for each replicate was deduced by adding all the weekly weight gains within the trial period.

3.5.4 Feed Conversion Ratio (FCR)

The weekly feed conversion ratio for each replicate was calculated as:

Weekly Feed Conversion Ratio (FCR) = $\frac{\text{weekly feed intake (g)}}{\text{weekly weight gain (g)}}$

Average Feed Conversion Ratio (AFCR) = $\frac{\text{Average feed intake within the trial period (g)}}{\text{Average weight gain within the trial period (g)}}$

3.5.3 Reproductive performance assessment

Each doe was individually taken to the buck's cage at age four months (120 days) for mating in the ratio 1 buck: 4 does, and the number of services per conception was carefully monitored. The does were made to be mated several times to ensure a successful conception. On the 14th day of mating, abdominal palpation was performed to verify successful mating. Non-pregnant does were then re-mated in order to establish pregnancy. On the 27th day of the gestation period, each doe was provided with the nesting box. The parameters were weighed with the Weighing EK-6000i electronic balance (A and D Co. Ltd, USA) (Kyere *et al.*, 2020).

The reproductive traits measured were:

- 1. Gestation length (GL) (days)**

This is the period from the day of successful mating (conception) to the day of kindling.

- 2. Litter size at birth (LS)**

This is the total number of kits born by a doe at single kindling.

- 3. Litter weight at birth (LWT)**

The total weight of all the kits born together by each doe was taken at birth. Bunnies born were weighed within 24 hours. The weights were expressed in grams (g)

- 4. Litter size at weaning (LSWe)**

This was the number of kits weaned by each doe. The bunnies were weaned at the 35th day post-partum.

- 5. Litter weight at weaning (WeWT)**

The total weight of all the kits born together by each doe was taken after the bunnies were weaned at the 35th day post-partum

6. Liveability rate (LV %)

This is the percentage of kits that survived at weaning per the litter size at birth for each replicate. It was calculated as:

$$\text{Liveability rate (LV \%)} = \frac{\text{litter size at weaning}}{\text{litter size at birth}} \times 100 \%$$

3.5.4 Haematological and biochemical analysis

Blood samples were collected from each of three randomly taken rabbits per treatment after overnight fasting on the 187th day of the experiment to determine the biochemical and haematological properties. For the assessment of blood indices, approximately 4.0 ml of blood from each rabbit was collected from the central auricular artery of the ear. 2 ml was put into vials containing ethylene diamine tetra-acetic acid (EDTA) as an anticoagulant for haematological analysis. The following haematological parameters were examined: Erythrocytes (RBCs), Haemoglobin concentration (HGB), Packed cell volume (PCV/HCT), Total leucocytes count (WBCs), Differential leucocytes count, which includes Lymphocytes and Granulocytes, Platelet count (PLT), Procalcitonin test (PCT), Mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC).

The remaining 2 ml was put into heparinized tubes for serum biochemistry analysis. The blood samples for the biochemical analysis were allowed to clot at room temperature for 1-2 hours, then centrifuged at 3000 rpm for 30 minutes. Only clear and non-haemolysed serum was obtained and kept frozen until used for the analysis. The following biochemical parameters were analysed; Total Proteins, Albumin, Globulin, Total Cholesterol, Triglycerides, Bilirubin, Blood Plasma Urea, Creatinine, High-density lipoprotein cholesterol (HDL - C), Low-density lipoprotein cholesterol (LDL - C), Liver

enzymes; Aspartate aminotransferase (AST), Alanine aminotransferase (ALT), Alkaline Phosphatase (ALP). The collection of blood samples was done in the morning to avoid excessive bleeding and stress on the rabbits. The blood samples were analysed at the Mampong Municipal Hospital Laboratory by using the Fully Rayto Automated Chemistry analyser method (Abdulsalam et al., 2018).

3.5.5 Carcass evaluation

At the end of the feeding trials, three animals from each treatment group were randomly selected and euthanized for the carcass evaluation. The selected animals were starved for 12 hours to reduce the gut content and contamination of the carcass, and live body weight was recorded. Each animal was electrically stunned with a stun voltage of 170 volts for 5 seconds to render them unconscious before slaughtering (Fuseini, 2023). After each animal was made unconscious, a midline incision was made through the abdominal cavity and the caecum with a sterile scalpel.

The pH probe of a calibrated pH meter was inserted into the caecum to read and record the pH. The animals were slaughtered by cutting the jugular vein in the neck to remove blood from the rabbit's body. The weight of each slaughtered rabbit was measured before skinning. The weight of the head of each replicate was taken. The visceral content comprising the heart, trachea, oesophagus, stomach, lungs, liver, intestines, and kidneys were removed and weighed individually, after which they were summed up as the weight of visceral content (WTVC) in grams (g). The percentage of dressed visceral content (VC %) was calculated as:

Percentage Visceral content (VC %) = (weight of dressed visceral content)/(live body weight) x 100 %

Each of the following parts of the dressed carcass were weighed and summed up as the weight of dressed carcass content (WTDC) in grams (g)

1. **Legs** - the hind limb of the rabbit, including the femur, tibia, and fibula bones, as well as the surrounding muscle and connective tissue
2. **Thigh** – the upper portion of the hind leg, including the femur bone and surrounding muscles
3. **Loin** – the back of the rabbit, including the lumbar vertebrae and the surrounding muscles.
4. **Shoulders** – the front leg of the rabbit, including the humerus, radius, and ulna bones, a well as the surrounding muscle and connective tissue.

The dressing percentage (DC %) of each rabbit was calculated as:

Dressing percentage (DC %) = (weight of the dressed carcass)/(live body weight) x 100 %

3.6 Statistical Analysis

Analysis of variance was performed on the collected data using the two-way ANOVA option program in the Statistix Software Release version 10.0, (2024). Differences in treatment means were separated by using the Tukey's least significant difference at 5 % probability level.

CHAPTER FOUR: RESULTS

4.1 Proximate Composition

The result of the proximate composition of the urea-treated maize husks is presented in Table 4.1.

Table 4.1: Proximate Compositions of Maize Husk Treated with Different Levels of Urea (% DM basis).

Parameters	0 % urea	2 % urea	4 % urea	6 % urea
Moisture content (%)	7.920	6.380	6.400	6.350
Crude protein (%)	5.600	7.420	9.240	11.06
Crude fibre (%)	30.00	32.00	30.00	32.00
Ether Extract (%)	18.00	21.90	23.95	25.85
Ash content (%)	3.000	3.500	3.300	3.600
Nitrogen Free Extract (%)	35.48	31.18	27.09	23.08
Digestible Energy (Kcal/kg)	2942	3175	3197	3344

Moisture content in the treated husk varied. The 0 % urea maize husk contained the highest moisture 7.920 % whereas the 6 % urea level treated maize husk recorded lowest moisture content (6.350 %). Crude protein content increased with increasing urea level with 6 % urea level recording the highest percentage 11.06 % and 0 % (without urea) recorded the lowest percentage 5.600 % of crude protein. The crude protein content of the maize husk increased as the urea level also increased. Crude fibre in the maize husk treated with the different levels of urea was similar among treatments. 0 % and 4 % urea levels recorded 30.00 %, whereas 2 % and 6 % urea levels recorded 32.00 %. Ether Extract (Fat) increased with increasing urea levels with 0 % urea level recording the lowest 18.00 % as against the 6 % treated level which recorded the highest 25.85 %. 6 % urea level recorded the highest ash content of 3.600 % followed by 2 % urea level (3.500

%) and the lowest Ash content 3.000 % was recorded 0 % urea level. The available carbohydrate (NFE) in the treated maize husk decreased with increasing urea levels. The 0 % urea level recorded the highest (35.48 %) NFE whereas 6 % urea level treated maize husk recorded the lowest (23.08 %). The digestible energy in the maize husk treated with the different levels of urea was also recorded. Digestible energy tended to increase with increasing urea levels with the 6 % urea treated maize husk recording the highest digestible energy 3344 Kcal/kg and the lowest energy was obtained in the 0 % urea treated maize husk 2942 Kcal/kg.

Table 4.2: Proximate Compositions of the Experimental Diets (%)

Parameter	PU0 %	NPU0 %	PU2 %	NPU2 %	PU4 %	NPU4 %	PU6 %	NPU6 %
Moisture	9.840	9.720	10.04	9.640	9.920	9.750	10.11	9.810
Crude Protein	16.28	16.32	16.63	16.75	16.85	16.97	17.20	17.18
Crude Fibre	15.72	15.78	15.55	15.82	15.68	15.74	15.62	15.70
Ether extract	5.510	5.230	6.870	6.500	6.440	6.140	6.830	6.530
Ash content	5.170	5.880	4.800	4.950	5.230	6.000	5.280	4.780
NFE	45.82	46.24	43.67	43.37	45.45	44.56	45.42	44.25
DE (Kcal/kg)	3134	3269	3165	3173	3265	3247	3209	3124

PU0 % = 0 % urea level pelleted, NPU0 = 0 % urea level non-pelleted, PU2 % = 2 % urea level pelleted, NPU2 % = 2 % urea level non-pelleted, PU4 % = 4 % urea level pelleted, NPU4 = 4 % urea level non-pelleted, PU6 % = 6 % urea level pelleted, NPU6 % = 6 % urea level Non- pelleted, NFE = Nitrogen Free Extract, DE = Digestible energy

Moisture contents in the various treatment feed ranged from 9.720 to 10.11 %. The trend of crude protein content tends to vary between feed forms per each treatment diet and it is higher with the non-pelleted feed form as compared to the pelleted. For instance, 6 %

urea level non-pelleted (NP6) feed recorded higher crude protein 17.18 % against 16.28 % crude protein for 0 % urea level pelleted (P0). In all, crude protein content was highest 17.18 % in the 6 % urea level non-pelleted feed form and lowest 16.28 % in 0 % urea level pelleted feed. Carbohydrate content (NFE) in the treatment diets varied with 0 % urea level non-pelleted having the highest content value 46.24 % and 2 % urea level non-pelleted recorded the lowest value 43.37 %. The crude fibre content also varied between feed form per each treatment diet and the trend tended to be higher for non-pelleted feed form as compared to the pelleted feed.

In all, 2 % urea level non-pelleted feed form recorded the highest crude fibre content 15.82 % against the lowest 15.55 % recorded for 2 % urea level pelleted feed form. Ether extract (fat) content in the various treatment diets also varied. The highest ether extract value was recorded for the treatment with the 6 % urea levels; 6 % urea level pelleted recorded 6.830 % and 6.530 % for 6 % urea level non-pelleted. However, 0 % urea level pelleted recorded 5.510 % ether extract and 0 % urea level non-pelleted recorded 5.230 %. Digestible energy of the feeds varied. The lowest digestible energy was recorded in the 0 % urea level pelleted feed 3234 Kcal/kg and the highest was recorded in the 6 % urea level pelleted 3409 Kcal/kg.

4.2. Growth Performance

Table 4.3: Effects of dietary urea-treated maize husk and pelleting on weekly feed intake (g) of rabbits from 8 - 20 weeks old.

Source	WFI 1	WFI 2	WFI 3	WFI 4	WFI 5	WFI 6	WFI 7	WFI 8	WFI 9	WFI 10	WFI 11	WFI 12
Form												
NP	498.3	583.4	624.8	660.9	674.6 ^b	714.9 ^b	809.9	836.3	844.1 ^b	890.1	872.0 ^b	936.6
P	512.3	566.3	618.3	650.8	717.7 ^a	762.2 ^a	783.6	819.3	874.3 ^a	862.8	901.3 ^a	932.9
SEM	29.79	19.72	14.32	14.40	13.04	12.09	14.35	13.19	12.62	16.55	12.25	15.45
P - Value	0.643	0.395	0.658	0.490	0.003	0.001	0.081	0.210	0.026	0.114	0.027	0.817
Urea levels												
0 % urea	465.1	592.3	644.9 ^a	679.1 ^a	710.1	763.4 ^a	835.6 ^a	856.1 ^a	888.9 ^a	902.9	907.0 ^a	946.3 ^{ab}
2 % urea	485.6	550.1	578.9 ^b	619.1 ^b	679.9	717.9 ^b	766.3 ^c	789.9 ^b	823.9 ^b	856.5	869.3 ^b	915.3 ^b
4 % urea	527.4	582.5	629.8 ^a	646.9 ^{ab}	680.3	709.9 ^b	774.6 ^{bc}	821.8 ^{ab}	852.5 ^{ab}	854.4	863.8 ^b	909.0 ^b
6 % urea	542.9	574.4	632.6 ^a	678.4 ^a	714.3	763.0 ^a	810.6 ^{ab}	843.4 ^a	871.6 ^a	892.1	906.5 ^a	968.5 ^a
SEM	42.13	27.89	20.25	20.37	18.45	17.10	20.29	18.65	17.85	23.41	17.33	21.84
P - Value	0.253	0.490	0.019	0.022	0.139	0.005	0.009	0.010	0.010	0.115	0.030	0.043
Form x Urea Interactions												
NP x 0 % urea	397.3 ^c	577.5	614.5 ^{bc}	641.5 ^{bcd}	701.8 ^{abc}	770.8 ^a	833.3 ^a	850.0 ^{ab}	879.0 ^a	900.8	908.0	911.0 ^c
NP x 2 % urea	449.3 ^{bc}	532.8	582.5 ^c	631.0 ^{cd}	726.8 ^{ab}	773.5 ^a	813.8 ^a	831.5 ^{ab}	875.0 ^{ab}	880.3	877.5	904.3 ^c
NP x 4 % urea	584.3 ^a	636.0	668.0 ^{ab}	679.5 ^{abc}	698.5 ^{abc}	728.0 ^{ab}	797.5 ^{ab}	837.3 ^{ab}	880.3 ^a	886.3	894.3	923.2 ^{bc}
NP x 6 % urea	562.3 ^{ab}	587.3	634.0 ^{abc}	691.8 ^{ab}	743.8 ^a	776.5 ^a	795.3 ^{ab}	826.5 ^{ab}	863.0 ^{ab}	893.3	925.3	1007 ^a
P x 0 % urea	533.0 ^{ab}	607.0	675.3 ^a	716.8 ^a	726.8 ^{ab}	755.3 ^a	838.0 ^a	862.3 ^a	898.8 ^a	905.0	906.0	981.5 ^{ab}
P x 2 % urea	522.0 ^{ab}	567.5	575.3 ^c	607.3 ^d	633.0 ^d	662.3 ^c	718.8 ^c	748.3 ^c	772.8 ^c	832.6	861.0	926.3 ^{bc}
P x 4 % urea	470.5 ^{abc}	529.0	591.5 ^c	614.3 ^d	662.0 ^{cd}	691.8 ^{bc}	751.8 ^{bc}	806.3 ^b	824.8 ^{bc}	822.5	833.3	894.7 ^c
P x 6 % urea	523.5 ^{ab}	561.5	631.3 ^{abc}	665.0 ^{abcd}	684.8 ^{bcd}	750.3 ^a	826.0 ^a	860.3 ^{ab}	880.3 ^a	891.0	887.8	929.3 ^{bc}
SEM	59.58	39.44	28.64	28.80	26.09	24.18	28.70	26.37	25.25	33.10	24.51	30.89
P - Values	0.033	0.066	0.025	0.016	0.046	0.043	0.026	0.025	0.006	0.403	0.371	0.016

a, b, c = means bearing different superscripts in the same column are significantly at 5 %, probability level ($p < 0.05$), WFI = Weekly Feed Intake, NP = Non-Pelleted, P = Pelleted, SEM = Standard Error of Means.

Table 4.3 showed weekly feed intake from weeks 1 to 12 of rabbits fed with dietary urea-treated and pelleting maize husk meal in response to the effects on feed form (non-pelleted and pelleted), urea levels (0 %, 2 %, 4 %, and 6 %) and their interactions. Feed form showed no significant difference ($p > 0.05$) on weekly feed intake in the first four weeks of the trial. However, in weeks 4 and 6, feed form showed significant effect on weekly feed intake with the pelleted feed form recording the highest mean against the non-pelleted feed; 717.7 vs 674.6 g and 762.2 vs 714.9 g respectively. Though, in some of the weeks, non-pelleted feed form recorded higher feed intake (weeks 2, 3), the values recorded did not show any significant effect ($p > 0.05$). There were significant differences ($p < 0.05$) in weekly feed intake in response to the different urea levels in weeks 3, 4 and 6 with the 0 % urea level recording the highest weekly feed intake; 644.9 g, 679.1 g, 763.4 g in weeks 3, 4 and 6 respectively.

There were significant interactions between feed form and urea levels across all the weeks except week 2. Non-pelleted feed form treated with 6 % urea level recorded the highest feed intake 743.8 g and 776.5 g for weeks 5 and 6 respectively. Whereas the pelleted feed treated with 0 % urea recorded the lowest mean 675.3 g and 716.8 g for weeks 3 and 4 respectively. Feed form showed no significant differences ($p < 0.05$) on weekly feed intake in weeks 7, 8, 10 and 12. However, non-pelleted feed form recorded the highest feed intake as compared to the pelleted feed; 809.9 vs 783.6 g, 836.3 vs 819.3 g, 890.1 vs 862.8 g and 936.6 vs 932.9 g for weeks 7, 8, 10 and 12 respectively. In weeks 9 and 11, feed form significantly ($p = 0.026$) and ($p = 0.027$) affected weekly feed intake favouring the pelleted as compared to the non-pelleted feed; 874.3 vs 844.1 g and 901.3 vs 872.0 g respectively. The urea levels also exhibited a significant effect on feed intake with the 0 % level recording the highest intake in weeks 7, 8, 9, 11 and 12. Significant

interactive effect ($p < 0.05$) was shown between the feed form and the urea levels in weeks 7, 8, 9 and 12. Pelleted feed treated with 0 % urea level recorded the highest feed intake in weeks 8, 9 and 10.

Table 4.4: Effects of dietary urea-treated maize husk and pelleting on weekly body weight (g) of rabbits from 8 - 20 weeks old

Source	INT. WT	WT 1	WT 2	WT 3	WT 4	WT 5	WT 6	WT 7	WT 8	WT 9	WT 10	WT 11	WT 12
Form													
NP	947.2	1073	1219	1346 ^b	1506 ^b	1680 ^b	1851 ^b	2036 ^b	2226 ^b	2404 ^b	2601 ^b	2798 ^b	3000 ^b
P	948.9	1093	1250	1414 ^a	1595 ^a	1784 ^a	1980 ^a	2170 ^a	2370 ^a	2564 ^a	2757 ^a	2962 ^a	3165 ^a
SEM	14.53	18.69	20.60	28.86	29.18	28.39	30.11	31.56	33.15	36.33	34.24	32.85	34.60
P - Values	0.909	0.298	0.142	0.028	0.006	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Urea levels													
0 % urea	934.6	1062	1223	1383 ^{ab}	1545 ^{ab}	1725 ^{bc}	1916 ^a	2103 ^{ab}	2300 ^{ab}	2488	2663	2853 ^b	3056
2 % urea	957.6	1072	1228	1390 ^a	1566 ^a	1747 ^{ab}	1929 ^a	2110 ^{ab}	2303 ^{ab}	2481	2677	2878 ^{ab}	3073
4 % urea	972.8	1129	1285	1442 ^a	1622 ^a	1809 ^a	1991 ^a	2181 ^a	2374 ^a	2557	2757	2962 ^a	3165
6 % urea	927.1	1069	1201	1304 ^b	1470 ^b	1649 ^c	1826 ^b	2019 ^b	2215 ^b	2409	2619	2827 ^b	3035
SEM	20.55	26.43	29.14	40.81	41.27	40.15	42.59	44.63	46.89	51.38	48.43	46.45	48.93
P - Values	0.133	0.068	0.052	0.024	0.012	0.007	0.008	0.015	0.025	0.067	0.063	0.045	0.068
Form x Urea Interactions													
NP x 0 % urea	895.0 ^c	1005 ^c	1157 ^d	1311	1462	1643	1820 ^d	1998	2182	2353	2525	2700	2895
NP x 2 % urea	988.5 ^a	1097 ^{ab}	1259 ^{abc}	1405	1565	1731	1892 ^{bcd}	2080	2273	2443	2636	2833	3027
NP x 4 % urea	988.3 ^{ab}	1125 ^a	1265 ^{abc}	1385	1548	1723	1888 ^{ghcd}	2069	2260	2443	2652	2864	3075
NP x 6 % urea	930.0 ^{abc}	1066 ^{abc}	1195 ^{cd}	1282	1450	1625	1803 ^d	1998	2188	2376	2593	2796	3004
P x 0 % urea	974.8 ^{ab}	1120 ^{ab}	1290 ^{ab}	1455	1627	1807	2012 ^{ab}	2208	2419	2623	2801	3005	3217
P x 2 % urea	926.8 ^{bc}	1046 ^{bc}	1197 ^{cd}	1375	1567	1762	1966 ^{bc}	2140	2333	2520	2718	2923	3120
P x 4 % urea	970.3 ^{ab}	1134 ^a	1306 ^a	1499	1696	1895	2094 ^a	2293	2487	2671	2862	3060	3255
P x 6 % urea	924.3 ^{bc}	1071 ^{abc}	1208 ^{bcd}	1327	1490	1673	1849 ^{cd}	2041	2243	2442	2645	2858	3066
SEM	29.06	37.37	41.20	57.72	58.36	56.78	60.22	63.11	66.31	72.66	68.48	65.70	69.20
P - Values	0.021	0.035	0.025	0.180	0.163	0.189	0.008	0.104	0.105	0.138	0.097	0.063	0.064

a, b, c = means bearing different superscripts in the same column different superscripts in the same column are significantly at 5 % probability ($p < 0.05$) level, NP = Non-pelleted, P = Pelleted, INIT. WT =Initial Weight (g), WT = Weekly Body Weight (g), SEM = Standard Error of Means.

Table 4.4 showed data recorded from weeks 1 to 12 on weekly body weight of rabbits fed with urea-treated and pelleted maize husk meal in response to the effects of feed form (non-pelleted and pelleted), urea levels (0 %, 2 %, 4 %, and 6 %) and their interactions.

Though, not statistically significant, the pelleted feed recorded the higher body weight against the non-pelleted in weeks 1 and 2; (1093 vs 1073 g, $p = 0.298$) and (1250 vs 1219 g, $p = 0.142$) respectively. In weeks 4, 5 and 6, there were significant differences ($p < 0.05$) in body weight shown in response to both feed forms and urea levels. The highest weight favoured the pelleted feed form against the non-pelleted feed. Moreover, 4 % urea level recorded the highest weight against the lowest weight recorded by the 6 % urea; (1442 vs 1304 g), (1622 vs 1470 g), (1809 vs 1649 g) and (1991 vs 1826 g) for weeks 3, 4, 5 and 6 respectively. The interactions between feed form and different urea levels favoured the 4 % urea level pelleted feed in all the weeks (1 to 6) with significantly showing in weeks 1, 2 and 6; ($p = 0.035, 0.025$ and 0.008) respectively.

Feed form showed a significant effect ($p < 0.05$) on weekly weight across all the weeks from weeks 7 to 12 with the pelleted feed against the non-pelleted feed, (2170 vs 2036 g), (2370 vs 2226 g), (2564 vs 2404 g), (2757 vs 2601 g), (2962 vs 2798 g) and (3165 vs 3000 g) for weeks 7, 8, 9, 10, 11 and 12 respectively. 4 % urea level continued to show highest weight from weeks 7 to 12 with significant effects showing weeks 7, 8 and 11. The 6 % urea level recorded the lowest body weight across all the weeks from 7 to 12. Interactions between feed forms and urea levels showed no significant effect from weeks 7 to 12. However, the highest weights were recorded for the 4 % urea level pelleted in all the weeks

Table 4.5: Effects of dietary urea-treated maize husk and pelleting on weekly weight gain (g) from 8 - 20 weeks old

Source	WTG 1	WTG 2	WTG 3	WTG 4	WTG 5	WTG 6	WTG 7	WTG 8	WTG 9	WTG 10	WTG 11	WTG 12
NP	126.3	150.0	157.6 ^b	160.8 ^b	174.1	170.1 ^b	185.3	189.9	178.1 ^b	197.6	197.1	201.7
P	144.5	157.1	173.3 ^a	181.0 ^a	189.3	196.0 ^a	189.7	200.5	193.3 ^a	192.9	205.0	203.0
SEM	8.904	11.06	7.195	4.769	8.573	6.631	7.799	6.780	6.864	5.924	6.739	4.995
P - Values	0.053	0.526	0.042	0.000	0.091	0.000	0.575	0.134	0.037	0.431	0.252	0.795
Urea levels												
0 % urea	128.3 ^{bc}	160.6	159.9	161.8 ^c	180.5	190.8	186.6	197.9	187.5	174.9 ^b	189.6	203.4
2 % urea	114.5 ^c	156.1	172.0	176.4 ^{ab}	180.3	182.0	180.8	193.4	178.4	195.8 ^a	201.1	195.3
4 % urea	156.9 ^a	156.3	175.5	179.8 ^a	187.0	182.3	189.6	193.3	183.3	200.1 ^a	205.3	203.0
6 % urea	141.9 ^{ab}	141.3	154.4	165.6 ^{bc}	179.1	177.1	192.9	196.4	193.6	210.3 ^a	208.0	207.8
SEM	12.59	15.64	10.18	6.745	12.13	9.377	11.03	13.56	9.706	8.378	9.530	7.064
P - Values	0.018	0.630	0.158	0.043	0.913	0.546	0.729	0.951	0.463	0.003	0.265	0.378
Form x Urea Interactions												
NP x 0 % urea	110.0	152.0	154.3	151.3 ^d	181.0	176.8	177.5	184.5	171.5	171.3	175.8	194.8
NP x 2 % urea	109.0	161.8	165.8	160.8 ^{cd}	165.8	160.5	188.0	193.8	169.7	193.0	197.0	193.5
NP x 4 % urea	149.8	140.0	158.3	162.8 ^{cd}	174.5	165.3	180.8	191.8	182.5	209.3	212.3	211.0
NP x 6 % urea	136.3	146.3	152.3	168.3 ^{cd}	175.3	177.8	194.8	189.8	188.5	217.0	203.3	207.5
P x 0 % urea	146.5	169.3	165.5	172.3 ^{bc}	180.0	204.8	195.8	211.3	203.5	178.5	203.8	212.0
P x 2 % urea	120.0	150.8	178.3	192.0 ^{ab}	194.8	204.0	173.5	193.0	187.0	198.5	205.3	197.0
P x 4 % urea	164.0	172.3	192.8	196.8 ^a	199.5	198.8	198.5	194.8	184.0	191.0	198.3	195.0
P x 6 % urea	147.5	136.3	156.5	163.0 ^{cd}	183.0	176.5	191.0	203.0	198.8	203.5	212.8	208.0
SEM	17.81	22.12	14.39	9.539	17.15	13.26	15.59	13.56	13.73	11.85	13.48	9.990
P - Values	0.704	0.446	0.493	0.033	0.571	0.131	0.376	0.496	0.466	0.332	0.213	0.166

a, b, c = means bearing different superscripts in the same column are significantly at 5 % probability level ($P < 0.05$), WTG = Weekly Weight Gain (g), NP = Non-pelleted, P = Pelleted, SEM = Standard Error of Means.

From Table 4.5, the pelleted feed form recorded the highest weight gain across all weeks. The difference was significant in weeks 3, 4, and 6, and 9 with means of (173.3 vs. 157.6 g, $p = 0.042$), (181.0 vs. 160.8 g, $p = 0.000$), and (196.0 vs. 170.1 g, $p = 0.000$) and (193.3 vs 178.1 g, $p = 0.037$), respectively. Urea levels had significant effects on weight gain in weeks 1 and 4, with the 4 % urea level recording the highest value. Although, urea levels showed no significant difference in the weight gain recorded in weeks 2, 3, and 5, the trend favoured the 4 % urea level. The interactions between feed form and urea levels showed no significant effect ($p > 0.05$) in all weeks except week 4. The pelleted feed treated with 4 % urea recorded the highest weight gains of (164.0 g), (172.3 g), (192.8 g), (196.8 g), and (199.5 g) in weeks 1, 2, 3, 4, and 5. The pelleted feed form significantly recorded the highest weight gain compared to the non-pelleted feed in week 9; (193.31 vs. 178.06 g, $p = 0.037$).

There were no significant differences ($p > 0.05$) in weight gain during weeks 7, 8, 10, 11, and 12 with respect to feed form. However, the pelleted feed form recorded the highest weight gain against the non-pelleted feed; (189.7 vs. 185.3 g, $p = 0.575$), (200.5 vs. 189.9 g, $p = 0.135$), (205.0 vs. 197.1 g, $p = 0.252$), and (203.0 vs. 201.7 g, $p = 0.795$) for weeks 7, 8, 11, and 12, respectively. A significant effect was observed in week 10 concerning urea levels, with the 6 % urea level recording the highest weight gain (210.3 g) and the 0 % urea level recording the lowest weight gain (174.9 g).

Table 4.6: Effects of dietary urea-treated maize husk and pelleting on Weekly Feed Conversion Ratio (FCR) of rabbits from 8 - 20 weeks old

Source	FCR 1	FCR 2	FCR 3	FCR 4	FCR 5	FCR 6	FCR 7	FCR 8	FCR 9	FCR 10	FCR 11	FCR 12
Form												
NP	3.976	4.026	4.016 ^a	4.122 ^a	4.314 ^a	4.536 ^a	4.416	4.434	4.962 ^a	4.568	4.624 ^a	4.669
P	3.649	3.715	3.628 ^b	3.653 ^b	3.613 ^b	3.683 ^b	4.199	4.113	4.395 ^b	4.498	4.276 ^b	4.609
SEM	0.204	0.242	0.149	0.116	0.174	0.167	0.215	0.171	0.185	0.136	0.150	0.152
P-values	0.123	0.212	0.016	0.001	0.001	0.000	0.324	0.074	0.006	0.612	0.030	0.699
Urea levels												
0 % urea level	3.654	3.790	4.088 ^{ab}	4.201 ^a	4.004	4.046	4.560	4.363	4.798	5.173 ^a	4.856 ^a	4.676
2 % urea level	4.235	3.635	3.389 ^c	3.568 ^b	3.830	4.060	4.300	4.124	4.698	4.390 ^b	4.348 ^b	4.699
4 % urea level	3.478	3.891	3.660 ^{bc}	3.653 ^b	3.985	3.993	4.130	4.289	4.683	4.277 ^b	4.218 ^b	4.493
6 % urea level	3.885	4.166	4.150 ^a	4.129 ^a	4.036	4.340	4.240	4.319	4.536	4.294 ^b	4.379 ^b	4.689
SEM	0.288	0.342	0.211	0.164	0.246	0.239	0.305	0.242	0.262	0.192	0.213	0.214
P-values	0.080	0.481	0.004	0.001	0.840	0.478	0.552	0.774	0.799	0.000	0.035	0.741
Form x Urea Interactions												
NP x 0 % urea	3.625	3.900 ^{abc}	4.078 ^{ab}	4.245 ^a	3.918 ^{abc}	4.398 ^a	4.748	4.618	5.140	5.265	5.203	4.705
NP x 2 % urea	4.065	3.383 ^{bc}	3.535 ^{bc}	3.950 ^a	4.403 ^{ab}	4.870 ^a	4.335	4.325	5.220	4.570	4.490	4.695
NP x 4 % urea	4.038	4.705 ^a	4.248 ^a	4.180 ^a	4.638 ^a	4.483 ^a	4.455	4.423	4.873	4.285	4.223	4.380
NP x 6 % urea	4.178	4.118 ^{ab}	4.203 ^a	4.113 ^a	4.300 ^{ab}	4.395 ^{ab}	4.128	4.373	4.615	4.153	4.583	4.895
P x 0 % urea	3.683	3.680 ^{bc}	4.098 ^{ab}	4.158 ^a	4.090 ^{ab}	3.695 ^{bc}	4.373	4.108	4.455	5.080	4.510	4.648
P x 2 % urea	4.405	3.888 ^{abc}	3.243 ^c	3.185 ^b	3.258 ^c	3.250 ^c	4.265	3.923	4.175	4.210	4.205	4.703
P x 4 % urea	2.918	3.078 ^c	3.073 ^c	3.125 ^b	3.333 ^c	3.503 ^c	3.805	4.155	4.493	4.308	4.213	4.605
P x 6 % urea	3.593	4.215 ^{ab}	4.098 ^{ab}	4.145 ^a	3.773 ^{bc}	4.285 ^{ab}	4.353	4.265	4.458	4.395	4.175	4.483
SEM	0.407	0.484	0.298	0.231	0.347	0.337	0.431	0.342	0.371	0.272	0.301	0.303
P-values	0.080	0.029	0.041	0.008	0.027	0.035	0.523	0.854	0.379	0.450	0.464	0.528

a, b, c = means bearing different superscripts in the same column are significantly at 5 % probability level ($p < 0.05$), FCR = Feed Conversion Ratio, NP = Non-Pelleted, P = Pelleted, SEM = Standard Error of Means

Table 4.6 illustrates the results obtained from weeks 1 to 12 on weekly feed conversion ratio (FCR) of rabbits fed with urea-treated and pelleted maize husk meal, in response to feed form (non-pelleted vs. pelleted), urea levels (0 %, 2 %, 4 %, and 6 %), and their interactions. The table indicates that neither feed form nor urea levels had a significant effect on FCR during weeks 1 and 2. However, the non-pelleted feed form exhibited a higher FCR as compared to the pelleted feed form (3.976 vs 3.649, $p = 0.123$) and (4.026 vs 3.715, $p = 0.212$), respectively. In the first two weeks, the 4 % urea level recorded the lowest FCR at (3.478), while the highest FCR was observed at the 2 % urea level (4.235). In week 1, the feed form significantly affected the weekly FCR in weeks 3, 4, 5, and 6, with the non-pelleted feed yielding higher weekly FC as compared to the pelleted feed (4.016 vs 3.625, $p = 0.016$), (4.122 vs 3.653, $p = 0.001$), (4.314 vs 3.613, $p = 0.001$), and (4.536 vs 3.683, $p = 0.000$) for weeks 3, 4, 5, and 6 respectively. In weeks 3 and 4, urea levels significantly influenced weekly FCR, with the 6 % level recording the highest FCR during the aforementioned weeks.

The 2 % urea level recorded the lowest weekly FCR in weeks 3 and 4, at (3.389 and 3.568), respectively. In weeks 5 and 6, the 6 % urea level continued to record the highest weekly FCR, though, this was not statistically significant. Interactions between feed forms and urea levels showed significant effects on weekly FCR from weeks 2, 3, 4, 5, and 6, with the pelleted feed treated with 4 % urea showing the lowest weekly FCR at (2.918, 3.075, 3.078, and 3.125) in weeks 1, 2, 3, and 4 respectively. Nonetheless, the non-pelleted feed form with 4 % urea recorded the highest weekly FCR in weeks 2, 3, and 5. Non-pelleted feed form recorded the highest weekly FCR against the pelleted in all the weeks from weeks 7 to 12 with a significant effect noticed on week 9 and 11; (4.962 vs 4.395, $p = 0.006$) and (4.624 vs 4.276, $p = 0.030$) respectively. Urea levels

showed no significant effects on weekly FCR in weeks 7, 8, 9 and 12. However, significant difference was observed in weeks 10 and 11 with the 4 % urea recording the lowest weekly FCR; (4.277) against the highest mean (5.173) recorded for 0 % urea level. In weeks 11 and 12, 4 % again recorded -the lowest weekly FCR (4.218 and 4.493) against (4.856 for 0 % urea) and (4.689 for 6 %) respectively. From weeks 7 to 12, the interactions between feed form and urea levels showed no significant difference in weekly FCR.

Table 4.7: Effects of dietary urea-treated maize husk and pelleting on the growth performance of rabbits at 4 months, 2 weeks old.

Source	TFI (g)	TBWT (g)	TWTG (g)	AFCR
Form				
NP	8851 ^b	3000 ^b	2088 ^b	4.631 ^a
P	9095 ^a	3165 ^a	2226 ^a	4.000 ^b
SEM	114.5	34.60	30.32	0.069
P-values	0.045	0.000	0.000	0.000
Urea levels				
0 % urea level	9198 ^a	3056	2122	4.342 ^a
2 % urea level	8652 ^b	3073	2126	4.080 ^{bc}
4 % urea level	8852 ^b	3166	2212	4.019 ^c
6 % urea level	9191 ^a	3035	2168	4.249 ^{ab}
SEM	161.9	48.93	42.88	0.097
P-values	0.006	0.068	0.156	0.011
Form x Urea Interactions				
NP x 0 % urea	8985 ^{ab}	2896	2001	4.495
NP x 2 % urea	8878 ^{bc}	3027	2059	4.315
NP x 4 % urea	9213 ^{ab}	3076	2138	4.320
NP x 6 % urea	9306 ^{ab}	3004	2157	4.315
P x 0 % urea	9397 ^a	3217	2243	4.190
P x 2 % urea	8427 ^c	3121	2194	3.845
P x 4 % urea	8492 ^c	3256	2286	3.718
P x 6 % urea	9090 ^{ab}	3067	2180	4.183
SEM	229.0	69.20	60.65	0.137
P-values	0.014	0.064	0.119	0.118

a, b, c = means bearing different superscripts in the same column are significantly at 5 % probability level ($p < 0.05$), TFI = Total Feed Intake, TBWT = Total Body Weight, TWTG = Total Weight Gain, AFCR = Average Feed Conversion Ratio, NP = Non-pelleted, P = Pelleted, SEM = Standard Error of Means

Table 4.7 shows the results on total feed intake (TFI), total body weight (TBWT), total weight gain (TWTG) and average feed conversion ratio (AFCR) of rabbits fed with dietary urea-treated maize husk meal and pelleting in response to feed form (non-pelleted vs. pelleted), urea levels (0 %, 2 %, 4 %, and 6 %) and their interactions. Feed form showed significant effects on TFI, TBWT, TWTG and AFCR. Pelleted feed form had the higher means against the non-pelleted feed form; (9095 vs 8851 g, $p = 0.045$), (3165 vs 3000 g, $p = 0.000$) and (2226 vs 2088 g, $p = 0.000$) on TFI, TBWT and TWTG respectively. On AFCR, the non-pelleted feed form significantly had the higher AFCR and the less efficient against the pelleted feed; (4.631 vs 4.000, $p = 0.000$). Urea levels had significant effects ($p < 0.05$) on TFI and AFCR. 6 % urea level recorded the highest TFI (9198 g) followed by the 0 % urea level (9191 g). The 2 % urea level had the lowest TFI (8652 g). 0 % urea level recorded the highest value of AFCR (4.342) followed by 6 % urea level (4.249).

Moreover, 4 % urea level recorded the lowest AFCR (4.019). Effect Urea levels on TBWT and TWTG were not statistically significant ($p > 0.05$). However, 4 % urea level had the highest TBWT (3166 g) whereas 6 % urea level recorded the lowest mean (3035 g). Also, 4 % urea level recorded the highest TWTG (2212 g) and the 0 % urea level recorded the lowest (2122 g). Interactions between urea levels and feed form showed significant effects on TFI and AFCR. 0 % urea level pelleted recorded the highest TFI (9397 g) followed by non-pelleted feed form treated with 6 % urea level (9306 g). 2 % urea level pelleted recorded the lowest TFI (8427 g) followed by 4 % urea level pelleted feed (8492 g). The interactions between 4 % urea level pelleted recorded the lowest AFCR (3.718) followed the 2 % urea level pelleted (3.845). The non-pelleted feed with 0

% urea recorded the highest TFCR (4.495) followed by the non-pelleted feed form with the 4 % urea level (4.320). Though, interactions between feed form and urea levels showed no significant differences on TBWT and TWTG, the 4 % urea level pelleted feed recorded the highest TBWT (3256 g) followed by the 0 % non-pelleted (2896 g). Also, the 4 % pelleted feed recorded the highest TWTG (2286 g) and the lowest was recorded by 0 % non-pelleted feed.

4.3 Reproductive Performance

Table 4.8: Effects of dietary urea-treated maize husk and pelleting on reproductive performances of rabbits at age 120 days (4 months)

Source	GL (days)	LS	LWT (g)	LSWe	LV (%)	WeWT (g)
Form						
NP	31.67	5.750 ^a	238.2 ^a	4.333 ^a	86.53	3355 ^a
P	31.67	4.083 ^b	197.4 ^b	3.417 ^b	79.40	2840 ^b
SEM	0.290	0.537	16.27	0.363	6.197	217.2
P-values	1.000	0.008	0.025	0.024	0.270	0.033
Urea levels						
0 % urea	31.17	3.833	199.1	3.333	89.72	2856
2 % urea	31.83	4.833	214.7	3.667	80.08	2797
4 % urea	31.83	6.000	239.8	4.167	73.89	3167
6 % urea	31.83	5.000	217.5	4.333	88.17	3573
SEM	0.411	0.760	23.01	0.513	8.765	307.2
P-values	0.308	0.084	0.397	0.235	0.279	0.087
Form x Urea Interactions						
NP x 0 % urea	31.00	2.667	163.0	2.333	91.67	2216
NP x 2 % urea	31.67	4.333	198.7	3.333	80.00	2592
NP x 4 % urea	32.00	5.333	233.7	4.333	81.11	3227
NP x 6 % urea	32.00	4.000	194.3	3.667	93.33	3328
P x 0 % urea	31.33	5.000	235.3	4.333	87.78	3495
P x 2 % urea	32.00	5.333	230.7	4.000	80.16	3002
P x 4 % urea	31.67	6.667	246.0	4.000	66.67	3107
P x 6 % urea	31.67	6.000	240.7	5.000	83.01	3817
SEM	0.581	1.075	32.54	0.727	12.40	434.4
P – Values	0.729	0.810	0.624	0.180	0.842	0.200

a,b,c = means bearing different superscripts in the same column are significantly at 5 % probability level ($p < 0.05$), GL = Gestation period (days), LS = Litter size, LWT = Litter weight (g), LSWe = Litter size at weaning, LV (%) = Percentage Liveability WeWT = weaning weight, NP = Non-Pelleted, P = Pelleted, SEM = Standard Error of Means

Table 4.8 presents results obtained on reproductive performance: gestation length (GL), litter size (LS), litter weight (LWT), litter size at weaning (LSWe), percentage livability (LV (%)), and weaning weight (WeWT) of rabbits fed dietary urea-treated maize husk and pelleting meal in response to feed form (non-pelleted vs. pelleted), urea levels (0 %, 2 %, 4 %, and 6 %), and their interactions. Feed form, urea levels, and their interactions showed no significant difference in gestation length. Feed form significantly affected ($p < 0.05$) both litter size and litter weight, with the non-pelleted feed form recording the highest values of 5.750 and 238.2 g, respectively.

However, urea levels and interactions did not exhibit any significant differences in litter size and litter weight. Additionally, feed form significantly influenced ($p < 0.05$) both litter size at weaning and weaning weight, with the highest means of 4.333 and 3355 g, respectively, both favouring the non-pelleted feed form. However, feed form showed no significant effect ($p > 0.05$) on livability. Furthermore, urea levels and interactions showed no significant differences ($p > 0.05$) in litter size at weaning, livability, and weaning weight.

4.4. Haematological Characteristics

Table 4.9: Effects of dietary urea-treated maize husk and pelleting on haematological characteristics of rabbits at age 187 days old (6 months 2 weeks old)

Source	GRA ($\times 10^9/L$)	GRA (%)	HCT (%)	HGB (g/dL)	LYM (%)	RBCs ($\times 10^{12}/L$)	LYM ($\times 10^9/L$)	WBC ($\times 10^9/L$)	PCT (%)	MCH (pg)	MCHC (g/dL)	PLT ($\times 10^9/L$)
Form												
N	0.171	1.850 ^b	38.51 ^a	12.61 ^a	85.96 ^a	5.331	5.422 ^a	6.484 ^a	0.264	23.33	33.36	446.0
P	0.131	2.646 ^a	34.32 ^b	11.35 ^b	77.75 ^b	5.047	4.147 ^b	5.186 ^b	0.233	21.70	31.80	387.4
SEM	0.034	0.301	1.494	0.485	3.296	0.224	0.447	0.477	0.039	1.001	1.439	57.70
P-values	0.252	0.019	0.014	0.021	0.026	0.226	0.013	0.017	0.443	0.127	0.297	0.327
Urea level												
0 % urea	0.072 ^c	1.450 ^b	32.30 ^b	11.08	87.73 ^a	4.637	4.582	5.102 ^b	0.240	24.10	34.38	415.3
2 % urea	0.098 ^{bc}	1.575 ^b	37.40 ^a	12.18	88.40 ^a	5.308	4.582	5.817 ^b	0.242	23.08	32.48	402.3
4 % urea	0.173 ^{ab}	2.867 ^a	35.77 ^{ab}	12.13	69.97 ^b	5.361	3.860	5.085 ^b	0.200	20.80	30.98	331.3
6 % urea	0.260 ^a	3.100 ^a	40.20 ^a	12.55	81.33 ^a	5.448	5.622	7.337 ^a	0.313	22.08	32.50	518.0
SEM	0.047	0.426	2.113	0.685	4.661	0.317	0.632	0.674	0.055	1.416	2.035	81.59
P-values	0.006	0.002	0.016	0.211	0.005	0.082	0.078	0.015	0.269	0.163	0.451	0.197
Form x Urea Interactions												
NP x 0 % urea	0.057 ^c	0.850 ^{cd}	32.20 ^{cd}	10.90 ^{cd}	96.40 ^a	4.367 ^{de}	6.137	6.367 ^{ab}	0.370 ^{ab}	25.10	34.00	645.0 ^a
NP x 2 % urea	0.160 ^{bc}	2.450 ^b	37.80 ^{bc}	12.40 ^{bc}	79.70 ^{bc}	5.170 ^{bcd}	5.367	6.707 ^{ab}	0.290 ^{abc}	24.15	32.55	500.5 ^{ab}
NP x 4 % urea	0.227 ^b	3.200 ^b	44.25 ^a	15.20 ^a	76.25 ^{cd}	6.797 ^a	4.757	6.287 ^{ab}	0.213 ^{bcd}	22.35	34.30	330.5 ^{bc}
NP x 6 % urea	0.080 ^c	0.900 ^{cd}	39.80 ^{ab}	11.95 ^{bc}	91.50 ^{ab}	4.990 ^{bcd}	5.427	6.577 ^{ab}	0.183 ^{cd}	21.70	32.60	308.0 ^{bc}
P x 0 % urea	0.087 ^{bc}	2.050 ^{bc}	32.40 ^{cd}	11.25 ^{bc}	79.05 ^{bc}	4.907 ^{cd}	3.027	3.837 ^c	0.110 ^d	23.10	34.75	185.5 ^c
P x 2 % urea	0.037 ^c	0.700 ^d	37.00 ^{bc}	11.95 ^{bc}	97.10 ^a	5.447 ^{bc}	4.780	4.927 ^{bc}	0.193 ^{cd}	22.00	32.40	304.0 ^{bc}
P x 4 % urea	0.120 ^{bc}	2.533 ^b	27.28 ^d	9.050 ^d	63.68 ^d	3.927 ^e	2.963	3.883 ^c	0.187 ^{cd}	19.25	27.67	332.2 ^{bc}
P x 6 % urea	0.440 ^a	5.300 ^a	40.60 ^{ab}	13.15 ^{ab}	71.15 ^{cd}	5.907 ^{ab}	5.817	8.097 ^a	0.443 ^a	22.45	32.40	728.0 ^a
SEM	0.067	0.602	2.989	0.969	6.591	0.449	0.894	0.953	0.078	2.002	2.878	115.4
P-values	0.000	0.000	0.000	0.000	0.004	0.000	0.074	0.030	0.003	0.576	0.283	0.001

a, b, c = means bearing different superscripts in the same column are significantly at 5 % probability level ($p < 0.05$), GRA = Granulocyte, HCT = Haematocrit, HGB = Haemoglobin, RBCs = Red Blood Cells, LYM = Lymphocyte, P = Pelleted, NP = non-pelleted, WBCs = White Blood cells MCH = Mean Corpuscular Haemoglobin, MCHC = Mean Corpuscular Haemoglobin Concentration, PCT = Procalcitonin, PLT = Platelet, = Standard Error of

Table 4.9 shows the results obtained on haematological characteristics; granulocyte percentage (GRA), haematocrit (HCT), haemoglobin (HGB), lymphocyte (LYM), red blood cells (RBC) Lymphocyte volume (LYM), White Blood Cells volume (WBC), Procalcitonin percentage (PCT), Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC) and Platelet count (PLT) of rabbits fed with dietary urea-treated maize husk and pelleting in response to feed form (non-pelleted vs. pelleted), urea levels (0 %, 2 %, 4 %, and 6 %) and their interactions. Granulocyte (GRA) levels increased significantly ($p < 0.05$) with increasing urea levels, with the highest mean recorded at 6 % urea level $3.1 \times 10^9/L$ and 0.260 % for granulocyte percentage and volume respectively. The interaction between feed form and urea levels significantly ($p < 0.05$) affected GRA with the highest means observed by the pelleted feed treated with 6 % urea level 5.300 % and $4.4 \times 10^9/L$ respectively. However, GRA and RBC level showed no significant different ($p > 0.05$), between feed form and urea level. However, the trend showed an increased in RBC count with respect to increasing urea levels 0 %, 2 %, 4 % and 6 % recorded as 4.637, 5.308, 5.362 and 5.448 $\times 10^{12}/L$ respectively.

Feed form significantly affected LYM with the highest mean $85.96 \times 10^9/L$ recorded for the non-pelleted feed against the pelleted feed form $77.75 \times 10^9/L$. LYM on the other hand, showed significant difference ($p < 0.05$) between urea levels and interactions with highest means recorded as 88.40 % on 2 % urea level and 97.01 % on the pelleted and 2 % urea level interactions. However, GRA, HCT and HGB showed significant difference ($p < 0.05$) between feed forms with the highest means of 2.645 % for GRA and 38.51 %, 12.61 g/dL for HCT and HGB respectively all for the non-pelleted feed form. Haemoglobin (HGB), statistically, showed no significant difference ($p > 0.05$) between

urea levels. However, both HCT and HGB levels tended to increase with higher urea levels, particularly at 2 %, 4 %, and 6 % urea. There were significant differences ($p < 0.05$) between the interactions of feed form and urea levels on GRA, HCT, HGB, and RBC with the highest means recorded as 3.200 %, 44.25 %, 15.20 g/dL, and $6.796 \times 10^{12}/L$ respectively on non-pelleted samples with 4% urea level. Urea showed significant difference for GRA, HCT.

Lymphocytes (LYM) statistically showed significant difference ($p < 0.05$) between feed forms with the higher means $5.422 \times 10^9/L$ recorded for non-pelleted against the lower mean $4.147 \times 10^9/L$ for the pelleted feed. MCH and MCHC showed no significant difference ($p > 0.05$) between feed forms, though, non-pelleted recorded the higher means of 23.33 vs 21.70 pg., ($p = 0.127$), and 33.36 vs 31.80 g/dL, ($p = 0.297$) respectively. Statistically, lymphocyte count, MCH, MCHC showed no significant difference ($p > 0.05$) between feed forms, urea level and their interactions. There were significant different ($p < 0.05$) between means of WBC on feed forms, urea levels and their interactions. With respect to feed form, the non-pelleted feed had a higher means of $6.484 \times 10^9/L$ as against the pelleted feed $5.186 \times 10^9/L$. the 6 % urea level had the highest volume of WBC $7.337 \times 10^9/L$ as against the 4 % urea level of $5.085 \times 10^9/L$.

The interaction between the pelleted and the 6 % urea level had the highest mean of $8.097 \times 10^9/L$ as against the lowest $3.837 \times 10^9/L$ recorded for the interaction between the pelleted feed and 0 % urea level. Feed forms and urea levels showed no significant effect on PCT. However, significant difference ($p < 0.05$) observed between the interactions between feed form and urea levels on PCT. The highest value 0.443 %, ($p = 0.003$) was recorded between pelleted feed interaction with 6 % urea level. Statistically, PLT

showed no significant difference ($p > 0.05$) on feed form. Though; the higher mean of $446.0 \times 10^9/L$ was recorded on non-pelleted feed form and the lower mean $387.4 \times 10^9/L$ on the pelleted feed form. PLT count showed no significant difference ($p > 0.05$) between urea levels but the trend tended to decreased with increasing urea levels with 0 % urea level recording the highest PLT count $518.0 \times 10^9/L$ as against the 6 % urea level recording the lowest value $331.3 \times 10^9/L$. The interactions of urea levels and feed form had a significant effect ($p = 0.001$) on PLT with the highest value $728.0 \times 10^9/L$ recorded for pelleted feed treated with 6 % urea level and the lowest $304.0 \times 10^9/L$ recorded for pelleted at 2 % urea level.

4.5. Serum Biochemical Characteristics

Table 4.10: Effects of dietary urea-treated maize husk and pelleting on serum biochemical characteristics of rabbits at age 6 months, 2 weeks old

Source	T. CHOL (mmol/L)	TRIG. (mmol/L)	UREA (mmol/L)	CREAT. (μ mol/L)	HDL (mmol/L)	LDL (mmol/L)	ALP (U/L)	ALT (U/L)	AST (U/L)
Form									
NP	2.804 ^a	0.786	4.339 ^a	103.6	1.498	1.508 ^a	84.50 ^a	60.16	126.8 ^a
P	2.223 ^b	0.771	3.959 ^b	100.9	0.943	0.969 ^b	43.65 ^b	60.86	65.40 ^b
SEM	0.138	0.048	0.175	7.039	0.596	0.107	13.84	6.897	15.24
P - Values	0.001	0.758	0.047	0.713	0.368	0.000	0.011	0.921	0.001
Urea levels									
0 % urea level	2.618 ^a	0.818 ^a	3.742 ^b	100.4	0.948	1.298 ^a	50.78	32.33 ^b	50.65 ^c
2 % urea level	2.073 ^b	0.763 ^{ab}	4.372 ^a	114.7	0.873	0.853 ^b	47.50	58.83 ^a	113.8 ^{ab}
4 % urea level	2.645 ^a	0.663 ^b	4.037 ^{ab}	104.0	0.960	1.387 ^a	77.25	72.90 ^a	148.2 ^a
6 % urea level	2.718 ^a	0.868 ^a	4.447 ^a	90.00	2.098	1.417 ^a	80.78	78.00 ^a	71.70 ^{bc}
SEM	0.196	0.068	0.247	9.954	0.843	0.152	19.58	9.754	21.55
P - Values	0.019	0.048	0.046	0.146	0.435	0.008	0.240	0.002	0.002
Form x Urea Interactions									
NP x 0 % urea	2.210	0.827 ^b	4.967	99.50	0.900	0.937	66.50	47.05 ^{cd}	69.70 ^b
NP x 2 % urea	1.927	0.830 ^b	4.217	119.4	0.890	0.657	65.50	82.00 ^b	173.6 ^a
NP x 4 % urea	2.620	0.760 ^{bc}	3.977	97.70	1.000	1.277	116.0	71.90 ^{bc}	203.6 ^a
NP x 6 % urea	2.137	0.667 ^{bc}	4.197	87.15	3.200	1.007	90.00	39.70 ^d	60.20 ^b
P x 0 % urea	3.027	0.810 ^b	3.927	101.3	0.827	1.660	35.05	17.60 ^d	31.60 ^b
P x 2 % urea	2.220	0.697 ^{bc}	4.527	110.0	0.857	1.050	29.50	35.65 ^d	53.95 ^b
P x 4 % urea	2.670	0.567 ^c	3.507	110.3	0.920	1.497	38.50	73.90 ^{bc}	92.85 ^b
P x 6 % urea	3.300	1.070 ^a	3.877	92.75	0.997	1.827	71.55	116.3 ^a	83.20 ^b
SEM	0.277	0.095	0.350	14.08	1.192	0.214	27.69	13.80	30.48
P - Values	0.052	0.002	0.100	0.739	0.488	0.210	0.489	0.000	0.016

a, b, c = means bearing different superscripts in the same column are significantly at 5 % probability level ($p < 0.05$), T. CHOL. = Total cholesterol, TRIG. = Triglyceride, CREAT. = Creatinine, HDL = High-density lipoprotein, LDL = Low-density lipoprotein, ALP = Alkaline phosphatase, ALT = Alanine Aminotransferase, AST = Aspartate Aminotransferase, NP = Non-pelleted, P = Pelleted, SEM = Standard Error of Means

Table 4.9 shows the results obtained on serum biochemical characteristics; Total Cholesterol, Triglycerides, Creatinine, Urea and Urea-Creatinine ratio, High-density lipoprotein (HDL), Low-density lipoprotein (LDL), Alkaline phosphatase (ALP), Alanine Aminotransferase (ALT), Aspartate Aminotransferase (AST) of rabbits fed with dietary urea-treated maize husk meal and pelleting in response to feed form (non-pelleted vs. pelleted), urea levels (0 %, 2 %, 4 %, and 6 %) and their interactions. Total cholesterol (T. Chol.) and Urea counts, in the serum showed significant difference ($p = 0.001$) on feed form with higher mean of 2.804 mmol/L recorded for non-pelleted feed form against 2.223 mmol/L for the pelleted feed form. For the serum Urea concentration, non-pelleted feed form significantly recorded the higher value 4.339 mmol/L against the pelleted feed form 3.959 mmol/L, ($p = 0.047$).

Trig, Creatinine showed no significant different ($p > 0.05$) on feed form though, the highest values obtained favoured the non-pelleted feed forms with values 0.799 mmol/L, 103.6 $\mu\text{mol/L}$ respectively. Also, T. Chol, Trig, Urea and showed significant difference ($p < 0.05$) between urea levels. The highest value of T. Chol 2.718 mmol/L was recorded on 6 % urea level and the lowest mean of 2.073 mmol/L was recorded on 2 % urea level. 6 % urea recorded the highest value 0.868 mmol/L of Trig against 4 % urea level recording the lowest 0.663 mmol/L. Also, 6 % urea level recorded the highest value; 4.446 mmol/L against 3.742 mmol/L for 0 % level on serum urea concentration. However, Creatinine showed no significant different ($p > 0.05$) between urea levels and feed form interactions. Though, the highest value was recorded as 114.7 $\mu\text{mol/L}$ on 2 % urea and 110.3 $\mu\text{mol/L}$ on pelleted with 4 % urea level. The interactions between feed forms and urea levels showed significant difference on Trig with the highest means of

0.830 mmol/L on non-pelleted with 2 % urea and 23.60 mmol/L on non-pelleted with 6 % respectively.

Feed form and urea levels and their interactions showed no significant ($p > 0.05$) effect on high-density lipoprotein level. However, non-pelleted feed form recorded the higher HDL against the pelleted feed form; 1.498 vs 0.943 mmol/L, ($p = 0.368$). With respect to urea levels, 6 % urea level recorded the highest HDL value 2.098 mmol/L, ($p = 0.435$). The interaction between non-pelleted feed form and 6 % urea level recorded the highest value of HDL 3.200 mmol/L, ($p = 0.488$). Feed form had significant effect ($p < 0.05$) on LDL, ALP and AST. All the respective values favoured the non-pelleted feed form against the pelleted feed form; 1.508 vs 0.969 mmol/L, ($p = 0.000$) for LDL, 84.50 vs 43.65 U/L, ($p = 0.011$) for ALP and 126.8 vs 65.40 U/L, ($p = 0.001$) for AST.

Statistically, both urea levels and interactions with feed form showed significant difference on ALT with the highest value of 78.00 U/L for 6 % urea level and 116.3 U/L for pelleted feed treated with the 6 % urea level. There was no significant difference ($p > 0.05$) showed between interactions of feed forms and urea levels on LDL, and ALP. However, the highest value of 1.827 mmol/L observed favoured pelleted feed form with 6 % urea level and 116.00 U/L favoured non-pelleted feed forms with 4 % urea level respectively. Interactions showed significant different ($p < 0.05$) on AST content with the highest value of 203.60 U/L, ($p = 0.016$) for non-pelleted with 4 % urea level.

Table 4.11: Effects of dietary urea-treated maize husk and pelleting on the Serum biochemical characteristics of rabbits at age 6 months, 2 weeks old

Source	VLDL (mmol/L)	T.P (g/L)	ALBU. (g/L)	GLOB. (g/L)	T. BIL. (μ mol/L)
Form					
NP	0.355	3.488	2.400 ^b	1.388 ^b	1.488
P	0.358	3.450	12.30 ^a	7.100 ^a	1.450
SEM	0.023	0.513	3.964	2.353	0.272
P - Values	0.915	0.943	0.026	0.029	0.892
Urea levels					
0 % urea levels	0.373 ^a	4.550	11.85	8.000	1.500
2 % urea levels	0.348 ^{ab}	3.625	10.03	5.475	1.675
4 % urea levels	0.302 ^b	3.400	4.825	2.175	1.425
6 % urea levels	0.402 ^a	2.300	2.700	1.325	1.275
SEM	0.033	0.726	5.605	3.327	0.384
P - Values	0.047	0.054	0.354	0.210	0.773
Form x Urea Interactions					
NP x 0 % urea	0.377 ^b	2.850 ^{bc}	1.350	0.900	0.750 ^c
NP x 2 % urea	0.380 ^b	4.350 ^{ab}	3.350	1.900	1.600 ^{abc}
NP x 4 % urea	0.347 ^{bc}	3.900 ^{bc}	1.050	0.700	2.050 ^{ab}
NP x 6 % urea	0.317 ^{bc}	2.850 ^{bc}	3.850	2.050	1.550 ^{abc}
P x 0 % urea	0.370 ^b	6.250 ^a	18.70	15.10	2.250 ^a
P x 2 % urea	0.317 ^{bc}	2.900 ^{bc}	20.35	9.050	1.750 ^{abc}
P x 4 % urea	0.257 ^c	2.900 ^{bc}	8.600	3.650	0.800 ^c
P x 6 % urea	0.487 ^a	1.750 ^c	1.550	0.600	1.000 ^{bc}
SEM	0.046	1.026	7.927	4.705	0.543
P - Values	0.006	0.014	0.290	0.160	0.018

a, b, c = means bearing different superscripts in the same column are significantly at 5 % probability level ($p < 0.05$), VLDL = Very low-density lipoprotein, T.P. = Total Protein, Albu. = Albumin, Glob. = Globulin, T. Bil = Total Bilirubin, NP = Non-pelleted, P = Pelleted, SEM = Standard Error of Means

Table 4.11 shows the results obtained on serum biochemical characteristics; total protein (T.P), albumin, very low-density lipoprotein (VLDL), globulin and total bilirubin of rabbits fed with dietary urea-treated maize husk and pelleting meal in response to feed form (non-pelleted vs. pelleted), urea levels (0 %, 2 %, 4 %, and 6 %) and their interactions. Feed forms showed no significant difference on VLDL, total proteins and total Bilirubin. However, significant differences of feed form were noted on Albumin and Globulin with the pelleted feed form in both cases recording the highest value against the non-pelleted feed, 12.30 vs 2.400 g/L, ($p = 0.026$) and 7.100 vs 1.338 g/L, ($p = 0.029$) respectively. Urea levels and feed form interactions showed no significant difference on Albumin and Globulin, though; the trend tended to decrease with increasing urea levels in both parameters.

The highest values were recorded as 11.85 g/L and 8.000 g/L for 0 % for both cases respectively. Also, there was a significant difference between urea levels and feed form interactions on VLDL with the highest value of 0.402 mmol/L for 6 % urea level as against the lowest 0.302 mmol/L recorded for 4 % urea level. With the interactive effect, the pelleted feed form with 6 % urea level recorded the highest VLDL concentration 0.487 mmol/L. Statistically, the interactions between urea levels and feed forms showed significant difference ($p < 0.05$) on protein content with the highest value 6.250 g/L recorded for pelleted feed with 0 % urea level. There were significant differences observed with the interactions between feed form and urea levels on total bilirubin concentration. 0 % urea level pelleted feed recorded the highest effect 2.250 $\mu\text{mol/L}$ as against the lowest bilirubin concentration 0.750 $\mu\text{mol/L}$, ($p = 0.018$) recorded for 0 % non-pelleted feed form.

4.6. Carcass Characteristics

Table 4.12: Effects of urea-treated and pelleted maize husk meal on the carcass characteristics of rabbits at age 6 months, 2 weeks old

Source	LvWT (g)	SLWT (g)	WTH (g)	CAECAL pH	WTVC(g)	VC (%)	WTDC (g)	DC (%)
Form								
NP	2219	2163	153.8	6.593 ^b	220.3	9.988	1248	56.62
P	2242	2144	159.5	7.038 ^a	220.5	9.858	1352	60.08
SEM	120.4	117.0	6.157	0.062	13.33	0.242	103.5	2.393
P - Values	0.852	0.875	0.363	0.000	0.9878	0.602	0.329	0.170
Urea levels								
0 % urea level	2300	2238	150.3	6.768 ^b	215.3	9.395 ^b	1350	58.67
2 % urea level	2300	2188	155.7	7.047 ^a	225.5	9.815 ^b	1280	55.08
4 % urea level	2308	2238	168.3	6.983 ^a	226.6	9.833 ^b	1289	56.33
6 % urea level	2013	1950	152.3	6.462 ^c	214.3	10.65 ^a	1280	63.32
SEM	170.2	165.4	8.707	0.087	18.86	0.343	146.3	3.384
P - Values	0.269	0.290	0.211	0.000	0.8687	0.018	0.955	0.121
Form x Urea Interactions								
NP x 0 % urea	2250	2175	144.7	6.447 ^c	221.7	9.893 ^{bcd}	1250	61.75
NP x 2 % urea	2150	2050	150.7	7.067 ^{ab}	194.0	9.017 ^{cd}	1210	56.10
NP x 4 % urea	2550	2475	172.0	6.820 ^b	248.7	9.743 ^{bcd}	1345	53.18
NP x 6 % urea	1925	1875	147.7	6.037 ^d	217.0	11.30 ^a	1185	61.60
P x 0 % urea	2350	2300	156.0	7.090 ^a	209.0	8.897 ^d	1450	61.75
P x 2 % urea	2450	2325	160.7	7.027 ^{ab}	257.0	10.61 ^{ab}	1350	54.05
P x 4 % urea	2067	2000	164.5	7.147 ^a	204.5	9.923 ^{bcd}	1233	59.47
P x 6 % urea	2100	2025	157.0	6.887 ^{ab}	211.7	10.00 ^{bc}	1233	65.04
SEM	240.7	233.9	12.31	0.123	26.67	0.4845	206.9	4.786
P - Values	0.148	0.152	0.674	0.001	0.0744	0.003	0.687	0.588

a, b, c = means bearing different superscripts in the same column are significantly at 5 % probability level ($p < 0.05$), LvWT = Live weight, WTH = Head Weight, SLWT = Slaughter Weight, WTVC = Weight of Visceral Content, VC (%) = Percentage Visceral Content, WTDC = Weight of Dressed Carcass, DC (%) = Dressing percentage, NP = Non-pelleted, P = Pelleted, SEM = Standard Error of Means.

Table 4.12 shows the results obtained on carcass characteristics; live weight before slaughtering, slaughter weight, head weight, caecal pH, weight of visceral content (WTVC), percentage visceral content (VC %), weight of dressed carcass (WTDC) and dressing percentage (DC %) of rabbits fed with dietary urea-treated maize husk and pelleting meal in response to feed form (non-pelleted vs. pelleted), urea levels (0 %, 2 %, 4 %, and 6 %) and their interactions. There was no significant difference ($p > 0.05$) in live weight between feed forms and urea levels. However, 4 % urea level showed the highest live weight, 2308 g, and a 6 % urea level recorded the lowest weight, 2013 g. Similarly, feed forms and urea levels showed no significant difference ($p > 0.05$) in slaughter weight. The highest slaughter weight was observed with 4 % urea, 2238 g, while 6 % urea resulted in the lowest, 1950 g.

Head weight did not differ significantly ($p > 0.05$) between feed forms and urea levels. Although, the 4 % urea level showed the highest head weight, 168.3 g. Significant differences ($p < 0.05$) were found in Caecal pH between feed forms, urea levels, and their interactions. The non-pelleted feed recorded the lowest Caecal pH 6.593 as against the pelleted feed form 7.038. There was a trend of decreasing caecal pH with increasing urea levels. Higher urea levels 6 %, recorded the lower caecal pH 6.462, as against the highest 7.047 for 2 % urea level. Feed form had no significant effect ($p > 0.05$) on the weight of visceral content, percentage of visceral content, and dressing percentage. However, urea levels had a significant effect ($p < 0.05$) on percentage visceral content, with 6 % urea level recording the highest value, 10.65 %, and the 0 % urea level recorded the lowest, 9.395 %. Although, non-pelleted feed resulted in a lower weight of dressed carcass of 1248 g against the pelleted feed 1352 g, this difference was not

statistically significant ($p > 0.05$). Urea levels also did not show any significant effects on the weight of the dressed carcass. No significant difference was observed in the dressing percentage between feed forms ($p > 0.05$). However, 6 % urea level had the highest dressing percentage value, 63.32 %, though, not statistically significant.

CHAPTER FIVE: DISCUSSION

5.1 Proximate Composition of the Experimental Diets

From the analysis of the proximate composition of the different experimental diets used in this study, the range of moisture content 9.720 to 10.11 % falls within the average 9.85 % as reported by Ismail *et al.* (2019) to be adequate for rabbit nutrient requirement. The amount of water in the feed determines its moisture content. This is an indication that the experimental diets would have a longer shelf life. According to Uyeh *et al.* (2021), since its defined ranges act as indicators for safe animal storage, mixing, and feeding, moisture content is a crucial metric for assessing the quality of feed and feed components. The authors also emphasized that too much water might quickly deteriorate the feed due to the growth of mold and bacteria. Lipan *et al.* (2020) reported that low moisture content will lead to a prolonged shelf life.

The crude protein content recorded in this study tends to vary between feed forms per each treatment diet and it is higher with the non-pelleted feed form as compared to the pelleted. The 0 % urea level non-pelleted (NPU0%) feed recording highest value 16.32 % against 16.28 % for 0 % urea level pelleted (PU0%) may suggest that physical form of the feed can have significant effect on crude protein content with the pelleted feed form recording the higher crude protein as compare to the non-pelleted feed from. This result corroborates with the findings of Cargo-Froom *et al.* (2022). There was a trend of increased crude protein content with increasing urea levels. The 6 % urea level non-pelleted feed form recording the highest value 17.18 % of crude protein as against the lowest value 16.28 % recorded for the 0 % urea level pelleted feed, in this study corroborates with Katole (2022) who opined that treating forage with urea increases the nitrogen content which leads to an increased in crude protein. It also affirms the value

16.44 % recorded by Jimoh *et al.* (2021). The range of crude protein value 16.28 – 17.18 % recorded in this study is slightly higher than 15 - 16 % as reported by Cherwon (2020), to be the recommended range but falls within 16 – 18 % as reported by Owoleke *et al.* (2016). Crude fibre content in this study varied between forms per each treatment diet. The non-pelleted feed form recorded a higher crude fibre value as compared with its corresponding pelleted feed form. 0 % urea level pelleted (P0) had crude fibre content of 15.72 % which is marginally lower than 15.78 % recorded for 0 % urea level non-pelleted feed form. The reduction in crude fibre content with the pelleted feed corroborates with the findings of Lindahl and Reynolds (1959); Cargo-Froom *et al.* (2022) and this results probably might be attributed to the rupture of certain cellular structures during the pelleting process as reported by Lindahl and Reynolds (1959) and also could be attributed to the potential loss of fibre during the pelleting process as reported by Cargo-Froom *et al.* (2022).

The range of crude fibre percentage values 15.55 - 15.82 % in the diet is adequate for the rabbits as it corroborates with the values of 13.09 -15.82 % recommended by Owoleke *et al.* (2016). The importance of crude fibre in rabbit's diet cannot be over emphasized. Fibre is important in the transit for digestive regulation and act as protection against digestive disorders (Gill *et al.*, 2021). Ether extract in the experimental diets tends to increase with increasing urea levels. This may be due to the ammonia released when urea is hydrolyzed by urease which may be soluble in ether. The ether extract values 5.230 - 6.870 % obtained for all the experimental diets were adequate as it conformed to 5.510 – 6.810 % reported by Owoleke *et al.* (2016). Ether extract improves diet palatability and increases energy level without causing carbohydrate overload of the hind gut (Usman *et al.*, 2016). By giving the rabbits necessary fatty acids and enhancing their

energy utilization, ether extract digestibility is a sign of improved utilization of the dietary fat in the diets (Ozung *et al.*, 2017). The nitrogen free extract (NFE) component of the diet 43.37 – 46.24 % in this study was all within the recommended range of 43-48.00 % as reported by Ingweye *et al.* (2024) for growing rabbits.

Digestible energy of the feeds varied. The lowest digestible energy 3234 Kcal/kg was recorded in the 0 % urea level pelleted feed and the highest 3409 Kcal/kg was recorded in the 6 % urea level pelleted. The increased in digestible energy level as a result of the increased urea level found in this study may be explained by the ability of the ammonia generated from urea to weaken the lignified outer walls, facilitating improved rumen microbial penetration and more efficient fermentation, as well as the release of nutrients and energy, as suggested by Khan *et al.* (2017). The digestible energy values recorded in this study contradicts with the findings of Osman *et al.* (2020) who found that normal rabbit diets had relatively low digestible energy levels, ranging from 2400 to 2800 kcal/kg weight diet. The higher digestible energy content in the diet used to feed the rabbit may be attributed to the high energy content of the main ingredients; maize husk used in the formulation of the experimental diets.

5.2 Effects of Dietary Urea-Treated Maize Husk Meal and Pelleting on Growth

Parameters of Rabbits

Rabbits fed with the pelleted feed form significantly ($p < 0.05$) recorded the higher feed intake in most of the weeks; (week 5, 6, 9, 11) and the total feed intake (TFI) as well. This observation confirms with Amin *et al.* (2019) who reported that pelleting increases feed palatability and stimulate the appetite of rabbits which will eventually enable the rabbits to consume adequate amount of the feed. Though, non-pelleted feed form showed higher weekly feed intake in some of the weeks; (weeks 2, 3, 4, 7, 8 and 10), the values recorded did not show any significant effect ($p > 0.05$). The lower feed intake of the rabbits fed with the non-pelleted feed form could be attributed to reduced palatability and also the bulkiness of the diet when not pelleted. A mash combined meal may also cause the rabbit to exhibit selective intake behaviour, which could alter the amount of nutrients it consumes. Animals fed on the pelleted feed form consistently showed higher weekly body weights, weekly body weight gains and total weight gain across all weeks and this indicates improved growth performances. This collaborates to what was recorded by Lancheros *et al.* (2020) that Pelletizing improves feed palatability, decreases feed waste, and improves nutritional digestibility which can lead to greater feed intake and higher weight gains. However, this finding deviates from what was reported by Safwat *et al.* (2014) who recorded low body weight gain and attributed it to the fact that tropical forages contain anti-nutritional conditions that impair nutrient absorption and digestion.

Malik *et al.* (2023) confirmed that animals fed pelleted diets typically exhibit better growth rates compared to those on non-pelleted diets. However, the response may vary depending on the overall diet composition and the animal's specific nutritional needs. The significant effect ($p < 0.05$) of 0 % urea levels on feed intake in weeks (3, 4, 6, 7, 8, 9, 11 and 12) observed in this study corroborates with Isikwenu (2014) who made similar observation when rabbits were fed with dietary urea-treated and fermented brewer's dried grain. This observation indicates that rabbits ate significantly more of the 0 % urea diet than the 2 %, 4 % and 6 % urea-treated diets, indicating that the 0 % urea diet was more palatable and acceptable to the rabbits as suggested by Isikwenu (2014).

However, the feed intake of treatment groups on 2 %, 4 % and 6 % inclusion levels were able to furnish the rabbits with adequate nutrients to obtain a higher growth rate as compare to the 0 % urea level. The 4 % urea level consistently and significantly ($p < 0.05$) led to the highest body weights across most weeks, total body weight (TBWT) and total weight gain (TWTG) and lower TFCR suggesting that moderate urea supplementation can enhance growth performance. Conversely, the 6 % urea level resulted in the lowest weights, probably indicates potential adverse effects of higher urea levels on growth. This may support the notion that moderate urea supplementation can enhance growth, while excessive levels may have detrimental effects, likely due to metabolic stress or toxicity (Yakubu and Wafar, 2014). Also, Ahmed *et al.* (2019), stressed that excessive urea can cause metabolic disturbances, or reduced feed efficiency, which is consistent with the observations in this study. The 4 % urea level recording the highest body weight in this study corroborates with the study conducted by Katole (2022), who indicated that it is ideal to treat forage with 3 - 5 % of urea per 100 kg with 4 % urea level been the optimum.

The Significant interactions ($p < 0.05$) between feed form and urea levels on weekly body weights were observed during the earlier weeks (1, 2, and 6), and indicates that the combination of pelleted feed and optimal urea supplementation 4 % is particularly beneficial for early growth stage. The significant effect on growth performance due to urea supplementation deviates with the findings of Mandour *et al.* (2012). Urea supplementation at 4 % and 6 % levels resulted in significantly higher feed intake compared to lower levels (0 % and 2 %) in some weeks, indicating a dose-dependent response. The interactions between pelleted feed forms and 4 % urea level consistently recorded the highest weekly body weights, total body weight (TBWT), total weight gain (TWTG) and significantly lowest FCR and lower AFCR which is an indication of a positive correlation. This finding corroborates with Ruknuzzaman, (2016) when rabbits were fed with dietary urea molasses multi-nutrient cake. The higher FCR exhibited by non-pelleted feed compared to pelleted feed across most weeks and the AFCR aligns with Matics *et al.* (2014); Nuamah *et al.* (2019) who recorded on the advantages of pelleted feeds over the non-pelleted in improving feed conversion efficiency. The observation indicates that the rabbits fed with the pelleted feed had the best feed conversion ratio suggesting the rabbits efficiently and effectively utilized the nutrient in the feed with a direct correlation with the quantity of feed consumed. The observed interactions in this study indicated that the effectiveness of dietary components can depend on their combination (Abdel-Azeem *et al.*, 2018). The 0 % urea level non-pelleted feed recording significantly the highest AFCR 4.495, ($p = 0.118$), indicates that rabbits fed on that feed had poor conversion of feed into body mass. However, the interactions between 4 % urea levels and pelleted recorded the lowest FCR and average FCR. These observations indicate that though, rabbits that were fed on 4 % urea level pelleted diet relatively recorded lower total feed intake 8492 g against the highest 9397 g

for 0 % pelleted, there were better conversion of feed into body mass and body weight gain and that showed better feed utilization. The findings indicate that pelleted feed generally offers better feed conversion efficiency compared to non-pelleted feed, particularly when supplemented with moderate levels of urea. The 6 % urea level had the highest mean followed by the 0 % on AFCR indicates poor performance of the animals in terms of converting feed into meat.

5.3 Effects of Dietary Urea-Treated Maize Husk Meal and Pelleting on the Reproductive Performances of Rabbits

The results from the study showed no significant difference ($p > 0.05$) in gestation length between non-pelleted and pelleted feed forms, and also with varying urea levels. The mean of 31.67 was recorded for both pelleted and non-pelleted. This may be attributed to the fact that gestation length is often stable across different feeding regimes, suggesting that factors such as genetics and overall health may play a more significant role than diet alone. The findings from this study are similar to the findings of Ruknuzzaman *et al.* (2018) who recorded a gestation period 31.60 - 32.30 days in rabbit does supplied with different levels of urea. However, an extreme dietary imbalances can affect gestation length (Lidfors and Edström, 2024), which was not evident in this study.

Non-pelleted feed resulted in a significantly higher litter size 5.750 as compared to the pelleted feed 4.080, ($p = 0.008$). The highest litter size was observed at 4 % urea 6.00 though not statistically different ($p > 0.05$). This affirms what Adeyemi (2014) reported that the average litter size of rabbit is about 6 in the tropics. This may be attributed to the fact that the pelleting process which involved the generation of heat might have impeded nutrient availability as a result of denaturation of protein and evaporation of nutrient

(Ayoola, 2020). Reproductive processes including follicular growth, ovulation, and fertilization, which depend on dietary nutrition, particularly dietary protein, may have declined as a result (Ruknuzzaman, 2016). Non-pelleted feed resulted in significantly higher litter weight 238.2 g compared to pelleted feed 197.4 g ($p = 0.025$). The results are consistent with findings that non-pelleted diets provide better nutritional support for developing offspring, likely due to higher digestibility (Fatufe *et al.*, 2010). However, the lack of significant effect between urea levels on litter weight at birth may suggest that while protein is critical, other factors such as energy content and micronutrient balance may also be influential.

Significantly higher litter size at weaning was noted for non-pelleted may be attributed nutrient bioavailability as a result of minimal processing. This finding corroborates to the findings by Herring *et al.* (2018) and Caton *et al.* (2019) who indicated that the quality of maternal nutrition directly impacts offspring survival and growth rates. Non-pelleted feed showed higher liveability 86.53 % as compared to pelleted feed 79.40 %, although, not statistically significant. Urea levels did not have significant ($p > 0.05$) influence on percentage liveability ($p = 0.279$). While non-pelleted diets often support higher survival rates, the lack of statistically significant effect in this study may indicate variability in individual animal responses or environmental factors affecting liveability. This is an indication that liveability can be influenced by a multitude of factors, including maternal health and environmental conditions such as increase of ambient temperature that could be attributed to the heat stress and reduction of dam's milk (El-Ashram *et al.*, 2020).

Non-pelleted feed led to a significantly higher weaning weight may be attributed to nutrient bioavailability especially protein because of the minimal processing which is a

factor in lactogenesis as reported by Katongole and Yan (2020). This indicates that early liveability performances of litter are closely related to the quantity and quality of the milk ingested as opined by Huang *et al.* (2024). The highest weaning weight was observed at 6 % urea 3573 g, though not statistically significant ($p = 0.087$), corroborates with the findings of Ruknuzzaman, (2016) and this may be attributed to the fact that higher urea level, 6 % may have increased the protein, which increased the protein balance in the rabbit milk and increased milk production. As a result, kits of the does given 6% had a better survival rate of 88.17% and produced larger litter sizes (Katongole and Yan, 2020). While non-pelleted diets appear to offer advantages, it is essential to ensure that they are well-balanced nutritionally. Poorly formulated non-pelleted diets can lead to deficiencies or imbalances that may negate the observed benefits.

5.4 Effects of Dietary Urea-Treated Maize Husk Meal and Pelleting on the Haematological Characteristics of Rabbits

Haematological characteristics of animals are greatly influenced by the quantity and quality of feed consumed. From the results of this study, there was significant increase in GRA levels with increasing urea percentage, particularly at 6 % urea. This is likely due to the role of urea in stimulating the immune system and inflammatory response. Statistically there was significant difference ($p < 0.05$) in HGB concentration with respect to feed form. The non-pelleted feed recorded the higher value as compared to the pelleted feed. This may be attributed to the fact that non-pelleted feed may have better nutrient bioavailability due to minimal processing, which can lead to improved nutrient utilization and haemoglobin production.

Haemoglobin (HGB), statistically, showed no significant difference ($p > 0.05$) between urea levels. This corroborates with the findings of the Mandour *et al.* (2012) who also did not find any significant difference in the HGB level in rabbit blood due to the feeding of urea-treated diet. The value of 11.075 g/dl recorded for 0 % urea level and 2.18 – 12.55 g/dl for other urea levels were within the normal range of 8 – 17 g/dl as reported by Akintunde *et al.* (2019). Normal range of values for HGB indicated that the vital physiological relationship of haemoglobin with oxygen in the transport of gases (oxygen and carbon dioxide) to and from the tissues of the body has been maintained and was normal. The tendency for HCT and HGB levels to increase with higher urea percentages, especially at 2 %, 4 %, and 6 % urea, aligns with the findings of Ogbuewu *et al.* (2019) who indicated that urea has been shown to enhance erythropoiesis and increase red blood cell production when the author fed poultry with urea-treated rice straw supplemented with garlic, leading to elevated HCT and HGB levels. This affirms a report by Bishir *et al.* (2021) who opined that both HCT and HGB were correlated with the nutritional status of an animal. Although, the 0 % urea level significantly recorded the lowest value of HCT as compared to the 6 % urea level recorded the highest value, all the values recorded fell within the normal physiological range of 30 – 50 % as reported by Idahor *et al.* (2018). The values obtained for HCT were higher than what was reported by Chineke *et al.* (2003), who stated that higher HCT readings indicated either an increase in the number of RBC or reduction in circulating plasma volume which was also observed in this study.

The 6 % urea level recording the highest value of HCT corroborates with the findings of Ruknuzzaman, (2016), when rabbits were fed with urea molasses multi-nutrient cake. Solomon *et al.* (2024) reported that HCT is an easily obtained measure for detecting

anaemia or polycythemia and can be useful in estimating changes in haemodilution or haemoconcentration. This result hence implies that the animals did not suffer from anaemia, dehydration or polycythemia in the course of the study. Although, urea levels showed no significant difference on RBCs counts, the trend turned to increase with increasing urea levels. This may be attributed to the increased in protein percentage in line with the increased in urea level which in turn increased the production of RBCs.

Both lymphocyte (LYM x 10⁹/L) count and percentages (LYM %) significantly favoured the non-pelleted feed form. This may be attributed to the fact that pelleted feed may reduce nutrient digestibility because of the pelletizing process which compresses and compacts ingredients which may make them harder for rabbit to digest as compared to the non-pelleted feed. The lack of significant effects of urea on MCH and MCHC levels is consistent with Attia *et al.* (2014), who also reported that these parameters are more closely related to the intrinsic properties of red blood cells and are less affected by external factors like urea supplementation. However, the values recorded in this study fell within the normal range of 18.26 – 38.11 pg (Jiwuba *et al.*, 2021) and 30 – 35 g/dL (Salihu, 2021) respectively. This suggests that the animals were not anaemic and the bone marrow's ability to produce RBCs with normal size and metabolic capacity were not adversely affected as opined by Shanbhag *et al.* (2019). Urea levels showed a significant effect on WBCs particularly those with the 6 % urea level recorded the highest mean 7.337 x 10⁹/L and the lowest 5.085 x 10⁹/L recorded for 4 % urea level. Ruknuzzaman, (2016), recorded a similar finding where the feed treated with 6 % urea recorded the highest concentration of WBC. The values recorded fell within the normal range 2.710 to 12.23 x 10⁹/L as reported by Beloumi *et al.* (2020) and that indicates that the experimental rabbits were healthy during the experimental period. Feed form

(pelleted and non-pelleted), urea levels as well as their interactions had significant effect on Haematocrit percentage (HCT %).

The values recorded showed no sign of danger in terms of the transportation of oxygen and absorbed food nutrients through the blood tissues since all the values recorded fall within the normal physiological range of 30 – 50 % for a normal healthy rabbit as reported by Idahor *et al.* (2018). The significant interaction effects between feed form (pelleted vs. non-pelleted) and urea levels on various parameters, such as GRA, HGB, LYM count and RBCs, showed no sign of danger since all the respective values recorded fell within the normal ranges of a healthy rabbit. Non-pelleted feed resulted in a significantly higher ($p < 0.05$) WBCs count as compared to the pelleted feed 6.484 vs $5.186 \times 10^9/L$, ($p = 0.017$). Although, values obtained were also within the normal physiological range for rabbits 2.71 – $12.23 \times 10^9/L$ as reported by Beloumi *et al.* (2020), the non-pelleted feed may stimulate the immune system, leading to an increase in WBCs production. The findings in this study suggest that rabbits fed mash (non-pelleted) diets had improved immune responses, including increased antibody production and activation of immune cells, compared to those fed pelleted diets. Both feed forms and urea levels statistically showed no significant effect ($p = 0.197$) on platelet (PLT) counts. However, the trend tends to decreased platelet count with increasing urea levels with 0 % recording the highest value $518 \times 10^9/L$ and 6 % urea level recording the lowest value $331.3 \times 10^9/L$. This observation affirms the findings by Özkan *et al.* (2012) who found that rabbits fed diets with high urea levels 2.5 % and 3.5 % had significantly lower PLT counts as compared to those fed a control diet (1.5 % urea). Amaechi *et al.* (2021) reported that urea toxicity is thought to be the primary cause of decreased PLT counts. High urea levels can lead to ammonia toxicity, which may cause damage to the bone

marrow, leading to decreased PLT production. However, all the values recorded for platelet count in this study fall within the normal physiological range of $75\text{--}763 \times 10^9/\text{L}$ as reported by Idahor *et al.* (2018) .

Significant interactions were noted for WBC count ($p = 0.030$) and PLT count ($p = 0.001$), suggesting combined effects of feed form and urea supplementation. This aligns with the findings reported by Bhatt *et al.* (2017) that the interaction of feed form and urea levels can significantly affect haematological parameters and overall animal health. These results showed that the experimental diets contained good quality proteins that met the rabbit nutritional requirements. The form of feed can influence the bioavailability and utilization of urea, leading to differential effects on haematological parameters. Also, it is a clear indication that there is evidence in literature that haematological characteristics of livestock suggest their physiological disposition to the plane of nutrition (Nuhu, 2010). 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.

5.5 Effects of Dietary Urea-Treated Maize Husk Meal and Pelleting on Serum

Biochemical Characteristics of Rabbits

Serum biochemical parameters, according to Edoh *et al.* (2019), provide essential information about visceral organ damage, particularly for the liver and the kidneys. Feed form (pelleted vs. non-pelleted) showed no significant effect on high-density lipoprotein (HDL). However, non-pelleted feed form recorded the higher concentration of HDL 1.498 mmol/L vs 0.943 mmol/L for pelleted feed form. This finding corroborates with a study conducted by Lebas *et al.* (2011), who noticed that rabbits fed on non-pelleted

diets had significantly higher HDL levels compared to those fed pelleted diets. Feed form also had a significant effect ($p = 0.000$) on LDL with non-pelleted recording the highest mean 1.508 mmol/L against 0.969 mmol/L for the pelleted feed form.

This finding contradicts with the findings of Omokore and Alagbe, (2019) who found that rabbits fed with pelleted diets had significantly higher LDL levels compared to those fed with the non-pelleted diets. This observation may be attributed to the compacted nature of the pelleted feed with reduced moisture content; potentially decreasing bacterial fermentation which resulted in decreased production of short-chain fatty acids and therefore decreased LDL concentration as stressed by Omokore and Alagbe (2019). 6 % urea level significantly recorded the highest LDL volume 1.417 mmol/L followed by 4 % urea level 1.38 mmol/L. These values are higher than the normal range of 0.5 - 1.0 mmol/L reported by Ference *et al.* (2017).

Cha *et al.* (2016) reported that higher urea levels (4 % and 6 %) significantly increase LDL levels in rabbits which may increase the risk of cardiovascular disease. Urea levels showed no significant effect on HDL levels. The study by Hassan *et al.* (2016) corroborates with this by showing that increased dietary protein levels can increase urea production and recycling without significantly affecting blood protein content. The significant effect ($p = 0.011$) of feed form on Alkaline Phosphatase volume (ALP), favouring the non-pelleted form. Non-pelleted feed showed significantly ($p < 0.05$) higher T. CHOL levels compared to pelleted feed 2.804 vs 2.223 mmol/L. Urea-treated feeds led to increased blood urea nitrogen, which may influence lipid metabolism and cholesterol levels (Wang *et al.*, 2021). Although, the values recorded were within the normal range for rabbits 0.3 to 3.0 mmol/L, as reported by Jiwuba *et al.* (2021), the non-

pelleted feed form was clearly reflected in the serum cholesterol level and that the increased cholesterol was mainly due to the increase in HDL level (Saeed *et al.*, 2019).

However, it can be concluded that the low level of cholesterol and liver lipid levels with the pelleted feed form can be employed to produce animal products with reduced cholesterol content. Serum ALT was significantly highest at 4 % and 6 % urea levels 72.26 and 78.00 U/L respectively. AST increases significantly at 4 % urea and 2 % urea levels 148.2 and 113.8 U/L. These recorded values of the two enzymes fell within the normal healthy level 45 – 80 U/L and 35 – 130 U/L respectively as reported by Mankga *et al.* (2022) and these suggest no damage to the liver had occurred by addition of urea. There was no significant effect of urea levels on ALP. Although, 6 % urea level recorded the highest value of 80.75 U/L for ALP, these values are within the normal range of 9.05 – 94.68 U/L as reported by Özkan and Pekkaya, (2019) and do not pose any danger to the liver function. Elevated levels of liver enzymes, particularly ALT and AST, with higher urea level have been documented. Yakubu and Afar (2014) have shown that prolonged feeding urea-treated diet can impact liver function, reflected in increased levels of liver enzymes. The interactions between feed form and urea levels significantly affecting AST and ALT aligns with the findings of Waly *et al.* (2021). These studies emphasize that the physical form of feed (pelleted vs. non-pelleted) combined with urea supplementation can have complex effects on metabolic and biochemical parameters.

Very-Low-Density Lipoprotein (VLDL) levels were significantly affected by urea levels, with the highest levels observed at 6 % urea and the lowest at 4 % urea level. These findings align with studies indicating that dietary urea can influence lipid metabolism, particularly VLDL production. According to Mafimidiwo *et al.* (2022), higher urea

levels may lead to increased hepatic lipogenesis, resulting in elevated VLDL levels which may lead to hyperlipidaemia and cardiovascular risk. VLDL is a type of lipoprotein that transports endogenous triglycerides from the liver to peripheral tissues. Conversely, optimum urea level, like 4 % may be associated with more balanced lipid metabolism.

There was no significant effect of urea levels on Albumin and Globulin levels, although pelleted feed forms significantly exhibited higher levels of both proteins. This finding is in line with Nuamah *et al.* (2019) who also recorded similar trend. The increased values of both Globulin and Albumin in pelleted feed form and both values falling within the normal physiological range 27 to 50 g/L (Olamilusi *et al.*, 2022) and 27.0 - 43.0 g/L (Özkan *et al.*, 2012) respectively, indicate that the experimental animals have higher levels of immunity and could demonstrate resistant to diseases. The lack of significant changes in Albumin and Globulin levels with varying urea supplementation may suggest that these proteins are more influenced by the overall protein intake and nutritional status rather than urea levels alone. Feed form and urea levels showed no significant effect on Total Bilirubin concentration and since all the values recorded fell within the normal physiological range, 3.4 – 8.5 $\mu\text{mol/L}$, it an indication of a healthy liver of the animals as reported by Beloumi *et al.* (2020). This finding is in line with studies suggesting that bilirubin levels can be influenced by liver function and haemolysis Elhanafy *et al.* (2023), rather than dietary urea levels. The stability of total bilirubin levels across different urea levels indicates that these dietary changes may not significantly impact liver function in the short term. The variation in bilirubin levels in response to urea levels may reflect changes in liver metabolism and excretory processes.

Studies have indicated that increased urea levels can affect liver function and bile production, potentially leading to altered bilirubin metabolism (Chakrabarti *et al.*, 2017).

The decrease in bilirubin 1.275 $\mu\text{mol/L}$ at higher urea levels, 6 % against 1.675 $\mu\text{mol/L}$ at lower urea level, 2 % may suggest an adaptive response of the liver to increased nitrogen load. Serum triglyceride concentration was significantly affected ($p < 0.05$) by urea levels with highest level 0.868 mmol/L recorded at 6 %, though all the values are within the normal range 0.5 – 2.5 mmol/L, as reported by Jiwuba *et al.* (2021). This is an indication that there is normal or reduced risk of cardiovascular diseases. There were significant effects ($p < 0.05$) of both feed form and urea levels on serum urea. Although, the values recorded falls within the normal range, 4.91 – 8.12 mmol/L as reported by Jiwuba *et al.* (2021), the findings in this study may be as a result of optimal renal function by degrading dietary urea by urease activity of the gastrointestinal tract to be excreted out instead of infusion into blood plasma as opined by Spek *et al.* (2013). The amount of urea degraded in the body may be increased by dietary manipulations which do not affect rumen fermentation directly. Feed form, urea levels and their interactions had no significant ($p > 0.05$) influence on serum creatinine concentrations.

Lack of significant effect on serum creatinine concentrations, may be attributed to the fact that creatinine is a more sensitive indicator of renal function, as it is not influenced by extra-renal factors such as protein intake. This is an indication that the rabbits' kidneys were functioning properly. Different urea levels showed no significant ($p > 0.05$) effects of serum protein. However, the trend of decreasing protein concentration with increasing urea levels may be attributed to the fact that high urea levels can increase deamination by the liver which reduces protein availability in the blood (Boteon *et al.*,

2019). Statistically, the interactions between urea levels and feed forms showed significant difference ($p < 0.05$) on protein content with the highest value 6.250 g/L recorded for pelleted with 0 % urea and it falls within the normal range of 5.0 – 7.5 g/dl as reported by Jatutu *et al.* (2024) and this may be attributed to the low urea level and the pelleting process which might have decreased the rate of deamination (Divya *et al.*, 2020).

However, since the value falls within the normal range in this study, it is an indication of nutritional adequacy of the dietary proteins for the rabbits. The other interactive values recorded on serum total protein significantly falling below the normal range may be attributed to the combined effect of the different urea levels and the mode of processing the feed. The study emphasizes the need for a well-balanced diet, as imbalances in other nutrients could confound the effects observed on biochemical parameters.

5.6 Effects of Dietary Urea-Treated Maize Husk Meal and Pelleting on Carcass

Characteristics of Rabbits

The findings from this study provide valuable insights into animal growth and yield. No significant differences ($p > 0.05$) were observed in live weight and slaughter weight between non-pelleted and pelleted feed forms. However, the trends showed the highest live weight 2308 g and slaughter weight 2238 g at 4 % urea, while 6 % urea level resulted in the lowest values 2013 g and 1950 g, respectively. The pelleted feed form recording significantly higher caecal pH of 7.038 against 6.593 for non-pelleted feed form corroborates with Truelock *et al.* (2020) who emphasized that non-pelleted feed may have insufficient starch gelatinization making it inaccessible to enzymes for fermentation. The trend of decreasing Caecal pH with increasing urea levels observed in

this study affirms what was reported by El-Deep *et al.* (2020) that rabbits fed a diet supplemented with urea exhibited a significant decrease in Caecal pH compared to those fed a control diet. These observations may be attributed to the mechanisms involved during hydrolysis of urea. Urease enzymes break down urea into ammonia, which combines with hydrogen ions to form ammonium, thereby reducing caecal pH. The findings in this study on caecal pH contradict with Miranda *et al.* (2024) who reported that urea-treated diets for rabbits may lead to an increase in pH levels, particularly in the caecum where fermentation of fibrous material occurs.

The pH values reported in this study pose no threat to the animals as they are within the normal range of what was reported by Maklad *et al.* (2023), (6.5 to 7.5 or even higher). This creates an ideal environment for the growth of beneficial bacteria that aids in the digestion of fibre. No significant differences were observed in weight of visceral content between feed forms and between urea levels. This may suggest that this parameter is less affected by dietary variations compared to other carcass traits. However, the trend of significantly increased percentage visceral content with respect to increasing urea levels in the feed may be as a result of an increased internal organ mass, which could be related to the metabolic demands of processing higher protein levels. Although non-pelleted feed resulted in lower dressed carcass content weight 1248 g as compared to pelleted feed 1352 g, the difference was not statistically significant. This may be related to the increase in growth performance and digestibility and also lower feed conversion ratio recorded on pelleted feed. Urea levels also did not show significant effects on dressed carcass content. The highest percentage dressed carcass percentage was observed at 6 % urea 63.32 % ($p = 0.121$), though, not statistically significant. Studies on the effects of feed form on dressed carcass content have shown mixed results, with some

reporting better carcass yield with non-pelleted diets and others finding no significant differences (Klinger *et al.*, 2018). The trend towards higher dressed carcass percentage at 6 % urea level suggest that moderate protein supplementation can enhance carcass yield, but the lack of statistical significance warrants caution in interpretation.

Ensuring a well-balanced diet is crucial, as imbalances in other nutrients may confound the effects of feed form and urea levels on carcass characteristics. Genetic factors, health status, and environmental conditions can contribute to individual variations in growth and carcass traits, complicating the interpretation of dietary effects (Attia *et al.*, 2014). The effects of feed form and urea levels may interact with other dietary components, such as fibre sources and energy levels, which were not explicitly investigated in this study.

CHAPTER SIX: SUMMARY, CONCLUSION, AND RECOMMENDATIONS

6.1 Summary of Findings

6.1.1 Effects of dietary urea-treated maize husk and pelleting on Growth Performances of rabbit

1. From the study, Rabbits fed with the pelleted feed form significantly recorded the highest feed intake in most of the weeks; (week 5, 6, 9, 11) and the total feed intake at the end of the feeding trial.
2. From the study, the diet treated with the 0 % urea level recorded significantly the highest weekly feed intake in most of the weeks (3, 4, 6, 7, 8, 9, 11 and 12) of the feeding trial than any other urea level.
3. Although, non-pelleted feed form showed higher weekly feed intake in most of the weeks, the values recorded did not show any significant effect.
4. Urea can potentially stimulate feed consumption, possibly through improved nutrient utilization or metabolic efficiency
5. Results from the study revealed that when rabbits are fed with pelleted feed form, their body weight and weight gains increase.
6. Body weight and weight gains were highest at 4 % urea level indicating that the 4 % urea level will do better when treating maize husk for feeding rabbits.
7. The interaction between pelleted feed forms with 4 % urea level recorded the lowest FCR which indicates more efficient feed utilization and better feed quality.

6.1.2 Effects of dietary urea-treated maize husk and pelleting on reproductive performances of rabbits

- Both feed form and urea levels showed no significant effect on gestation period.
- Feed form had no significant effect on gestation period. Both forms recorded an average gestation length of 31.67 which was similar to the findings of Ruknuzzaman *et al.* (2018) who recorded a gestation period 31.60 - 32.30 days.
- Non-pelleted feed form recorded the highest average litter size, liveability percentage, litter size at weaning and weaning weights.
- The interaction between non-pelleted and 6 % urea level may be best in improving their productive and reproductive performances.

6.1.3 Effects of dietary urea-treated maize husk and pelleting on haematological characteristics of rabbits

- a) There was a trend of increased both GRA count and percentages with increasing urea levels. RBCs, HCT and HGB also followed similar trend with HCT level showing significant difference.
- b) There were elevated levels of HCT and HGB with response to increasing urea levels. This confirms a report by Armaini *et al.* (2018) that urea has been shown to enhance erythropoiesis and increase red blood cell production, leading to elevated HCT and HGB levels.
- c) Both LYM count and percentage significantly favoured the non-pelleted feed form.
- d) Both feed form and urea levels showed no significant effect on MCH and MCHC indicating that these parameters are intrinsic property of RBCs and less affected by external factors such as urea supplementation

- e) Those that were fed on the non-pelleted feed form recorded the highest WBCs count which may result from the fact that non-pelleted feed may stimulate the immune system, leading to an increase in WBCs production.
- f) There was a trend of decreased PLT count as urea levels increases. The decreased in PLT may arise from ammonia toxicity which can damage bone marrow leading to decreased in PLT production.

6.1.4 Effects of dietary urea-treated maize husk and pelleting on serum biochemical characteristics of rabbits

- a) Rabbits feed on the non-pelleted feed form showed significantly the highest total cholesterol as a result of increased in HDL level.
- b) Enzyme levels, including ALP, ALT, and AST, were significantly affected by urea supplementation levels.
- c) Higher urea levels (4 % and 6 %) significantly increased LDL, VLDL and HDL levels in rabbit which may increase the risk of cardiovascular diseases.
- d) The findings revealed that low level of Cholesterol and liver lipid levels with the non-pelleted feed form with lower urea level can be employed to produce animal products with reduced cholesterol content.
- e) The non-pelleted feed form significantly recorded the highest Aspartate Aminotransferase (AST) levels. The interactive effect between non-pelleted feed and 4 % urea level also recorded a significantly higher AST level.
- f) The increased in serum AST levels may be an indication damaged to liver or gastrointestinal tract.
- g) Pelleted feed form showed higher levels of Albumin and Globulin levels which reflect better nutrient absorption and utilization.

- h) The finding revealed an optimal liver and enzyme activity since there was better conversion of urea to serum triglycerides.

6.1.5 Effects of dietary urea-treated maize husk and pelleting on carcass characteristics of rabbit

- a) Both feed form and urea levels showed no significant effect on live weight, head weight and slaughter weight.
- b) The pelleted feed form recording significantly higher caecal pH of 7.038 against 6.593 for non-pelleted feed form and may be attributed to insufficient starch gelatinization during the pelleting making it inaccessible to enzymes for fermentation.
- c) Rabbits that were fed with the non-pelleted feed form significantly recorded lower caecal pH as a result of changes in microbial fermentation pattern influencing gut acidity affecting microbial activity and digestion
- d) There was a trend of decreasing Caecal pH with increasing urea levels in this study.
- e) All the significant pH values reported in this study pose no threat to the animals as they are within normal physiological range of 6.5 to 7.5 as reported by Maklad *et al.* (2023).
- f) The 6 % urea level showed higher percentage visceral content indicating an increased in internal organ mass, which could be related to the metabolic demand of processing higher protein levels.
- g) The pelleted feed form recorded the higher dressed carcass weight and percentage though not statistically significant. This is mainly related to the increased in growth performances, digestibility and lower FCR.

6.2 Conclusions

It can be concluded from this study that:

- a) Rabbits could tolerate processed maize husk in their diet without negatively affecting their physiological functions.
- b) The interactions between 4 % urea level pelleted feed forms significantly recorded the higher growth performances than the non-pelleted feed which indicates more efficient feed utilization and better feed quality.
- c) If the optimum urea level is used to treat maize husk, the Gestation period will not be affected irrespective of any feed form.
- d) Urea treated maize husk meal can be fed to rabbits in the non-pelleted form and it likely to increase average litter size, liveability percentage, litter size at weaning and weaning weights.
- e) Non-pelleted feed significantly ($p < 0.05$) recorded the highest WBCs, HCT, GRA, HGB, RBCs and LYM counts, total cholesterol, serum urea, ALP, AST and LDL against the pelleted.
- f) Higher urea level, 6 % can also be used to treat maize husk for rabbit nutrition but long-term effect may be detrimental on the animal.
- g) Prolong use of high urea level in rabbit nutrition can cause an increase LDL, VLDL, HDL, and liver enzyme AST which may cause cardiovascular diseases
- h) Maize husk meal treated with optimum urea level can be fed in non-pelleted form without any adverse effect on rabbit's haematological characteristics which indicates more efficient feed utilization and better feed quality

6.3 Recommendations

This study makes the following recommendations:

1. Maize husk is recommended for use as feed ingredient in rabbit production.
2. It is recommended to use moderate levels of urea supplementation, specifically around 4 – 6 %, to optimize blood parameters and growth performance in animals. Higher levels, such as 6 %, showed positive effects on certain blood parameters but should be used with caution to avoid potential adverse effects.
3. Non-pelleted feed is recommended for improving certain blood parameters, such as WBC and cholesterol levels, and for enhancing reproductive performances. However, pelleted feed is more beneficial for growth performance. Therefore, the choice of feed form should be based on the specific production goals, whether focused on reproduction or growth.
4. Regular monitoring of lipid profiles and liver enzyme levels is recommended when using urea-treated maize husk particularly at higher levels (6 %). This practice can help in early detection of any metabolic or liver function issues, ensuring timely intervention.
5. It is recommended that further studies should be carried out to determine the effects of dietary urea-treated maize husk and pelleting on the reproductive performances of male rabbits.
6. Further studies should be carried out to determine the costs and benefits of using urea-treated and pelleted maize husk meal in rabbit production.

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