COMPARATIVE EVALUATION OF PROTEIN PROFILES AND CARCASS QUALITY TRAITS OF SOME RABBIT GENOTYPES IN SOUTH-WESTERN NIGERIA

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Abstract

A study on protein profiles and carcass quality traits was conducted using four purebred rabbits comprising New Zealand White (NZW), Chinchilla (CHL), Zealand Red (NZR) and the Cinnamon(CNM) in a diallele crossbreeding experiment that generated 16 genotypes involving four straight breeds and 12 crossbreds respectively. The performance of these rabbit genotypes was monitored to evaluate the crossbreeding effect on blood protein and carcass traits. Genotypes significantly (P<0.05) affected blood protein studied in which better performances were recorded in Cinnamon (CNM), New Zealand Red (NZR)and their crosses. Carcass quality traits also followed a similar pattern as obtained in blood proteins. The CNM, NZR and their cross recorded high live weight with higher percentage dressed weight due to high level of means of meat to bone ratio (61:24%) coupled with lowest percentage of Gastro Intestinal Tract (GIT) which statistically (P<0.05) accounted for less than 15% of its total carcass yield. The study therefore underscored the importance of crossbreeding effect in improving the protein and the carcass yield in rabbits, for sustainable livestock development in Africa.

Key Words: *Carcass quality, Genotypes, Protein profiles, Rabbit, Traits,*

INTRODUCTION

It is a widely accepted truth that diet plays a very important role in the health status of people in every community (Akanni et al.,2018 a and b; Akanni and Ajayi, 2021). In fact, inadequate protein consumption has led to cause a number of health deficiencies such as muscle wasting, degradation of important body parts, decreased immunity, and other protein deficiency diseases which are on the alarming rate amidst people of all age ranges (Akanni, 2012). This is because proteins are involved in almost every process within the cells and tissues. In addition to providing structure to the organs, muscles, nails and hair, this nutrient helps aids cells to cell communication, and allows contraction and relaxation of muscles, and the transmission of nerve impulses.

This calls for needs to examine the strategies and possibilities of reducing, if not curbing the challenge, addressing it from the nutritional health perspective, by using value additions in rabbits with a view to enhance the growth performance, nutrient utilization and meat quality available for consumers in order to reduce the consumption of bulk proteins withnon-essential amino acids, undesirable fat, cholesterol, sodium and potassium present in other livestock species such as beef, pork, veal, chicken and eggs (Akanni 2017). If quality meat is available for human consumption, there would be availability of adequate nutrients, and reduction in cardiovascular diseases.

The present state of the economy coupled with the current inflationary trend, scarcity and high cost of production contributes to the poor production of animal protein which is required in high demands. It has been reported that out of the 44g protein supply per caput, animal products constitute about 2%, leading to malnutrition and under-nutrition of all age groups in Nigeria (FAOSTAT, 2102; FAOSTAT, 2016). Animal protein supply has also been reported inadequate because of low population of livestock in relation to human population, low level of animal productivity in terms of slow growth rate, slow reproduction cycle, slow milk, meat, and egg yield which has direct influence on general well-being and health of the ever increasing population (Akanni, 2012).

To overcome the animal protein insufficiency, the need to improve on the genetic, reproductive and productive potentials of livestock in Nigeria becomes imperative. This can be achieved by the introduction of non-traditional meat sources such as rabbits for small scale farmers for its meat and other by-products. Mini livestock such as rabbits are small sized animals which are little known but are beneficial nutritionally and economically and can also provide good animal protein and B-complex vitamins (salvatori et al.,2004; Scendro, et al., 2020.

Protein makes up immune molecules, blood cells, hormones and enzymes, and it also assists body cells in synthesizing new proteins. Too little protein in the daily diet can lead deficiencies, affecting one or more of these essential functions and cause symptoms ranging from unpleasant to life threatening. All the cells of the body contain protein, whereas, the body does not store protein, and this implies the need for adequate amounts of protein in daily diet. In case of amino acids deficiency, especially essential amino acids, body breaks down protein-rich tissues (for example, muscles) to access them. Therefore, the initial effect of low protein intake or essential amino acids deficiency can be muscle wasting accompanied by increasing weakness (Adejinmi et al.,2005; Akanni, 2009). There could also be a greater number of infections because the immune system can't produce enough antibodies or other immune molecules. Extreme protein deficiency can result in shock and eventual death.

To keep protein intake from being too low, it is recommended that a minimum of 0.8 gram of high-quality protein should be consumed every day for each kilogram of individual weight. High-quality protein sources contain all essential amino acids and include meat, fish and milk products. Most plant sources of protein lack at least one essential amino acid, so must be combined in such a way that, together, they supply all the essential amino acids needed for the proper function of the body. For example, eating whole grains with legumes or nuts provides the full complement of amino acids that can help you prevent muscle wasting and other symptoms of protein deficiency.

Although animal protein sources are usually preferred, they have some other contents like fat that tends to put a restraint on their consumption for man. Of the domestic animals, rabbits are species that is widely accepted in terms of taboos and bias (Akanni and Ajayi 2021).

The status of rabbit production in Africa

Rabbit (Orictolagus cunniculus) is one of the least domesticated animals in humid and sub-humid climates like Nigeria despite its nutritional composition, medicinal value and importance in human diet. Although it is highly profitable and has good demand at the local and international markets, no significant effort has been made at its large commercial farming (Akanni, 2012; Akanni et al., 2018).

According to the FAO, reports from year 1998 to 2020 the global demand for rabbit meat is still far outreach supply as evident in relatively low production (Trocino et al., 2019; Szendrö et al., 2020) as 980,785,000 rabbits were slaughtered in 2016 around the world, and 1,428,085 tons of rabbit meat were produced (compared with the global meat production of 329,890,425 tons). Asia is recorded the largest rabbit meat producer in the world (approx. 73% of the global market) followed by Europe, Africa, and the Americas whose share of the global market is approximately 20%, 6.1%, and 1%, respectively.

Nutritive value of rabbit meat

The leanest cut of meat in the rabbit carcass is the loin, which contains an average lipid content of 1.8 g/100 g of meat, whereas the fattest is the foreleg, with an average lipid content of 8.8 g/100 g of meat. The quantitatively most important cut is the hind leg, with a moderate lipid content (an average of 3.4 g/100 g) compared with most types of meat consumed today. Lipid content depends on the portion considered and productive factors, especially diet (Dalle Zotte, 2002). Rabbit meat has a moderately high energy value (from 603 kJ/100 g in loin meat to 899 kJ/100 g in foreleg meat) that essentially depends on its elevated protein content, which accounts for 80% of its energy value. Together with its increased protein content, rabbit meat contains high levels of essential amino acids (EAA). Compared with other meats, rabbit meat is the richest in lysine (2.12 g/100 g), sulfur-containing amino acids (1.10 g/100 g), threonine (2.01 g/100 g), valine (1.19 g/100 g), isoleucine (1.15 g/100 g), leucine (1.73 g/100 g), and phenylalanine (1.04 g/100 g; Dalle Zotte, 2004). Increased and balanced content of EAA combined with easy digestibility give rabbit meat proteins their increased biological value. Furthermore, rabbit meat does not contain uric acid and also has low purine content (Hernández and Dalle Zotte, 2010).

The variation of vitamin content in meats is greater than with other meat nutrients because of the strong effect of the diet composition and the level of vitamin supplementation. The amount of vitamin E contained in rabbit meat may be increased by more than 50%, for example, with the use of the right supplements (Castellini et al., 1998). Vitamin E is involved in numerous physiological functions, is an essential nutrient for reproduction, and is a powerful anti-oxidant. The latter function of vitamin E makes it an essential nutrient for improvement of meat quality because it prevents the oxidation of the fatty acids and promotes the colour desired in the meat. Meat is an important source of bioavailable vitamin B, with contents that vary from one species to another and even from one cut of meat to another in the same species, while cooking reduces the original content (LombardiBoccia et al., 2005). On average, the consumption of 100 g of rabbit meat provides around 8% of the riboflavin (vitamin B2), 12% of the pantothenic acid (vitamin B5), 21% of the pyridoxine (vitamin B6), and 77% of the niacin (vitamin B3) required daily (Hernández and Dalle Zotte, 2010). The lack of vitamin B12 created by the popularity of vegetarianism is a growing cause of concern in the most developed nations of the world. Meat from ruminants and rabbits are the richest sources of vitamin B12, and the consumption of 100 g of rabbit meat provides three times the recommended daily intake (RDI) of vitamin B12 (Dalle Zotte and Szendr?, 2011).

Rabbit meat, like other white meats, contains only modest amounts of iron (1.3 and 1.1 mg/100 g in the hind leg and loin, respectively; Parigi Bini et al.,1992). However, the iron contained in meat is principally heme iron, which is easily absorbable, and for this reason, rabbit meat may contribute to meeting a part of our daily iron RDI. Rabbit meat is characterized by a low content of sodium: 37 mg/100 g in the loin and 49.5 mg/100 g in the foreleg (Parigi Bini et al., 1992). This characteristic makes rabbit meat suit an inclusion in the diets of people suffering from hypertension.

Consumers' preference of rabbit meat

Production and consumption of rabbits in Nigeria is increasingly gaining importance and popularity in the sub-humid zone(Akanniet al.,2018a and b; Akanni and Ajayi, 2021). It is worthy of note domestic rabbits can open up new frontiers in the meat industry considering its efficient convertibility of feed into meat as source of protein for human consumption and, comparing this parameter, one can suggest the possibility that domestic rabbit will become more and more important in furnishing the meat supply of the country, especially as human population is on the increase and competes to a greater extent with the meat-producing animals for the cereal grains. The importance of the domestic rabbit for supplying meat for human consumption in thickly populated countries like Nigeria could be illustrated by the number of rabbits raised either as backyard or as commercial farming because of its genetic flexibility and variability, adaptability and productivity in a wide range of production systems.

Materials and method

Description of the Experimental site

The research was carried out at the Rabbitry Unit of the Department of Primary Education, School of Education, Federal College of Education, Osiele, Abeokuta, Nigeria. Osiele (7010'N and 302'E) is in Odeda Local Government Area of Ogun State, Nigeria. The experiment was conducted using 16 does and 2 bucks from each of the pure line and their crosses. These animals were raised between February 2018 and January 2019 in an experiment that lasted for 52 weeks.

Methodology

The experimental rabbits comprised 20 each of four pure breeds; the New Zealand White (NZW) and the American Standard Chinchilla (CHL), New Zealand Red (NZR) and the Cinnamon (CNM) rabbits. These exotic rabbit breeds were sourced from the on-going TETFund Rabbit Breeding and Multiplication experimental farm. The pure breeds served as a control line to all the crosses. Twelve lines inclusive of straight and reciprocal crosses were generated from the 4 x 4 dialled crossing of these rabbit breeds. 320 growing rabbits (progenies) averaging six weeks in age and 750g - 850g in body weight were reared till puberty (20 weeks of age when the average body weight reaches 2450g) and used as parental base population.

Management of experimental animals

Bucks and does from each genetic group were properly identified by ear tagging. The rabbits were housed in hutches and on deep litter (floor) system. Each hutch has the following dimensions. Length - 144cm; width - 24cm / 48cm and height - 36 cm for both growers and breeders' hutches. The hutches were raised on both wooden and metal legs about 24cm above the ground. The rabbits in hutches were placed inside a low walled house built with wooden material and corrugated iron sheets as roofing material. The wooden hutches were covered to some extent with mesh that would permit inspection, ventilation and dropping of rabbit feaces and urine to the floor. The experimental rabbits were fed commercial that supplies 16.50% crude protein and 9.66 MJ/kg metabolizable energy in the morning, supplemented intermittently with 100g each of wilted Sweet potato, Tridax Procumbens and Benth leaves in the evening throughout the course of the experiment.

Blood collection and typing: Blood samples (about 2ml) were collected at the end of the experiment from ten randomly selected rabbits in each genetic group after weighing the animals and before feeding them in the morning. The blood was withdrawn from the ear vein of each of the randomly selected animals by means of 2ml (23GR) sterile needle and syringe into labelled bijou bottles containing a speck of dried ethylene diamine tetra acetate (EDTA) powder, an anti-coagulant for blood plasma analysis and another 2ml were collected into bottles without anti-coagulant for blood serum analysis. The bottles were immediately capped and the contents mixed gently for about a minute. The bottles were labelled for individual rabbit in each genetic group and stored in the refrigerator.

Serum protein biochemical studies: The serum prepared earlier was thawed, Serum protein, Albumin, Globulin and Calcium levels, etc. were then assayed (Lamb, 1981; Akanni, 2012).

Carcass analysis

Four rabbits (20 weeks of age) were selected from each genetic group, half of which were males and the others females for slaughtering and carcass yield processing. Feed was withdrawn for 12 hours from the rabbits so as to empty their caeca and to reduce the variability in body weight due to intestinal content. At slaughter, head of these rabbits were severed from the neck through the jugular vein. The rabbit was dehaired by miled roasting in fire, washed with clean water so as to be free of dirt. The gastro intestinal tract (G.I.T) and the organs (Kidney, Liver, Heart, Lungs and Spleen) were removed after evisceration and weighed. The empty body weight (EBW), hot carcass weight (HCW) and shrunk body weight (SBW) were determined and recorded. The carcasses were cut into retail parts (Shoulder, Rack, Loin, Legs, Head and Tail) and then weighed with a sensitive electronic weighing balance of 0.01g sensitivity. Individual weight were noted for each rabbit and expressed as percentage of live weight. The dressing percentage of the carcass based on the genotype was calculated using the formula:

$$\text{Dressing \%} = \frac{\text{Dressed weight (g)}}{\text{Live weight (g)}} \times 100$$

The shrunk body weight (SBW), empty carcass weight (ECW) and hot carcass weight (HCW) were also determined using the following relationship:

EBW = SBW - GIT

HCW = EBW - Trotters and head

Statistical Analysis

Analysis of carcass traits was carried out using the model;

$$Y_{ijkl} = \mu + G_i + P_j + S_k + (GP)_{ij} + (GS)_{ik} + (GPS)_{ijk} + e_{ijkl}.$$

Where:

Y_{ijkl} = Observation on the l^{th} rabbit in the k^{th} season, j^{th} sex and i_{th} genetic group
μ = Overall mean
G_i = Effect of the i^{th} genotype
P_j = Effect of j^{th} sex
S_k = Effect due to k^{th} season
$(GP)^{ij}$ = Interaction of I^{th} genotype with j^{th} sex
$(GS)^{ik}$ = Interaction of I^{th} genotype with k^{th} season
$(PS)^{jk}$ = Interaction of jth sex with k^{th} season
$(GPS)^{ijk}$ = Interaction among I^{th} genotype, j^{th} sex and k^{th} season
e^{ijkl} = Random residual error associated with each observation, assumed to be normally distributed with zero mean and variance (δ^2_e)

The effect of genotype and age on the blood protein traits were estimated from two-way analysis of variance with sub-samples using the General Linear Model of SAS (2012). Significant differences among means were separated. Correlations were also computed using SAS (2012). All effects except error terms were considered as fixed effects.

The model was:

$$Y_{ijk} = \mu + G_i + S_j + (GS)_{ij} + bA + e_{ijk}$$

Where:

Y_{ijk} = Observation on the k^{th} rabbit in j^{th} sex and I^{th} genetic group
μ = Overall mean
G_i = Effect of the I^{th} genotype
S_j = Effect of the j^{th} sex
$(GS)_{ij}$ = Interaction of I^{th} genotype with j^{th} sex
b = Regression coefficient
A = Covariate (Age in weeks)
e_{ijk} = Random residual error normally distributed with zero mean and variance (δ^2_e)

Results

Genotype effect on blood protein profiles traits

Tables 1, 2 and 3 present the significant (P<0.05) genotype effect on the blood chemistry, serum chemistry and blood electrolytes of the experimental rabbits at20 weeks of age. Higher statistical values for Haemoglobin Concentration, Packed Cell Volume (%), Red Blood Cells, and White Blood Cells were reported. The HBC for Cinnamon X Chinchilla, Chinchilla pure line, Cinnamon X New Zealand White, Chinchilla X New Zealand White, Cinnamon pure lines and the Cinnamon were 16.64±0.01gdl^{-1}, 16.30±0.03gdl^{-1}, 16.25±0.15gdl^{-1} with PCV 16.20±0.15gdl^{-1}, 16.14±0.17gdl^{-1} and 16.10±0.10gdl^{-1}. Similar values were noticed in haemoglobin Concentration (HBC) and Red Blood Cells and White Blood Cells, Mean Cell Volume and Mean Cell Haemoglobin across the genetic groups. The reverse was the case for blood glucose such that higher values were observed in New Zealand White and the Chinchilla X Cinnamon (86.30±1.30mg-100ml and 80.00±0.00mg-100ml) while the lowest values of 44.81±0.20mg-100ml and an average of 75.70±0.50mg-100ml was recorded for New Zealand Red pure line and its crosses with New Zealand White (NZR X NZW) as shown in Table 32. Generally there is wide variation in blood haematology traits of the rabbits across the genetic groups.

Similar results were also recorded in blood serum and electrolytes respectively, as higher values for serum albumin and total protein were recorded for Cinnamon pure line and its cross with Chinchilla (CNM X CHL) followed by New Zealand White X Cinnamon and Cinnamon X New Zealand White while New Zealand Red and its crosses with Chinchilla (NZR X CHL) had the least in descending order of 71.10±1.00gdl^{-1}, 70.55±1.15gdl^{-1}, 66.86±1.19gdl^{-1}, 65.91±0.09gdl^{-1}, 46.03±1.17gdl^{-1} and 45.75±1.15gdl^{-1} ; 68.90±0.00gdl^{-1}, 68.55±2.85gdl-163.75±4.75gdl^{-1}, 63.36±1.57gdl^{-1}, 52.25±2.25gdl^{-1} and 51.75±8.75gdl^{-1} respectively. However, the reverse was the case with serum urea, cholesterol and the sodium content of the serum (Table 2).

The effect of genotype was found to significantly (P<0.05) affect the blood electrolytes of rabbits across the genetic groups. The results showed that higher values of Calcium, Phosphorus, Alkaline Phosphatase, Alanine Amino Transferase, Aspatate Amino Transferase and Serum Creatinine but lower values of Sodium, Potassium and inorganic phosphorus were recorded for Cinnamon X New Zealand White, Cinnamon X Chinchilla, Cinnamon, Cinnamon and Chinchilla pure lines; New Zealand White X Cinnamon and Chinchilla X New Zealand White compared to other genotypes (Table 3).

Genotype effect on carcass quality traits

Tables 4, 5 and 6 presents the least squares means of the carcass traits. Four animals per genotype were slaughtered for the carcass evaluation (slaughter weight, retail cut parts and organ weight). The carcass data relative to live weight, shrunk body weight, empty body weight, the hot carcass weight and the dressed weight (carcass yield) expressed as percentage of live weight were taken at twenty weeks of age. Chinchilla X Cinnamon, Chinchilla X New Zealand White and Cinnamon X Chinchilla statistically had the highest live weights at slaughter with the corresponding values of 2418.11±9.33g, 2398.15±10.98g and 2378.55±10.86g while Cinnamon X New Zealand Red and New Zealand Red pure line had the least live weight in descending order of 1845.17±19.13g and 1726.97±12.32g respectively (Table 4). Significant (P<0.05) effect of genotype was also observed in shrunk body weight as presented in Table 45. Higher weights were recorded in New Zealand Red X Chinchilla, Chinchilla X Cinnamon and Cinnamon X Chinchilla with corresponding values (1990.42±17.24g, 1981.50±19.19g and 1963.80±10.27g respectively while Cinnamon had the lowest value of 1479.14±10.16g respectively. Similar observation was recorded in empty body weight and hot carcass weight as it followed the same pattern as noticed in shrunk body weight of the slaughtered rabbit such that higher weights were significantly (P<0.05) observed in New Zealand Red X Chinchilla, Chinchilla X Cinnamon and Cinnamon X Chinchilla while Cinnamon had the least weights at slaughter. The effect of genotype was also found to be significant on percent dressed weight, which is an indication of carcass yield.

The results from the table indicated that Chinchilla X Cinnamon had the highest percent dressed weight of 74.09±0.19g closely followed by New Zealand White X Chinchilla, New Zealand Red X Cinnamon, Cinnamon X Chinchilla, New Zealand Red X Chinchilla, Chinchilla X New Zealand White and the New Zealand White pure line with the corresponding values of 73.86±1.10g, 73.23±1.11g, 72.36±1.29g, 71.56±1.12g, 71.40±0.18g and 71.19±1.10g respectively. Chinchilla, New Zealand Red and Cinnamon pure breeds statistically had the least values in descending order of 55.38±1.16g, 54.50±1.17g and 52.21±1.16g respectively as presented in the table. Results also showed that percentage lean meat and percent bone were also significantly (P<0.05) affected by genotypes. Chinchilla X Cinnamon and Cinnamon X Chinchilla had higher percentage of lean meat (76.70±1.86% and 76.43±1.29%) compared to other genotypes. The reverse was the case for the percentage bone such that the lowest values in ascending order (10.00±0.11%, 10.07±0.15% and 10.08±0.21%) were recorded for Chinchilla X Cinnamon, New Zealand Red X Chinchilla and Cinnamon X Chinchilla respectively while the highest percentage weight was recorded for the Cinnamon. Values for other genotypes are shown in the Table.

Data on retail parts expressed as percentage of live weights, in terms of the head, neck, trotter, shoulder rack, loin, thigh (legs) and tail as affected by genotypes are shown in Table 30. Results showed that genotype significantly (P<0.05) affected the retail parts. The percentage weights of the trotters were highest in Cinnamon X Chinchilla and Chinchilla X Cinnamon while Chinchilla X New Zealand Red had the least. With the corresponding values of 9.93±0.18% and 9.78±0.14% 3.38±0.21%. Chinchilla pure breed had the highest shoulder weight of 10.94±0.10% closely followed by Cinnamon (10.35±1.17%) while Cinnamon X Chinchilla had the least value of 6.96±0.18%. There were significant (P<0.05) differences observed for the relative weights of different organs among the rabbit genotypes expressed as percentage of the live weight. The percentages of gastro intestinal tract (GIT) kidney, liver, spleen and bile were highly noticed in Cinnamon and New Zealand Red, closely followed by New Zealand White while New Zealand Red X Chinchilla had the least with the corresponding values of 9.14±0.08%, 2.94±0.08%, 3.16±0.01%, 0.18±0.14% and 0.09±0.04%; and 12.02±0.22%, 9.48±1.43%, 2.22±0.16%, 0.04±0.00% and 0.02±0.01% for New Zealand White and New Zealand Red X Chinchilla respectively (Table 6). Significant (P<0.05) differences were observed among the rabbit genetic groups in terms of percentages of lungs and heart respectively. Cinnamon had the highest value of 0.92±0.00% and 0.32±0.10% closely followed by Cinnamon and New Zealand Red (0.90±0.00%, 0.90±0.04% and 0.30±0.04%, 0.30±0.05%).

Table 1: Least squares means ± SEM of blood chemistry traits as affected by genotype

GENOTYPE	N	HBC	PCV	RBC	WBC	MCV	MCH	GLU
NZW	20	14.69±0.15^{b}	41.45±1.09^{b}	4.62±0.12^{b}	5.45±0.15^{bc}	78.62±0.02^{a}	33.33±0.03^{a}	86.30±1.20^{a}
CHL	20	16.30±0.03^{a}	50.90±0.00^{a}	7.30±0.42^{a}	7.05±0.35^{ab}	74.55±5.35^{a}	32.65±2.15^{a}	70.30±1.17^{ab}
NZR	20	9.82 ±0.18^{c}	36.40 ±0.1^{c}	6.06±0.01^{ab}	8.63±0.30^{a}	56.34±3.40^{bc}	28.66±2.15^{ab}	44.81 ±0.20^{c}
CNM	20	16.14±0.17^{a}	51.55±0.05^{a}	7.54±0.44^{a}	7.39±0.23^{ab}	76.20±0.80^{a}	22.35±3.05^{b}	50.60±1.00^{bc}
NZW X CHL	20	11.89±0.19^{bc}	34.96±1.16^{c}	3.97±0.09^{c}	4.53±0.33^{c}	62.70±2.60^{b}	33.15±0.05^{a}	57.10±0.20^{bc}
NZW X NZR	20	11.18±0.18^{bc}	33.46±0.16^{c}	4.02±0.17^{c}	5.92±0.00^{b}	67.75±0.85^{b}	28.50±4.10^{ab}	68.36 ±1.21^{b}
NZW X CNM	20	13.10±0.18^{bc}	39.16±6.13^{bc}	5.95±0.45^{ab}	6.15±1.65^{b}	65.65±1.35^{a}	32.70±7.10^{a}	53.05±3.05^{bc}
CHL X NZR	20	13.98±0.15^{bc}	42.00±4.17^{b}	5.96±0.03^{ab}	8.12±0.29^{a}	45.75±11.15^{c}	30.20±0.10^{a}	71.50±1.21^{ab}
CHL X CNM	20	13.81±0.15^{bc}	41.40±0.10^{b}	7.61±0.61^{a}	7.00±2.00^{ab}	87.43±0.02^{a}	33.30±0.10^{a}	80.00 ±0.00^{a}
CHL X NZW	20	16.20±0.15^{a}	51.60±1.10^{a}	7.90±0.15^{a}	7.15±1.65^{ab}	61.55±5.35^{b}	33.70±2.15^{a}	70.00±1.07^{ab}
NZR X NZW	20	15.82±0.12^{ab}	45.62±0.09^{b}	5.06±0.01^{b}	8.35±0.85^{a}	76.02±3.19^{a}	28.66±2.14^{ab}	45.70 ±0.50^{c}
NZR X CHL	20	14.40±0.15^{b}	41.95±1.09^{b}	4.64±0.11^{b}	5.45±0.15^{bc}	66.00±0. 11^{b}	23.05±3.05^{b}	51.00±5.00^{bc}
NZR X CNM	20	9.02 ±0.18^{c}	49.00±1.10^{ab}	6.00±0.00^{ab}	7.05±0.09^{ab}	62.30±2.60^{b}	33.15±0.05^{a}	58.00±0.91^{bc}
CNM X NZW	20	16.25±0.15^{a}	51.40±0.01^{a}	7.28±0.01^{a}	8.63±0.30^{a}	77.05±0.85^{a}	28.50±4.10^{ab}	68.36 ±6.31^{b}
CNM X CHL	20	16.64±0.01^{a}	51.65±1.00^{a}	7.74±0.04^{a}	8.67±0.00^{a}	80.65±14.35^{a}	32.70±7.10^{a}	53.00±0.05^{bc}
CNM X NZR	20	11.89±0.19^{bc}	35.96±1.06^{c}	4.17±0.49^{bc}	5.53±0.29^{bc}	45.85±11.15^{c}	33.20±0.10^{a}	70.00±11.30^{ab}

a,b,c: Means in the same column with different superscripts are significantly different (P<0.05)

HBC = Haemoglobin Concentration (gdl^{-1}); PCV = Packed Cell Volume (%)
RBC =Red Blood Cell (x106mm^{-3}); WBC=White Blood Cells (x106mm^{-3})
MCV = Mean Cell Volume (Fl); MCH= Mean Cell Haemoglobin (Pg)
GLU = Glucose (mg-100ml)

Table 2: Least squares means ± SEM of serum chemistry traits as affected by genotype

GENOTYPE	N	SALBM	SGLBLN	S UREA	STPRT	CHOLST	Na^{+}
NZW	20	59.20±1.10^{bc}	26.85±0.25^{bc}	31.50±1.20^{a}	60.20±5.90^{ab}	115.65 ±6.25^{b}	136.00 ±3.50^{ab}
CHL	20	55.78±0.12^{bc}	33.00±0.25^{b}	24.82±1.20^{b}	56.90±2.80^{b}	90.70 ±4.20^{c}	111.80±11.80^{bc}
NZR	20	45.75±1.15^{c}	28.05±0.26^{b}	30.20±1.00^{a}	52.25±2.25^{c}	130.30 ±7.20^{b}	137.50 ±1.50^{a}
CNM	20	71.10±1.00^{a}	43.77±0.25^{a}	19.20±0.20^{c}	68.90±0.00^{a}	87.90 ±0.10^{c}	94.75 ±1.75^{c}
NZW X CHL	20	46.00±0.10^{c}	37.20±0.10^{ab}	31.15±1.10^{a}	57.42±0.10^{b}	87.70 ±0.20^{c}	96.80 ±7.20^{c}
NZW X NZR	20	49.55±1.15^{c}	27.45±0.25^{b}	31.07±1.25^{a}	57.20±5.00^{b}	144.20 ±0.10^{a}	113.55±15.35^{bc}
NZW X CNM	20	66.86±1.19^{ab}	22.88 ±0.24^{c}	19.05±1.05^{c}	63.75±4.75^{ab}	90.71 ±25.19^{c}	101.40 ±8.20^{bc}
CHL X NZR	20	55.25±1.15^{bc}	24.26±0.00^{bc}	22.05±0.25^{bc}	59.70±1.00^{b}	107.70±10.10^{b}	136.72 ±3.27^{a}
CHL X CNM	20	49.20±1.10^{c}	27.05±0.00^{b}	31.76±0.00^{a}	57.10±2.90^{b}	114.8 ±5.20^{b}	132.35 ±2.85^{ab}
CHL X NZW	20	49.78±0.10^{c}	23.12 ±0.25^{c}	25.02 ±1. 2^{b}	58.65±1.85^{b}	93.95 ±7.25^{c}	101.25 ±0.75^{bc}
NZR X NZW	20	56.45±1.10^{bc}	27.05±0.25^{b}	28.30±1.10^{ab}	60.75±1.25^{ab}	115.50 ±9.20^{b}	136.00 ±0.00^{a}
NZR X CHL	20	46.03±1.17^{c}	40.27 ±0.05^{a}	29.00±0.00^{ab}	51.75±8.75^{c}	121.10±11.20^{b}	136.00 ±0.50^{a}
NZR X CNM	20	56.80±0.10^{bc}	37.00±0.20^{ab}	31.15±1.25^{a}	60.90±0.17^{ab}	122.4 ±3.20^{b}	106.25 ±6.05^{bc}
CNM X NZW	20	65.91±0.09^{ab}	23.08 ±0.24^{c}	19.68±1.25^{c}	63.36±1.57^{ab}	99.25 ±5.25^{c}	115.15±14.85^{bc}
CNM X CHL	20	70.55±1.15^{a}	28.45±0.00^{b}	19.03±1.05^{c}	68.55±2.85^{a}	99.85 ±22.25^{c}	102.80 ±7.00^{bc}
CNM X NZR	20	55.25±1.15^{bc}	24.10±0.16^{bc}	23.25±0.00^{b}	61.22±0.27^{ab}	120.96±50.24^{b}	128.00 ±2.00^{ab}

a,b,c: Means in the same column with different superscripts are significantly different (P<0.05)

SALBM = Serum Albumin (gdl^{-1}); SGLBLN= Serum Globulin (gdl^{-1})
S UREA = Serum Urea (gdl^{-1}); STPRT= Serum Total Protein (gdl^{-1})
CHOLST= Cholesterol (mgdl^{-1}); Na+ = Sodium (mgdl-1)

Table 3: Least squares means ± SEM of blood electrolytes as affected by genotype

GENOTYPE	N	K^+	Ca^{2+}	P	ALP	ALT	AST	CRTN
NZW	20	4.45±0.37^{bc}	16.97±0.12^{a}	5.95±0.10^{a}	42.30±1.10^{bc}	65.25±3.05^{a}	43.00±1.00^{ab}	1.04±0.00^{a}
CHL	20	3.80±0.20^{c}	16.25±0.05^{a}	4.30±0.10^{b}	39.95±1.15^{c}	44.95±0.35^{b}	37.50±14.5^{b}	0.30±0.00^{bc}
NZR	20	5.42±0.12^{b}	12.65±0.35^{c}	4.10±0.10^{b}	57.16±14.16^{ab}	59.87±1.12^{ab}	38.00±1.00^{b}	0.20±0.00^{c}
CNM	20	4.07±0.02^{bc}	16.40±0.60^{a}	4.50±0.10^{b}	58.13±1.17^{ab}	66.37±2.62^{a}	31.87±1.67^{c}	0.85±0.05^{b}
NZW X CHL	20	3.82±0.17^{c}	10.91±0.68^{c}	3.30±0.10^{c}	60.25±1.15^{a}	52.80±3.50^{a}	36.90±1.30^{b}	0.65±0.05^{b}
NZW X NZR	20	3.65±0.45^{c}	13.35±0.74^{bc}	3.33±0.17^{c}	55.85±1.05^{ab}	63.60±3.60^{a}	49.15±1.15^{a}	0.10±0.00^{c}
NZW X CNM	20	5.17±0.05^{b}	16.61±0.28^{a}	5.78±1.12^{a}	60.40±1.10^{a}	59.66±5.35^{ab}	47.50±1.50^{a}	0.70±0.00^{b}
CHL X NZR	20	4.22±0.66^{bc}	13.3±0.35^{bc}	4.16±0.18^{b}	43.94±0.19^{bc}	25.40 ±1.5^{c}	42.20±1.40^{ab}	0.48±0.03^{bc}
CHL X CNM	20	4.87±0.22^{bc}	11.77±0.37^{c}	5.22±0.17^{a}	43.15±1.15^{bc}	60.75±5.15^{a}	38.00±1.00^{b}	0.25±0.05^{c}
CHL X NZW	20	3.85±0.05^{c}	16.45±0.55^{a}	5.20±0.10^{a}	42.35±1.15^{bc}	44.10±3.10^{b}	48.50±1.50^{a}	0.25±0.05^{c}
NZR X NZW	20	6.28±0.01^{a}	13.70±0.20^{bc}	4.50±0.10^{b}	53.69±1.06^{b}	58.84±1.21^{ab}	43.37±1.37^{ab}	0.50±0.00^{b}
NZR X CHL	20	6.01±0.01^{a}	15.75±0.25^{ab}	5.25±0.15^{a}	63.31±1.18^{a}	66.31±0.06^{a}	36.80±1.20^{b}	0.35±0.05^{bc}
NZR X CNM	20	3.77±0.55^{c}	11.70±0.30^{c}	2.62±0.26^{c}	61.85±1.15^{a}	57.60±2.60^{ab}	38.05±1.95^{b}	1.05±0.05^{a}
CNM X NZW	20	3.48±0.92^{c}	16.50±0.00^{a}	3.98±0.12^{bc}	61.20±1.10^{a}	62.20±0.90^{a}	34.40±1.60^{c}	0.90±0.00^{ab}
CNM X CHL	20	3.93±0.71^{c}	16.91±0.00^{a}	5.62±0.19^{a}	65.55±1.15^{a}	53.66±9.33^{b}	30.41±1.58^{c}	0.88±0.00^{b}
CNM X NZR	20	3.70±0.70^{c}	11.74±0.24^{c}	3.81±0.18^{bc}	52.49±1.10^{b}	47.40±13.90^{b}	46.45±1.35^{a}	0.91±0.08^{ab}

$^{a,b,c:}$ Means in the same column with different superscripts are significantly different (P<0.05)

K+ = Potassium (mmolL^{-1}); Ca^{2+} = Calcium; P = Phosphorus; ALP= Alkaline Phosphatase (iuL^{-1})
ALT = Alanine Amino Transferase (iuL^{-1}); AST = Aspatate Amino Transferase (iuL^{-1}); CRTN = Creatinine

Table 4 : Least squares means ± SEM of carcass traits (slaughter weight) of rabbit genotypes

$^{a,b,c,d:}$ Means in the same column with different superscripts are significantly different (P<0.05)

Genotype	N	LVWT (g)	SBWT (g)	EBWT (g)	HCWT (g)	DRSWT (%)	LN MET%	BONE %
NZW	4	1947.80±11.58^{b}	1789.97±11.82^{abc}	1429.02±16.55^{b}	1170.85±19.71^{c}	71.19±1.10^{a}	75.74±1.09^{a}	15.39±0.20^{abc}
CHL	4	1950.32±13.75^{b}	1596.47±12.73^{d}	1119.32±11.33^{d}	868.42±11.61^{d}	55.38±1.16^{d}	67.55±1.91^{c}	16.05±0.39^{ab}
NZR	4	1726.97±12.32^{d}	1488.82±13.44^{d}	1094.10±10.53^{d}	834.55±10.83^{d}	54.50±1.17^{d}	71.97±1.17^{b}	15.59±0.0^{abc}
CNM	4	2137.50±15.51^{ab}	1789.00±12.07^{bc}	1196.00±11.57^{cd}	969.60±10.65^{d}	69.10±1.13^{b}	72.31±1.13^{ab}	14.22±039^{abc}
NZW X CHL	4	1954.20±15.20^{b}	1639.20±13.42^{cd}	1305.82±13.02^{cd}	1119.02±16.15^{cd}	73.86±1.10^{a}	69.27±1.26^{bc}	16.90±0.98^{ab}
NZW X NZR	4	2155.37±13.10^{ab}	1704.57±15.83^{bc}	1374.45±15.73^{bc}	1128.10±17.93^{cd}	64.19±1.13^{bc}	72.11±1.50^{ab}	14.86±095^{abc}
NZW X CNM	4	2187.20±10.29^{ab}	1659.60±18.01^{cd}	1289.22±19.72^{cd}	1094.90±14.31^{cd}	70.96±1.10^{ab}	70.49±1.80^{b}	10.50±0.92^{d}
CHL X NZR	4	2038.15±11.55^{b}	1703.25±17.41^{bcd}	1336.67±11.95^{bc}	1148.20±19.45^{cd}	63.73±1.18^{bc}	72.56±1.29^{ab}	12.70±0.78^{cd}
CHL X CNM	4	2418.11±9.33^{a}	1981.50±19.19^{a}	1601.57±14.56^{a}	1407.52±18.10^{ab}	74.09±0.19^{a}	76.70±1.86^{a}	10.00±0.11^{d}
CHL X NZW	4	2234.00±11.17^{ab}	1940.15±12.85^{ab}	1574.90±12.13^{ab}	1390.85±15.70^{b}	71.40±0.18^{a}	72.75±0.38^{ab}	15.16±0.60^{abc}
NZR X NZW	4	2047.72±10.34^{ab}	1821.05±10.58^{abc}	1466.87±13.09^{abc}	1270.75±12.04^{cd}	68.78±0.19^{b}	75.12±1.54^{a}	14.93±0.71^{abc}
NZR X CHL	4	2022.10±18.09^{ab}	1990.42±17.44^{a}	1623.20±16.75^{a}	1427.72±11.96^{a}	71.56±1.12^{a}	71.53±1.92^{b}	10.07±0.35^{d}
NZR X CNM	4	2022.40±18.41^{ab}	1947.62±10.06^{ab}	1593.52±18.89^{ab}	1394.60±17.45^{b}	68.92±1.09^{b}	70.87±1.83^{b}	14.11±0.56^{abc}
CNM X NZW	4	2378.40±10.86^{a}	1895.27±19.41^{abc}	1530.97±18.80^{abc}	1353.30±15.14^{ab}	73.23±1.11^{a}	71.21±1.42^{b}	14.87±0.72^{abc}
CNM X CHL	4	2398.55±10.92^{a}	1963.80±10.27^{a}	1624.20±10.05^{a}	1475.25±16.71^{a}	72.36±1.12^{a}	76.43±1.29^{a}	10.08±0.21^{d}
CNM X NZR	4	1845.17±19.13^{c}	1752.72±13.08s^{abc}	1403.95±10.72^{b}	1290.87±13.23^{cd}	69.74±1.18^{b}	68.13±1.59^{c}	13.21±003^{bcd}

$^{a,b,c,d:}$ Means in the same column with different superscripts are significantly different (P<0.05)

LVWT = Live weight; DRSWT = Dressed weight; SBWT = Shrunk body weight
EBWT = Empty body weight; HCWT = Hot carcass weight; LNMET = Lean meat

Table 5: Least squares means ± SEM of carcass traits (retail parts) of rabbit genotypes

GENOTYPE	N	GIT (%)	KIDNEY (%)	LIVER (%)	LUNGS (%)	SPLEEN (%)	HEART (%)	BILE (%)
NZ W	4	16.74 ±0.10^{ab}	0.55 ±0.05 ^{b}	2.18 ±0.07 ^{d}	0.82 ±0.02 ^{ab}	0.07 ±0.01 ^{bc}	0.28 ±0.01 ^{ab}	0.07 ±0.01 ^{bc}
C H L	4	17.99 ±0.87^{ab}	0.57 ±0.03 ^{b}	2.58 ±0.25^{bcd}	0.83 ±0.03 ^{ab}	0.09 ±0.01 ^{bc}	0.28 ±0.02 ^{ab}	0.07±0.01 ^{ab}
N Z R	4	18.41 ±0.12^{ab}	0.57 ±0.02 ^{b}	2.35 ±0.04 ^{cd}	0.90 ±0.04 ^{a}	0.08 ±0.01 ^{bc}	0.30 ±0.05 ^{a}	0.07 ±0.00 ^{ab}
CN M	4	13.23 ±0.30 ^{c}	0.49 ±0.06 ^{b}	2.59 ±0.13^{bcd}	0.90 ±0.00 ^{a}	0.05 ±0.00 ^{cd}	0.30 ±0.04 ^{a}	0.07 ±0.01 ^{ab}
NZW X CHL	4	13.31 ±0.32 ^{c}	0.57 ±0.01 ^{b}	2.41 ±0.11 ^{cd}	0.65 ±0.01^{bcd}	0.03 ±0.00 ^{d}	0.27 ±0.01 ^{ab}	0.04 ±0.00^{bcd}
NZW X NZR	4	13.14 ±0.43 ^{c}	0.50 ±0.01 ^{b}	2.36 ±0.20 ^{cd}	0.68 ±0.05^{bcd}	0.03 ±0.00 ^{d}	0.23 ±0.01 ^{bc}	0.03 ±0.00^{bcd}
NZW X CNM	4	15.02 ±0.01^{bc}	0.51 ±0.01 ^{b}	2.57 ±0.24^{bcd}	0.61 ±0.05^{bcd}	0.06 ±0.00 ^{bcd}	0.17 ±0.00 ^{d}	0.05 ±0.01^{bcd}
CHL X NZ R	4	14.92 ±0.06^{bc}	0.50 ±0.04 ^{b}	2.53 ±0.11^{bcd}	0.64 ±0.02^{bcd}	0.07 ±0.00 ^{bcd}	0.19 ±0.02 ^{cd}	0.05 ±0.01^{bcd}
CHL X CNM	4	12.27 ±0.35 ^{c}	0.77 ±0.08 ^{b}	3.32 ±0.07 ^{a}	0.59 ±0.04 ^{c}	0.09 ±0.01 ^{b}	0.25 ±0.03 ^{b}	0.05 ±0.00^{bcd}
CHL X NZW	4	13.07 ±0.39 ^{c}	2.76 ±2.32 ^{a}	3.21 ±0.18a	0.74 ±0.08^{bcd}	0.04 ±0.00 ^{d}	0.27 ±0.05 ^{ab}	0.04 ±0.00^{bcd}
NZR X NZW	4	13.80 ±0.58 ^{c}	2.17 ±1.41 ^{ab}	3.15 ±0.11 ^{a}	0.72 ±0.02^{bcd}	0.14 ±0.02 ^{ab}	0.25 ±0.02 ^{b}	0.04 ±0.00^{bcd}
NZR X CH L	4	13.02 ±0.22 ^{c}	0.48 ±0.03 ^{b}	2.22 ±0.16 ^{d}	0.50 ±0.06 ^{d}	0.04 ±0.00 ^{d}	0.27 ±0.05 ^{ab}	0.02 ±0.01 ^{d}
NZR X CNM	4	12.57 ±0.17 ^{c}	2.09 ±1.42 ^{ab}	2.88 ±0.10^{abc}	0.65 ±0.05^{bcd}	0.15 ±0.01 ^{ab}	0.22 ±0.01 ^{c}	0.04 ±0.01^{bcd}
CNM X NZW	4	13.42 ±0.59 ^{c}	0.55 ±0.03 ^{b}	2.97 ±0.23 ^{ab}	0.71 ±0.07^{bcd}	0.02 ±0.00 ^{d}	0.23 ±0.03 ^{bc}	0.06 ±0.00^{abc}
CNM X CHL	4	13.70 ±0.68 ^{c}	0.53 ±0.03 ^{b}	2.31 ±0.05 ^{d}	0.60 ±0.02 ^{cd}	0.02 ±0.00 ^{d}	0.24 ±0.02 ^{bc}	0.04 ±0.01^{bcd}
CNM X NZ R	4	13.59 ±0.00 ^{c}	0.51 ±0.03 ^{b}	2.35 ±0.14 ^{cd}	0.58 ±0.06 ^{cd}	0.04 ±0.01 ^{d}	0.22 ±0.01 ^{c}	0.03 ±0.00 ^{cd}

a,b,c,d: Means in the same column with different superscripts are significantly different (P<0.05) TRTER =Trotter; SHLDER =Shoulder

Table 6: Least squares means ± SEM of organ weight of rabbit genotypes

a,b,c: Means in the same column with different superscripts are significantly different (P<0.05)

Genotype	N	HEAD (%)	NECK (%)	TRTER (%)	SHLDR (%)	RACK (%)	LOIN (%)	Thigh (%)	TAIL (%)
NZ W	4	7.69±0.14^{abc}	1.77±0.09 ^{d}	7.15±0.25 ^{bc}	9.41±0.13 ^{bcd}	15.61±1.02^{abc}	16.43±0.19 ^{ab}	16.31±0.15^{bc}	0.37±0.01^{abc}
CH L	4	8.41±0.17^{ab}	2.25±0.08^{ab}	8.14±0.72 ^{ab}	10.94±0.16 ^{a}	16.38±1.09^{ab}	16.39±0.15 ^{ab}	18.53±0.18^{ab}	0.35±0.03^{ab}
N Z R	4	8.63±0.18 ^{a}	2.29±0.07 ^{a}	8.42±0.33 ^{ab}	9.65±0.12^{bcd}	15.21±0.04^{abc}	17.41±0.13 ^{ab}	17.61±0.18 ^{b}	0.35±0.02 ^{a}
CN M	4	8.44±0.19^{ab}	2.21±0.07^{abc}	8.97±0.62 ^{ab}	10.35±1.17^{ab}	17.75±2.06 ^{a}	17.69±0.13 ^{a}	17.12±0.18 ^{b}	0.31±0.03^{abc}
NZW X CHL	4	7.53±0.12^{abc}	2.00±0.05^{bc}	7.90±0.26 ^{ab}	9.50±0.15^{bcd}	13.99±0.01^{bc}	15.93±0.14^{abc}	16.20±0.17^{bc}	0.24±0.02^{bcd}
NZW X NZR	4	7.31±0.15^{abc}	1.99±0.03^{bc}	6.75±0.60 ^{c}	8.24±0.11 ^{cd}	15.54±1.03^{abc}	14.11±0.11^{bcd}	17.64±0.00 ^{b}	0.24±0.01^{bcd}
NZW X CNM	4	7.29±0.15$_{abc}$	1.96±0.01^{cd}	8.26±0.82 ^{ab}	7.28±0.19 ^{d}	16.96±0.07^{cd}	17.66±0.13 ^{a}	18.73±0.12 ^{a}	0.26±0.03^{bcd}
CHL X NZ R	4	7.14±0.19^{abc}	1.97±0.08^{bd}	3.38±0.21 ^{d}	7.34±0.19 ^{d}	14.41±0.09^{bc}	15.22±0.10^{bcd}	17.04±0.1 ^{b}	0.25±0.01^{bcd}
CHL X CNM	4	6.75±0.11 ^{c}	1.72±0.01 ^{d}	9.78±0.14 ^{a}	8.04±0.14 ^{d}	13.42±1.08 ^{c}	17.13±0.17 ^{ab}	17.17±0.15 ^{b}	0.30±0.02^{bcd}
CHL X NZW	4	6.18±0.18 ^{c}	1.74±0.04 ^{d}	8.97±0.16 ^{ab}	8.18±0.10 ^{cd}	13.42±0.04 ^{c}	13.02±0.11 ^{cd}	16.51±0.15^{bc}	0.25±0.06^{bcd}
NZR X NZW	4	7.21±0.18^{abc}	1.88±0.08^{cd}	4.58±0.11 ^{cd}	9.98±0.10^{abc}	13.27±0.07 ^{c}	17.47±0.14 ^{ab}	18.19±0.12^{ab}	0.27±0.03^{cd}
NZR X CH L	4	6.33±0.19 ^{c}	1.75±0.04 ^{d}	4.35±0.38 ^{cd}	8.14±0.12 ^{cd}	13.50±1.01 ^{c}	13.29±0.16^{bcd}	17.00±0.19 ^{b}	0.20±0.02^{bcd}
NZR X CNM	4	6.49±0.13 ^{c}	1.75±0.04 ^{d}	4.35±0.15 ^{cd}	8.23±0.18 ^{cd}	13.54±1.08 ^{c}	13.24±0.18^{bcd}	15.87±0.17 ^{c}	0.35±0.03^{ab}
CNM X NZW	4	6.46±0.13 ^{c}	1.78±0.03 ^{d}	9.50±0.08 ^{a}	6.96±0.18 ^{d}	10.71±0.07 ^{d}	17.65±0.16 ^{a}	18.99±0.19 ^{a}	0.30±0.05^{bcd}
CNM X CHL	4	7.11±0.26^{abc}	1.90±0.08^{cd}	9.93±0.18 ^{a}	8.66±0.11 ^{cd}	16.39±0.08 ^{c}	17.65±0.17 ^{a}	18.47±0.14^{ab}	0.20±0.02 ^{d}
CNM X NZR	4	6.93±0.26 ^{c}	1.92±0.09^{cd}	4.17±0.29 ^{cd}	7.79±0.10^{bcd}	14.79±1.08^{bc}	12.45±0.14 ^{d}	16.53±0.19^{bc}	0.22±0.01^{cd}

GIT = Gastro Intestinal Tract

Discussion of Findings

Significant (P<0.05) differences observed in the various haematological and serum Chemistry traits. Variation is both genetically and environmentally influenced. The results of haematological and serum indices obtained in this study showed that their values increased numerically (P>0.05) with increase in age of rabbits across their genetic groups up to week sixteen except cholesterol, sodium and calcium. This trend showed the health and nutritional status of rabbit which is best utilized when consumed by human at sixteen weeks of age, above that age would mean that the muscle would have become fibrous and fatty in nature with consequence reduced flavour, taste, palatability and aroma. This is in agreement with the reports of Chineke (2003), Akanni, (2012), North et al. (2018) and Daszkiewicz and Janiszewski (2020).

The superior performance of Cinnamon and New Zealand White and their crosses suggests that they are good meat type and can serve dual purpose functions. Breed selected for lean meat usually has enhanced haematological and serum characteristics (Akanni, 2009). This makes rabbit an excellent meat for people with diabetes, hypertension and other heart related problems. The values obtained for HBC, PCV, RBC, WBC, Serum albumen, serum globulin and serum urea generally were higher than those documented by Onhayoun et al. (1986a and b), Abdullahiet al. (2003), Akanni (2012)and Daszkiewicz and Janiszewski(2020), in their separate studies, however, concluded that high PCV haematocrit reading indicated either an increase in the number of circulating RBC or reduction in circulating plasma volume in the body. The significant effect of age on HBC, PVC, RBC and WBC observed in this study was in agreement with the findings of Chineke (2003).

The results of biochemical and serum traits as observed in this study agreed with values documented by Chineke et al. (2002) and Chineke (2003). The effect of genotype on serum total protein, serum urea, serum albumin and serum globulin recorded in this study between New Zealand White, Cinnamon and Chinchilla. The serum proteins which are most easily obtainable in the animal's body are of a great value to the veterinarians in diagnosis, treatment and determination of prognosis of many disease conditions, as reported by Joshua and Aba-Adulagba (1990).

Environmental factors rather than genetic, could be another reason for the disparity in both haematological and biochemical serum indices noticed in this study. However, the primary functions of the erythrocyte are to serve as carrier of haemoglobin that reacts with oxygen carried in the blood to form oxyhaemoglobin during respiration. The packed cell volume (PCV) normal range is influenced by age, species of animal, previous excitement, and presence of anaemia or hypoprotenaemia. A PVC volume between 30 and 40% Joshua and Aba-Adulagba (1990) is considered normal. Generally PVC increases with age and is said to be high in sire than dams (Abdullahiet al., 2003; Akanni, 2012). The PCV range recorded in this study was in line with the reports of Joshua and Aba-Adulagba (1990) and Chineke (2003). These authors concluded that the PCV normal range for rabbits is 35-40%. The values of Mean Cell Volume (MCV) and the Mean Cell Haemoglobin (MCH) obtained in this study was in line with range of 86-89% and 31-35% obtained by Joshua and Aba-Adulagba (1990) and Ehebha et al. (2008) in their separate studies on New Zealand White rabbits. The serum glucose is an indicator of energy (Wilson and Brigstocke, 1981. The Serum glucose level is known to increase when there is conservation and retention of energy that would have been used for metabolic activities in the body. Thus, the trend in the serum glucose obtained in this study was in line with the finding of Ehebha et al. (2008).

Serum total protein is a combination of a number of protein fractions; such as the albumin and globulin and other serum electrolytes. The variation observed in these traits across the genetic groups of rabbit considered in this study disagreed with the results of Adedokun (2001). The author had reported that different breeds of rabbits have essentially similar level of biochemical constituents in their sera, and that rabbit blood chemistry does not show any differences due to species, age and sex. Akanni (2012), in their investigation with several strains of rabbit reported that plasma proteins increase with advancing age. The authors, however, stated that total plasma protein increased with age in New Zealand White rabbits from 5.4±0.60gdl-1 at 35 days to 6.7±0.60gdl-1 at60days of age. Kozma et al. (1967) had earlier reported a serum protein in New Zealand White rabbits that ranged from 4.4 to 6.3g in males and between 4.3 to 7.3g in females; with a mean of 5.2 and 5.7g respectively.

Environmental factors in terms of nutrition might have also been accounted for the differences in the albumin, globulin and the total serum protein observed in this study. Iyayi and Tewe (1998) also reported that total serum protein content in mammals is greatly influenced by both the quality and quantity of the crude protein supplied in the diet. These authors further explained that the amount of available protein in the body is related to the serum protein and albumin synthesis and that a reduction in those components is an indication of liver dysfunction. This implied that any change in nutritional status is easily reflected in albumin rather than globulin of the serum. Thus the trend in the albumin/globulin values observed in this study suggested that albumin is more secreted than globulin, probably due to its relatively high requirement in the animal body. Serum urea serves as indicator of protein status (Akanni, 2012). Blood urea is highly positively correlated with protein intake. The range of values obtained in this study for serum urea 20-36g/dl was in line with those range (20-27g/dl) reported by Adesina (1988), 17-24g/dl by Ewuola et al. (2008) and 28-36g/dl reported by Ehebha et al. (2008).

Many reasons have been attributed to the variation in carcass traits of the rabbit genotypes considered in this study. Since carcass yield is best evaluated in terms of the ratio of slaughter weights, organs weight and cutoff parts expressed as a percentage of live weight or dressed weight. The differences in proportion of these traits of a carcass are of great importance. Live weigh at sexual maturity seems also to have influenced the carcass traits in this study. The trend noticed in percentage dressed weight was similar to that observed in the litter productivity indices discussed above; the individual kit weight gain and their efficiency of feed utilization. This implied that better weight gain and feed efficiency of individual kit per litter among genotypes were translated to the proportionate superior dressing percentage. This could also be buttressed by the fact that big bodied, meat type rabbit deposited more protein as muscle tissue than dual purpose and smaller bodied rabbits as noticed in New Zealand Red, Cinnamon and their crosses.

Higher values of carcass traits obtained in most of the crossbreds than the pure breeds could be due to high degree of heterozygosity of genes which had brought about high rate of genetic advantage over their parents. The practical significance of this is that crossbreeding programme will be a faster and effective process of improving the carcass yield in rabbits. The dressing percentage obtained in this study among crossbred genotypes, however, were within the ranges reported Oni (2009). Performance for shrunk body weight, empty body weight and hot carcass weight in crossbreds were better than the pure bred. This implied the high level of heterozygosity that produced hybrid vigour. Fanimo et al. (2003) cited by Sulaiman (2005) reported that loins and legs are the most economical important portion of the carcass providing the greatest portion of edible meat in rabbits. Thus the considerable performance noticed in this study in terms of cut parts especially the trotters, shoulders, loins and legs agreed with the finding of Olayemi et al. (2006). The legs, loins and trotters (thigh) which forms the major part of the hind are mostly early maturing parts of the body and contained long bones. This could have responsible for the significant differences noticed among the genetic groups. Akanni (2012) reported that the body parts located in the hindquarters of rabbits have faster growth rate according to their characteristics pattern of locomotion.

Environmental factors rather than genetic in terms of nature of diet, water intake and management practices may have contributed to the differences observed in organ weights of the rabbit genotypes. Percentage of gastro- intestinal tract (GIT) observed in pure bred parents; Local-hare, New Zealand Red, Chinchilla and New Zealand White except Cinnamon could be linked with the larger size, longer length, and the thickness of the intestine in response to the residual high fibre content of the diet. This indicated the measure of the stronger intestinal capacity to handle roughages that result in bulkiness of the digester. Similar observation was reported by Onhayoun et al. (1986a and b) who recorded increased oesophageal epithelium, thickened wall and intestinal weight of rabbits fed tannin containing diets. The liver weight differences with respect to genotypic variation were still non-conclusive as reported by Onhayoun et al. (1986a). De Horo and Lopez (1985) also reported negative allometric growth of these organs from 8-16 weeks.

Conclusion

The overall results of blood biochemical traits obtained in this study has led to the premise that the metabolic system involved in the physiology of growth and reproduction to a great extent is dependent on some blood components and that rabbit is a good animal of choice with a promising veritable tool for ameliorating meat production and supply in Nigeria.

The effect of non-genetic factors on blood chemistry traits as observed in the study had brought to a promise that protein profiles in terms of blood pictures or values of rabbit are influenced by certain factors such as nutrition, management, sex, age, diseases, method of breeding, breeds of animal, housing, feeding, fasting, extreme climatic conditions, exercise, transport, castration and stress factors.

The differences in proportion of carcass quality traits are of great importance to this study: live weight at sexual maturity seems also to have influenced the carcass traits as noticed in this study. The trend noticed in percentage dressed weight was similar to that observed in the blood chemistry indices; this could also be buttressed by the fact that big bodied, meat type rabbit deposited more protein as muscle tissue than dual purpose and smaller bodied rabbits as noticed in New Zealand Red, Cinnamon and their crosses.

Higher values of carcass traits obtained in most of the crossbreds than the pure breeds were due to high degree of heterozygosity of genes which had brought about high rate of genetic advantage over their parents.

The practical genetic significance of this study is that crossbreeding programme is a faster and effective process of improving the carcass yield in rabbits. Cinnamon recorded high live weight with higher percentage dressed weight was due to high level of meat to bone ratio (61:24%) coupled with lowest percentage of Gastro Intestinal Tract (GIT) which statistically accounted for less than 15% of its total carcass yield.

Recommendations

Variations that existed in the blood chemistry profiles and carcass quality traits among the rabbit genotypes should be thoroughly exploited through crossbreeding and selection programmes. This is desirable in order to take advantage of heterosis in enhancing protein and carcass yield which is the key goal for improving the performance of rabbits under commercial conditions.

A continuous crossbreeding (tri hybrid crossing) and other genetic improvement programmes involving [CNM X CHL) X BVR)] [CNM X NZW) X CHL] and [(CHL X NZW) X NZW)] with a full exploitation of heterosis should be explored. The strains could be improved upon and developed into breeding and meat type rabbits to be raised using locally available inputs for tropical environment.

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