BREEDING AND EVALUATION OF CHOLESTEROL CONTENTS OF PURE AND CROSBRED RABBITS RAISED IN HUMID CLIMATE

By

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Study Area: Animal Breeding & Genetics

Abstract

The study was conducted using four purebred rabbits comprising New Zealand White (NZW), Chinchilla (CHL), Zealand Red (NZR) and the Beveren (BVN) through a diallele crossbreeding experiment that generated 16 genotypes involving four straight breeds and 12 crossbreds respectively. The crossbreeding program of these rabbit genotypes was monitored to evaluate the breeding effect on productive potentials in terms of average litter size (ALZ) average litter weight (ALW) and cholesterol content respectively. Genotypes significantly (P<0.05) affected all productive traits in which better performances were recorded in BVN, NZR and their crosses than the original parents, with the corresponding values of 7.85±0.07g, 8.87±0.03g, 7.90±0.08g, 8.00±0.04g, 8.93±0.03g, 8.96±0.00g. The litter weight, tissue and serum Cholesterol contents also followed similar pattern as obtained in litter size. Significant (P<0.05) differences in the cholesterol content among the various rabbit genetic groups implies that cholesterol content to large extent is a function of genetic variability. The study therefore underscored the importance of crossbreeding effect on the productive potentials and nutritive of rabbits for sustainable livestock development in Africa.

Key Words: ***Breeding, Cholesterol, Humid Climate, Rabbit***

INTRODUCTION

Nutrition especially balanced diet is very essential to the sustenance of the human life and the execution of normal, usual, daily physiological and psychological body activities. Among the components of good and balanced diet, protein, which could be of either plant or animal origin, is of significant importance to the human healthy

living. 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).

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.

Essentially, the world rabbit meat production increased up to 1.68 million tonnes in 2010 (FAOSTAT, 2012). Currently the leading producer of rabbit meat in the world is China with 669.000 t/year, while, in Europe, the main producer is Italy (255.400 t/year), followed by Spain (66.200 t/year), France (51.665 t/year), Czech Republic (38.500 t/year) and Germany (37.500 t/year) (FAOSTAT, 2020). The consumer preferences for rabbit meat have been investigated by some researchers across the globe: in Spain, France, Hungary, Poland, Romania, China, Indonesia, Mexico, USA, South Africa, Kenya, Tanzania, and in Nigeria as an example, some studies are presented on what authors from different countries have examined in relation to rabbit meat consumption (North et al., et al., 2020).

However, rabbit exhibit preference for diets based on forages rather than animal protein or commercial/ conventional feeds, this makes it a manipulable dietary means of regulating cardio-vascular diseases and other body ailments in all aged people. Considering the protein, iron, folic acid and low fat, sodium and cholesterol content of rabbits, rabbit meat is very tasty, highly nutritious and readily acceptable to many consumers without any socio-cultural or religious taboo. It is regarded as delicacy in hotels, restaurants and bars as well as during ceremonies. Also, because of the medicinal importance of rabbit meat, it has been recommended for diabetes, whooping cough, reduction of high blood pressure, asthma, anemia obesity and good infant growth (North et al., 2020).

Due to the awareness on the nutritional importance of rabbit meat, there have been increased demand for, and consumption of rabbit meat especially during the Covid 19 pandemic period when there was food shortage during lockdown crisis with consequent sharp growth of the rabbit industry. Reports have shown that rabbit meat production has increased in recent years, but not in all regions of the

world. The highest increase was noted in Asia, accompanied by a limited increase in Africa and a decrease in Europe, North America, and South America. In Europe, rabbit farming is concentrated in Spain, France, and Italy, representing around 80% of the total EU production (Frunza et al., 2019; Sk?adanowska-Baryza et al.,2019; Martínez-Alvaro et al., 2019; North et al. 2020; Daszkiewicz et al., 2020; H?ogberg et al.,2020).

Rabbit meat is used in the production of protein-rich convenient foods such pepper soup, stews, cooked foods, pancakes, waffles and snack foods. But, recent concern about the amount of cholesterol in human diet has led to the many attempts to further reduce the cholesterol content of rabbit meat sold in hotels, supermarkets, parks, bars and joints in each city around us and the number of rabbits supplied to them, it is clear that the supply of rabbit meat is far lesser than its demand, resulting from its effects on human health (Akanni et al., 2018).

Cholesterol is a monoatomic alcohol, found in animal fats and oils, bile, blood, brain tissue, milk, egg yolk, myelin sheaths of nerve fibres, liver, kidneys, and adrenal glands. It is a precursor of all the steroid hormones such as oestrogen, estradiol, testosterone; vitamin D and bile acids. Furthermore, esters of cholesterol predominate in plasma and adrenals, whereas nearly all cholesterol present in brain and nerve tissue is in free form; livestock products especially milk and meat contain small amounts although egg yolk contains fairly high amount. Cholesterol in animal tissues originates mainly from biosynthesis of acetyl co-enzyme A by condensation reactions of isoprene units, and to a lesser extent from dietary cholesterol absorbed from the intestine. The major site of cholesterol synthesis is the liver, but it also occurs in the intestinal mucosa, wall of arteries and other tissues. It is very essential to the functioning of some systems e.g. the nervous system in the body. As useful and important as cholesterol is in the body, it has its ill effects that are sequel to it's over concentration in body tissues (North et al., 2020).

Genetically, various diseases and abnormalities in human bodies have been traced to high concentration of cholesterol in the body (Akanni, 2012). Some of which include: Arteriosclerosis which is an arterial disease characterized by thickening and loss of elasticity of the arterial walls with subsequent thrombus formation in coronary and cerebral vessels; which underlies most instances of heart attacks and strokes, A-betalipoprotienaemia, an autosomal recessive disorder also known as the Bassen-Kornzweig syndrome. There is impairment of transport of fat-soluble vitamins. It could be controlled by low fat diet. Cholesterolosis, a condition that is characterized by the formation of cholesterol deposits in the various organs and tissues, and that is caused by a disturbance in lipid metabolism. Other disorders associated with lipid (cholesterol) metabolism are cholesterolaemia, cholesteroluria, and cholelithiasis.

However, the cholesterol content of rabbit meat is of great public interest. The demand for accurate cholesterol determination has been met with recently developed technologies for chromatography, detection, and measurement, which

has allowed for incredible specificity, sensitivity, accuracy, and precision. This review examines the cholesterol content of rabbit meat in light of recent data and discusses the controversial effects of fat content and type of meats on cholesterol content. For example, the cholesterol intake is also emphasized in the Dietary Guidelines for Americans, which recommends that less than 300 mg/d be consumed (USDA/HHS 2010). Fundamental research on biological functions and chemical properties of cholesterol has been the driving force for the development and application of analytical technologies for the determination of cholesterol. Sophisticated techniques, such as isotopic tracing and mass fragmentation, were originally developed for qualitative purposes to study biosynthetic pathways or absorption and metabolism of cholesterol, although they have been adopted for quantitative purposes.

This study however, underscores the breeding and genetic potentials of rabbits in ameliorating the health implications of cholesterol content in body tissues of some rabbit ecotypes sold for human consumption in humid environment, since there have been a number of such researches on the meats of exotic breeds of rabbits in order to make recommendations for production and human consumption.

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 Beveren (BVR) 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 labeled 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 labeled for individual rabbit in each genetic group and stored in the refrigerator.

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

Cholesterol determination: The cholesterol content of the rabbit muscle was determined by colorimetric analysis (Epoll-20® spectrophotometer, Poll Ltd. Sp. z o. o.,Warsaw, Poland at a wavelength of 520 nm), during an enzymatic reaction catalyzed by cholesterol peroxidase using the Pointe Scientific assay kit with the reference standard of 200 mg/100 cm3 according to Pointe Scientific, Warsaw, Poland (Tomasz And Andrzej, 2020; Dinh et al., 2021).

Statistical Analysis

The effect of age on the production parameters were estimated from two-way analysis of variance (Completely Randomized Design) with sub samples using General Linear Model of SAS (2012) using the model:

$Yij = \mu + Ti + \Sigma ij.$

Where,

Yij = Observed value of the dependent variable (% amount of cholesterol)
μ = Population mean
Ti = Effect of i^{th} strains (i= 1, 2,…16)
Σij = Random residual

In addition, the values obtained from the analysis of the body tissues of the pure and crossbred rabbits were analyzed separately with the model:

$Yij = M + Ti + \Sigma ij$

Where,

Yij = Observed value of the dependent variable (level of cholesterol)
μ - Population mean
ti - Effect of i^{th} rearing systems (i = 1 and 2)
Σij = Error or residual

Significant differences among means were also separated. Correlations were computed using SAS (2012). All effects except error terms were fixed. The data obtained were arc-transformed into percentages, means and analysis of variance.

Results and Discussion:

Table 1 present Significant differences (P<0.05) in the performance characteristics, due to variation in litter size across the genetic groups at weaning and post weaning ages. This is a reflection of the genetic variation in monogastrics especially gestating rabbits. It has been reported that reproduction and litter performance are important traits in determining the breeding efficiency and productivity of commercial stock rabbits. Mating buck had little or no effect on litter traits at birth and at weaning but more of genotype (sire strain) influence at post weaning ages. Comparatively, the doe contributes greatly to the performance of litter at birth and weaning (Akanni 2018). This suggests that litter traits in terms of litter size could be improved primarily through the selection of the does breed on her own a dam's performance. Akanni et al. (2007) had reported that litter size is a function of breed differences. The average litter size (ALZ) at birth for New Zealand Red, Beveren and their crosses (NZR X CHL, BVR X CHL, NZR X BVR and BVR X NZR with the corresponding values of 7.85±0.07, 8.87±0.03, 7.90±0.08, 8.00±0.04, 8.93±0.03, 8.96±0.00 obtained in this study was greater than values obtained in New Zealand White, Chinchilla and Californian White breeds by Ehiobu and Kyado (2004) compared favourably with the findings of Akanni, et al. (2018) who obtained values that ranged from 6.00-9.3 in crossbred rabbits. The variation in litter size obtained in this study and those from the aforementioned authors supported the evidence that litter size is a function of breed characteristics.

Environmental factors in terms of climate, weather, nutrition, disease condition and management that influence the expression of most qualitative trait could be another reason for this. Poor feed and feeding regime negatively influence litter size in rabbits while disease condition such as presence of pregnancy toxaemia, enterotoxaemia as well as hepatic coccidiosis in pregnant does could lead to abortion and stillbirth. Poor management practices and housing also reduce litter size at birth, weaning and post weaning (Akanni, 2012; Akanni et al., 2018). The position of litter in the parity set at which data were obtained could have also been another factor for the higher and appreciable values of litter size obtained in this study. Thus, the lowest litter size observed in New Zealand White could be due to its low rate of physiological and morphological fitness compared to other

genotypes at sexual maturity. The considerable high level of performance of the cross is an indication of high degree of hybrid vigour over their pure line parents (NZW, CHL, NZR and BVR). Ovulation rate, egg and embryo viability are components of litter size at birth.

Genetic and environmental reason may have accounted for variability in litter weight at different ages among the genotypes considered during this study. There are wide variation in the trend of litter weight between pure breeds and their crosses (Table 2). Litter production is a function of breed characteristics, rearing mortality, the disparity in the onset of sexual maturity of the doe and the semen quality of the buck. The considerable performance in litter size recorded in Beveren, New Zealand Red and their crosses agrees with the reports of Iyeghe –Erakpotobor et al. (2001). This suggests that any of these genotypes; Beveren, New Zealand Red and their crosses can be used in crossing with one another to produce viable commercial litter and meat producing rabbits. In addition, since doe productivity is best measured in terms litter size and litter weight, genetic improvement in either litter size or litter weight will surely lead to correlated responses in other doe productivity traits. Thus, variation in pre-weaning litter weight, weaning and post weaning ages of 21, 42 and 84 days among the genetic groups is a function of the differences in their genetic component. The trend of litter weight gains over the period of study was in agreement with the observations of Akanni and Ajayi (2021). The authors observed a continuous increase in litter weight at pre-weaning, weaning (day 42) and post weaning age (day 84), followed by steady – increase (constant) and a gradual decline as the rabbits aged in production. The practical significance of these results is that purebred and crossbred rabbit's reproductive performance in terms of litter traits must be monitored for at least 105-120 days from birth before they are selected to make a meaningful assessment of their productive potentials in litter production as foundation stock.

Better performance, as noticed in Beveren, New Zealand Red and Chinchilla showed that the breeds possess genetic potential for long term litter traits (multiparous) which make the animal an ideal meat producer. Considerable performance in terms of kindling to weaning livability noticed in New Zealand Red, Beveren and their crosses could be related to high degree of hardiness. The breeds were selected for dual purpose of high productivity, (meat and prolificacy) and good tolerance to tropical environment that is characterized by disease and heat stress especially in tropical climates like Nigeria.

Significant ($P<0.05$) differences in the cholesterol content and serum traits among the various rabbit genetic groups considered in this study (Tables 3, 4 and 5) has brought to a premise that tissue or body cholesterol content to large extent is a function of genetic variability rather than environment. The differences in cholesterol content among species are generally explained by variations in absorption and biosynthesis of cholesterol, lipoprotein metabolism, diet, muscle fiber type distribution, genetic variation, subcutaneous and intramuscular fat, body

weight (Salvatori et al., 2004; Padre et al., 2006; Bragagnolo 2009; Nistor et al. ,2013; Tomasz and Andrzej 2020), as well as cell size. With a significant portion of cholesterol in meat residing in the cell membrane, a difference in cell size and number of cells per unit of muscle volume or weight can lead to a divergence in total membrane surface area and ultimately the content of membrane components, including cholesterol. Le Lay et al., (2001) reported a possible link between size of adipocytes and their metabolic activities, which provided evidence of size of adipocytes influencing lipid raft formation and adipocytes metabolism by altering the cholesterol content of membranes.

Among rabbit species, especially, Orictolagus, the rate of cholesterol synthesis in the body is a function of body weight, which inversely and markedly influences the synthesis and turnover of cholesterol in the cellular membrane. Reports have also indicated that Animal size also tremendously affects the removal rate of cholesterol in low?density lipoprotein (LDL) from plasma, and ultimately the LDL cholesterol turnover, to an even greater extent than it does the cholesterol synthesis (Nistor et al., 2013). Thus, the cholesterol values obtained in this study agrees with the reports of Tomasz and Andrzej (2020). An interesting report however, shown that de novo synthesis of cholesterol varies among species, depending on the response of the liver to dietary cholesterol. Moreover, ruminant species had been recommended to be fed low cholesterol diets; this is because the de novo synthesis in their intestines and extra?hepatic tissues greatly contributes to total body cholesterol. Interestingly, Pratiwi et al. (2006) observed an increase in total cholesterol concentration in muscles taken from younger and lighter castrated Boer goats compared with older and heavier counterparts, which might indicate an effect of body weight × age interaction on the cholesterol content of muscle. Although, admitted that cholesterol contents increase with age, as obtained in this study. This implies that there is direct relationship between tissue or serum cholesterol and body size or weight.

Adding more evidence to cholesterol variation among species, as observed in this study, the effects of fiber type seem to be caused by size of muscle fibers and are associated with the amount of lipids accumulating in the muscles, which have shown that oxidative muscles with red muscle fiber, smaller fiber diameter, and greater fat content tend to have more total cholesterol. In a study focused on fiber types of rabbit muscles (glycolytic: longissimus lumborum and psoas major; oxidative: soleus and semimembranosus propriosus; intermediate: gastrocnemius laterale), Alasnier et al. (1996) cited in Andrzej (2020) concluded that oxidative muscles contained more total lipids, triglycerides, and cholesterol than the glycolytic ones. This support the evidence that suggested rabbit an excellent meat for people with cardio-vascular diseases and better meat for all aged people. Considerable results noticed in New Zealand Red, Beveren and their crosses suggest that the breed could be selected for improved rabbit meat production for the dietary treatment of body cardio-vascular diseases in all age people.

A recent advances revealed that multiple factors such as sex, animal age at sexual maturity, degree of marbling, subcutaneous fat thickness, animal breed, dietary energy level, different feeding treatments (restricted diet or ad libitum), and muscle location / type of cut had been observed and documented to influence the cholesterol content in monogastrics (Cifuni et al., 2004; Padre et al., 2006; Bragagnolo, 2009; Dinh, 2016; Nistor et al. ,2013). This could have informed the results obtained in this study. High, positive and significant correlation among the biometric parameters and serum profiles showed that selection for one will automatically increase the others. This suggested that given optimum feed efficiency; there is a close relationship between body weight and serum profile, in terms of protein, fat and cholesterol during the growth phase of rabbits especially the edible portions and the economic important traits. This is in line with the finding of Akanni, (2012) who obtained a positive correlation between average growth rate from birth to 90 days and average growth rate from 90 to 150 days in pure and crossbred rabbits. The non-significant correlation observed, may be due to the fact that factors other than environment; feeding regime high ambient temperature, and housing, management and feeding became more important in controlling those traits.

Table 1: Least square means ± SEM of reproductive traits as affected by age at sire's maturity at different ages.

GENOTYPE	ALZ (0)	ALZ (6)	ALZ (12)
NZW	7.25±0.02a	4.43±0.03c	3.07±0.02c
CHL	6.82±0.08b	6.42±0.42ab	4.50±0.02bc
NZR	7.55±0.07ab	6.56±0.40ab	5.91±0.08b
BVR	8.87±0.07a	8.37±0.00a	7.45±0.03a
NZW X CHL	5.30±0.01b	3.70±0.00c	2.90±0.03c
NZW X NZR	5.66 ± 0.00^{b}	4.66 ± 0.18^{c}	3.66 ± 0.08^{c}
NZW X BVR	7.50 ± 0.08^{ab}	6.16 ± 0.03^{b}	5.63 ± 0.00^{bc}
CHL X NZR	7.83 ± 0.02^{ab}	6.66 ± 0.01^{b}	5.75 ± 0.01^{b}
CHL X BVR	7.64 ± 0.07^{ab}	5.90 ± 0.31^{b}	5.61 ± 0.01^{bc}
CHL X NZW	5.35 ± 0.00^{b}	4.51 ± 0.28^{c}	3.25 ± 0.05^{c}
NZR X NZW	7.20 ± 0.00^{b}	6.00 ± 0.00^{b}	5.00 ± 1.02^{bc}
NZR X CHL	7.90 ± 0.08^{ab}	6.00 ± 0.01^{b}	5.50 ± 0.00^{bc}
NZR X BVR	8.93 ± 0.03^{a}	8.26 ± 0.00^{b}	6.86 ± 0.00^{b}
BVR X NZW	7.18 ± 0.05^{ab}	6.20 ± 0.03^{b}	5.74 ± 0.05^{b}
BVR X CHL	8.00 ± 0.04^{ab}	6.07 ± 0.04^{bc}	5.54 ± 0.01^{bc}
BVR X NZR	8.96 ± 0.00^{a}	7.98 ± 0.00^{ab}	7.15 ± 0.07^{a}

a,b,c; Means in the same column with different superscripts are significantly different ($P<0.01$)
ASM = Age at sire's maturity (days); ALZ (0) = Average litter size at birth
ALZ (6) = Average litter weight at weaning (g); ALZ (12) = Average kitten weight at post weaning (g)

Table 2: Least square means ± SEM of reproductive traits as affected by age at sire's maturity at different ages.

GENOTYPE	ALW (0)	ALW (6)	ALW (12)
NZW	495.64±12.06^{b}	2838.20±18.53^{b}	4807.14±30.81^{b}
CHL	388.58±1.70^{a}	1823.68±34.45^{c}	5335.00±20.32^{b}
NZR	614.67±1.04^{a}	2788.75±21.01^{b}	5026.41±38.53^{b}
BVR	706.93±1.08^{a}	2967.25±19.24^{ab}	6001.31±34.06^{a}
NZW X CHL	365.39±1.42^{a}	2631.75±15.38^{b}	4655.00±26.12^{c}
NZW X NZR	433.62±0.51^{b}	2997.75±14.87^{ab}	5092.70±28.49^{b}
NZW X BVR	781.25±0.03^{a}	2979.40±21.09^{ab}	4381.13±26.16^{c}
CHL X NZR	465.36±1.31^{b}	3157.24±22.87^{a}	5706.25±25.27^{ab}
CHL X BVR	556.13±1.02^{b}	2932.49±15.64^{ab}	5170.19±35.77^{b}
CHL X NZW	314.42±5.39^{c}	2659.60±14.71^{b}	4855.12±38.04^{c}
NZR X NZW	305.93±1.06^{c}	2917.25±31.82^{ab}	4920.66±26.16^{c}
NZR X CHL	349.89±1.07^{c}	2759.89±11.49^{bc}	5409.52±27.08^{bc}
NZR X BVR	780.82±0.05^{ab}	3686.20±83.82^{a}	6366.30±39.27^{a}
BVR X NZW	582.75±16.59^{b}	1809.60±19.03^{bc}	5931.50±24.74^{ab}
BVR X CHL	547.09±13.61^{b}	1905.13±17.05^{b}	5303.90±20.67^{b}
BVR X NZR	814.01±.045^{a}	2916.62±19.89^{ab}	6557.53±35.33^{a}

a,b,c; Means in the same column with different superscripts are significantly different (P<0.01)

ASM = Age at sire's maturity (days); ALW (0) = Average litter weight at birth (g)
ALW (6) =Average litter weight at weaning (g); ALW(12) =Average litter weight at post weaning (g)

Table 3: Least squares means ± SEM of cholesterol contents (mgdl-1) of rabbit genotypes at different ages.

GENOTYPE	N	WEEK 12	WEEK 15	WEEK 18	WEEK 20
NZW	20	95.65±1.25^{a}	102.16±1.25^{a}	107.33±1.25^{a}	110.06±1.05^{a}
CHL	20	80.70±0.20^{ab}	89.70±1.20^{b}	90.70±0.10^{b}	93.20±1.20^{ab}
NZR	20	65.30±0.02$^{b\,c}$	80.30±0.02^{bc}	83.30±0.00^{bc}	88.10±0.20^{c}
BVR	20	57.90±0.10^{c}	66.90±0.10^{c}	71.90±0.10^{c}	87.90±0.10^{c}
NZW X CHL	20	87.70±0.20^{ab}	87.70±0.20^{b}	87.70±0.20^{bc}	117.70±0.20^{a}
NZW X NZR	20	84.20±0.10^{ab}	94.09±0.10^{ab}	94.20±0.10^{b}	102.20±0.10^{a}
NZW X BVR	20	70.00±0.00^{b}	91.11±0.00^{ab}	91.03±0.00^{b}	93.01±05.19^{ab}
CHL X NZR	20	67.70±0.10^{b}	71.11±0.10^{c}	87.20±0.10^{bc}	96.10±10.10^{ab}
CHL X BVR	20	74.08±0.00^{b}	80.11±2.20^{b}	94.02±1.10^{a}	104.08±0.10^{a}
CHL X NZW	20	93.95±1.05^{a}	93.95±1.25^{ab}	93.95±3.25^{b}	113.15±0.25^{a}
NZR X NZW	20	91.50±1.00^{a}	115.50±1.20^{a}	115.50±2.20^{a}	115.50±1.20^{a}
NZR X CHL	20	61.10±1.00^{c}	67.10±1.20^{c}	71.10±1.20^{c}	91.10±1.00^{b}
NZR X BVR	20	58.04±0.00^{c}	62.14±0.20^{c}	67.02±0.00^{c}	82.00±0.00^{c}
BVR X NZW	20	59.25±0.01^{c}	69.25±1.25^{c}	79.25±1.05^{c}	99.25±0.05^{b}
BVR X CHL	20	59.85±0.01^{c}	69.05±0.02^{c}	79.85±0.05^{c}	99.15±0.05^{b}
BVR X NZR	20	57.96±0.00^{c}	62.06±0.24^{c}	73.00±0.24^{c}	81.06±0.04^{c}

a,b,c; Means in the same column with different superscripts are significantly different (P<0.01)

Table 4: Correlation coefficients among biometric parameters and serum profiles.

	BWT	FED INT	BGL	TKL	DRM	CPT	FAT	CHO
BWT	1.000	0.742**	0.806**	0.742**	0.631**	0.893**	0.864**	0.707**
FED INT		1.000	0.560**	0.423*	0.713**	0.575**	0.525**	0.726**
BGL			1.000	0.083^{ns}	0.076^{ns}	0.061^{ns}	0.330*	0.074^{ns}
TKL				1.000	0.444*	0.041^{ns}	0.418*	0.442*
DRM					1.000	0.028^{ns}	0.475*	0.426*
CPT						1.000	0.893**	0.824**
FAT							1.000	0.632**
CHO								1.000

** (Highly significant P<0.01)
* (Significant P<0.05)
ns (Not significant P>0.05)
BWT = Body weight (g)
FED INT = Feed intake (g)
BGT = Breast girth length (cm)
TKL = Trunk length (cm)
DRM = Dry matter (%)
CPT = Crude protein (%)
FAT = Muscle Fat (%)
CHO = Cholesterol (mgdl)

Table 5: Least squares means ± SEM of blood chemistry profiles as affected by genotype at week 20

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}
BVR	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 BVR	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 BVR	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 BVR	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}
BVR 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}
BVR 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}
BVR 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<0.01)

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)

Conclusions and Recommendation

Better performance, as noticed in Beveren, New Zealand Red and Chinchilla showed that the breeds possess genetic potential for long term litter traits (multiparous) which make the animal an ideal meat producer.

The better performance observed in New Zealand Red X Beveren, Beveren X New Zealand Red and their reciprocal crosses revealed the effect of high degree of hybrid vigour over their original parents; New Zealand Red and Beveren optimized the nicking ability during hybridization of genes that generated better hybrids.

It is therefore, recommended that crossbreeding programs, which is a better tool of enhancing the genetic potentials of rabbits for optimal productivity, in terms of better reproductive capacity, and productive ability should be employed in commercial rabbit breeding and production, as a scientific and technological innovation for sustainable livestock development in Africa.

The Beveren and New Zealand Red purebred and crossbred rabbit's productive performance in terms of litter traits must be monitored for at least 105-120 days from birth for cholesterol status before they are selected to make a meaningful assessment of their productive potentials in terms of litter production and meat quality as foundation stock.

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