

Effects of breed, sex, parity, diet and interactions on growth parameters of rabbit fed tiger nut-based diet

Uchechukwu Ihendu^{*1}, Opeyemi Micheal Awolusi¹, Kabiru Oladapo Hammed¹, Mariam Abidemi Lawal¹, and Clifford Adinma Chineke¹

^{*}corresponding author: ihenduu@futa.edu.ng

¹ Department of Animal Production and Health, the Federal University of Technology, Akure, Ondo State, Nigeria.

ABSTRACT

This study evaluated the effects and interactions of breed (Dutch Belted, Hyla Max, New Zealand White), sex, parity (1st, 2nd, 3rd), and dietary inclusion of dried tiger nut (0, 10, 20, 30 g/kg) on the growth performance and linear body measurements of rabbits over a 52-week period, producing 357 kits. Significant effects and interactions ($p < 0.05$) were observed on body weight and various morphometric traits (body length, hind limb length, chest girth, height at withers, etc.). At Week 1, New Zealand White rabbits had higher hind leg length (6.07 cm) than Dutch Belted (5.88 cm), and males showed higher body length (19.97 cm) than females (19.02 cm). At Week 5, 30 g/kg tiger nut diet produced the highest body length (26.43 cm), particularly in second-parity offspring. These results emphasize the influence of genetic and nutritional factors on rabbit growth and suggest that moderate supplementation (20–30 g/kg) of tiger nut enhances morphometric development.

Keywords: rabbit breeds, tiger nut, morphometric traits, parity, growth performance

INTRODUCTION

Rabbit production represents a sustainable means of providing animal protein for human consumption, particularly in developing regions. Rabbits have high reproductive potential, efficient feed conversion rates, and short generation intervals. However, growth performance is strongly influenced by genetic, physiological, and environmental factors, such as breed, sex, parity, and diet composition (Lebas et al., 2011; Szendrő & Dalle Zotte, 2011).

Phenotypic and morphometric characterizations provide critical insight into breed differences and help predict production potential (Chineke, 2000; ILRI, 2011). Previous studies revealed significant variation among rabbit breeds in growth and morphometric parameters (Akanno & Ibe, 2006; Alves et al., 2015). Nutritional interventions using energy-rich feed ingredients have also been reported to improve performance; however, the interactive effects of diet, breed, and parity are less understood (Adeyemi, 2018).

Tiger nut (*Cyperus esculentus*) is a promising feed additive due to its high energy, fat, and fiber content (Belewu & Belewu, 2007). It contains valuable nutrients such as oleic acid, carbohydrates, and proteins, yet few studies have explored its effect on rabbit morphometric growth or how it interacts with growth traits and genetic factors. This research addresses this gap.

Therefore, the objectives of this study were to assess the main and interaction effects of breed, sex, parity, and tiger nut inclusion on growth and morphometric traits of rabbits; and identify optimal inclusion levels for maximum productivity. It was hypothesized that moderate inclusion (20–30 g/kg) of tiger nut would improve morphometric and growth parameters in rabbits, particularly in high-performing breeds and second-parity offspring.

MATERIALS AND METHODS

Experimental Site

The study was carried out at the Rabbit Unit, Livestock Teaching and Research Farm of the Federal University of Technology, Akure, Ondo State, Nigeria. Akure is situated on 350.52m above the sea level at latitude 7° 15'N and 5° 12'E (Climate data, 2018). The temperature is 26.20 °C and the relative humidity is 78%. The vegetation of the area is that of the rainforest characterized by hot and humid climates. (Climate data, 2018).

Pre-experimental operations

Prior to sourcing the rabbits, cleaning, washing and disinfection of both inside and surroundings of the pens were carried out. The cages were repaired, disinfected and arranged properly and thereafter; the rabbits were arranged according to their breeds and dietary treatments.

Experimental animals and managements

An intensive farming system was employed to manage the rabbits during the study. Forty-eight female rabbits (20–22 weeks old) from three breeds—Dutch Belted, Hyla Max, and New Zealand White that is the parent stock were sourced from reputable rabbitries along with twelve bucks for mating. Upon arrival, the rabbits were housed in secure, well-ventilated pens, with regular cleaning and disinfection to maintain hygiene. The rabbits were provided with a balanced diet consisting of concentrates and forage (grasses), while water

was supplied *ad libitum* to ensure constant availability. A 52-week experimental trial commenced that covered for the first parity, second and third parity that produced a total of 357 offsprings through a pure line mating procedure. During this period, rabbits were mated, kindled, and their milk was collected at each parturition. Accurate records of all management activities, including feeding and health treatments, were maintained using the unique identification numbers assigned to each rabbit.

Experimental diet

A tiger nut pelletized diet was formulated to meet the nutrient requirements of the rabbits. The tiger nut (*Cyperus esculentus*) was mixed with other ingredients to form four (4) experimental diets comprising the control and tiger nut at levels of 10, 20 and 30 g/kg. The feed compositions for matured does as well as pregnant and lactating does include the litters are presented in Tables 1 and 2.

Ethics

All rabbits for the experiment were handled according to the EU Directives 2010/63/EU for laboratory animal experiments (European Union, 2010).

Table 1. Percentage compositions of experimental diets fed to matured does and bucks

Ingredients	Compositions (g/kg)
Maize	8.00
Wheat offal	18.00
Rice bran	42.00
Groundnut cake	5.00
Palm kernel cake	25.50
Limestone	1.00
Grower's Premix	0.10
Salt	0.20
Lysine	0.10
Methionine	0.10
Total	100
Calculated Compositions	
Metabolizable energy (Kcal/kg)	2586.41
Crude protein	14.86
Crude fibre	13.29
Calcium	0.48
Available phosphorus	0.66
Lysine	1.17
Methionine	0.73

Table 2. Percentage compositions of experimental diets fed to pregnant and lactating does include the weaned kits

Ingredient	Compositions (g/kg)
Maize	16.50
Soya Bean Meal	9.50
Rice bran	22.95
Wheat Bran	29.50
Palm kernel cake	18.00
Limestone	1.70
Bone	1.00
Grower's Premix	0.10
Salt	0.20
Lysine	0.15
Methionine	0.40
Total	100
Calculated Compositions	
Metabolisable energy (kcal/kg)	2525.35
Crude protein	16.03
Crude fibre	13.09
Calcium	1.02
Available phosphorus	0.51
Lysine	0.94
Methionine	0.68

Data Collection

Immediately after kindling, basic information on breed and age were recorded and the sex determination was done at week five because the genital tracts have been expressed. All these operations were repeated for first, second and third parity.

Morphometric measurements

Morphometric measurements were recorded weekly from day-7 till weaning stage (day-35) to track the growth and physical characteristic changes of the rabbits. The data generated were also analyzed for correlation to determine the extent of relationship among the measured phenotypic parameter and for heritability and repeatability estimates.

The parameters studied includes:

Bodyweight (BW): rabbits were weighed using a digital scale (kg) to monitor growth patterns during the experimental period.

Heart girth (HG): This measurement was taken by wrapping a measuring tape (cm) around the chest, just behind the fore legs to assess the girth of the

thoracic cavity. It provided an indicator of the overall body condition and growth.

Height at Withers (HW): The vertical distance from the head to the highest point of the shoulders (withers) was measured using a measuring tape (cm). This parameter helped in assessing the skeletal development of the rabbits.

Body Length (BL): The distance from the point of the shoulder (scapula) to the pin bone (ischium) was measured (cm) to determine the overall length of animal's body. This measurement is useful in estimating body conformation and growth patterns.

Leg Length (LT): The length of the leg was measured (cm) from the point of the stifle joint (knee) to the ground, providing insight into limb development and proportionality in relation to the body.

Ear Length (EL): This was measured (cm) from the base of the ear (where it attaches to the head) to the tip, which can be an indicator of breed characteristics.

Tail Length (TL): The length of the tail was measured (cm) from its base (at the point of attachment to the body) to the tip. Tail length can sometimes be related to breed traits and overall body proportionality.

Shoulder to tail length (ST): The distance from point of shoulder to the pin bone or to the end of the coccygeal vertebrae.

Head to shoulder length: The distance from the nose to the point of the shoulder.

Fore-leg: Measured as distance from the proximal extremity of the olecranon process to the mid lateral point of the coronet.

Rump height: Measured as distance from highest point of the rump to the ground

These morphometric measurements were critical for analyzing growth rates, breed-specific characteristics and the overall physical development of the rabbits. For the purpose of this study, selected body traits were analyzed for linear body morphometric measurements because of their economic importance.

Statistical Analysis

All data collected were subjected to analysis of variance using statistical software package SAS (2018) and Duncan Multiple Range Test was used to separate the mean differences among treatments while a regression equation was developed for modeling. The experimental design is a 2 x 3 x 3 x 4 factorial arrangement in Completely Randomized Design.

$$Y_{ijk} = \mu + B_i + S_j + D_k + P_l + (BS)_{ij} + (BD)_{ik} \\ + (SD)_{jk} + (BP)_{il} + (BSD)_{ijk} + (BSP)_{ijl} \\ + (BSDP)_{ijkl} + e_{ijk}$$

Where: Y_{ijk} = individual observation

μ = overall mean

B_i = fixed effect of i -th breed ($i = 1, 2, 3$)

S_j = fixed effect of j -th sex ($j = 1, 2$)

D_k = random effect of the diet (1, 2, 3, 4)

PI = effect of I -th level of parity ($I = 1, 2, 3$)

BS_{ij} = interaction between breed and sex

BD_{ik} = interaction between breed and diet

SD_{jk} = interaction between sex and diet

BP_{il} = interaction between breed and parity

BSD_{ijk} = interaction among breed, sex and diet

BSP_{ijl} = interaction among breed, sex and parity

$BSDP_{ijkl}$ = interaction among breed, sex, diet and parity

e_{ijk} = residual error.

RESULTS

Significant ($p < 0.05$) effects of breed, sex, parity, diet, and their interactions were observed across all weeks (Tables 3–7). At Week 1, New Zealand White rabbits recorded the highest hind leg length (6.07 cm) and rump length (10.07 cm). Males showed higher morphometric values than females across all traits, while second-parity offspring had superior measurements compared to first and third parities. Tiger nut inclusion at 30 g/kg significantly improved body length (19.87 cm) and forelimb length (6.79 cm).

At Week 3, Hyla Max males exhibited the highest body length (22.39 cm), and New Zealand White had longer hind legs (12.03 cm). The 30 g/kg tiger nut diet improved ear length (5.85 cm) and forelimb length (8.59 cm). A strong parity $\times$ diet interaction was observed, with second-parity kits on 30 g/kg showing superior body growth. By Week 5, males weighed 0.38 kg on average compared to 0.35 kg in females. The 30 g/kg diet achieved the highest body length (26.43 cm), while second-parity offspring on 30 g/kg diets attained the highest height at withers (17.56 cm).

Table 3. Effects of breed, sex, parity, diet and their interactions on body weight (kg) and linear body measurements (cm) of three breeds of rabbits at week 1 old

Variations	BW	BL	HW	EL	HG	ST	SL	FL	TL	HL	Rump
Breeds											
DUT	0.1±0.01	19.18±0.24	12.6±0.13	3.66±0.06	10.71±0.16	14.8±0.20	5.1±0.08	6.73±0.09	2.02±0.03	5.88±0.07 ^c	9.66±0.12 ^b
HYLA	0.09±0	19.77±0.21	12.55±0.12	3.77±0.08	10.84±0.14	15.03±0.16	5.34±0.08	6.75±0.09	2.21±0.07	5.94±0.06 ^b	9.84±0.1 ^b
NZW	0.09±0.01	19.24±0.19	12.64±0.11	3.72±0.06	10.46±0.15	14.81±0.16	5.25±0.07	6.50±0.10	2.07±0.03	6.07±0.07 ^a	10.07±0.1 ^a
Sex											
Female	0.09±0.01	19.02±0.14 ^b	12.39±0.08 ^b	3.70±0.05	10.48±0.10 ^b	14.63±0.12 ^b	5.13±0.05 ^b	6.56±0.07 ^b	2.06±0.03	5.88±0.05 ^b	9.75±0.08 ^b
Male	0.1±0.01	19.97±0.23 ^a	12.96±0.12 ^a	3.74±0.06	10.94±0.16 ^a	15.27±0.18 ^a	5.4±0.07 ^a	6.8±0.09 ^a	2.15±0.03	6.12±0.06 ^a	10.07±0.11 ^a
Parities											
P1	0.1±0.01	19.64±0.21 ^b	12.76±0.11 ^a	3.63±0.06 ^b	11.2±0.1 ^a	15.09±0.16 ^a	5.34±0.07 ^a	6.92±0.07 ^b	1.98±0.05 ^b	6.11±0.06 ^a	9.83±0.11
P2	0.1±0.01	19.9±0.2 ^a	12.79±0.11 ^a	3.72±0.06 ^{ab}	11.26±0.1 ^a	15.26±0.16 ^a	5.46±0.07 ^a	7.11±0.06 ^a	2.10±0.02 ^{ab}	6.14±0.05 ^a	10.00±0.1
P3	0.09±0.01	17.9±0.15 ^c	11.93±0.11 ^b	3.89±0.09 ^a	8.45±0.16 ^b	13.7±0.14 ^b	4.58±0.06 ^b	5.25±0.07 ^c	2.31±0.05 ^a	5.38±0.08 ^b	9.72±0.1
Diets											
10g	0.09±0.01	18.76±0.22 ^d	12.32±0.13 ^b	3.59±0.07 ^c	10.24±0.17 ^b	14.67±0.21	5.01±0.08 ^b	6.45±0.11 ^c	1.99±0.03 ^c	5.96±0.09 ^b	9.91±0.13
20g	0.09±0	19.15±0.23 ^c	12.35±0.09 ^b	3.66±0.08 ^b	10.54±0.11 ^b	14.71±0.17	5.11±0.08 ^b	6.68±0.09 ^b	2.07±0.04 ^b	6.03±0.06 ^a	9.75±0.13
30g	0.11±0.01	19.87±0.24 ^a	12.82±0.14 ^a	3.93±0.08 ^a	10.97±0.16 ^a	14.95±0.17	5.47±0.08 ^a	6.79±0.11 ^a	2.17±0.05 ^a	6.04±0.07 ^a	9.9±0.12
CNTRL	0.09±0.01	19.7±0.28 ^b	12.89±0.17 ^a	3.68±0.08 ^b	10.86±0.22 ^a	15.14±0.23	5.32±0.09 ^a	6.69±0.12 ^b	2.15±0.07 ^a	5.86±0.09 ^b	9.92±0.13
Breed	0.87	0.40	0.63	0.92	0.55	0.72	0.19	0.71	0.12	0.00	0.04
Sex	0.16	0.00	0.00	0.54	0.00	0.00	0.01	0.01	0.12	0.01	0.05
Parities	0.20	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.18
Diets	0.23	0.00	0.02	0.00	0.00	0.44	0.00	0.00	0.03	0.00	0.75
Breed * Sex	0.59	0.61	0.67	0.98	0.81	0.59	0.84	0.79	0.87	0.87	0.97
Breed * Parities	0.81	0.72	0.19	0.88	0.45	1.00	0.16	0.69	0.64	0.42	0.29
Breed* Diet	0.73	0.14	0.38	0.30	0.18	0.78	0.91	0.75	0.97	0.64	0.37
Sex * Parities	0.38	0.06	0.39	0.85	0.27	0.09	0.46	0.32	0.08	0.17	0.79
Sex * Diet	0.95	0.34	0.67	0.69	0.55	0.80	0.54	0.83	0.91	0.52	0.39
Parities * Diets	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BREED * Sex*	0.82	0.71	0.85	0.77	0.77	0.85	0.51	0.69	0.96	0.66	0.79
Diet											
Breed * Sex *	0.71	0.99	0.83	0.96	0.98	0.69	0.34	0.63	0.79	0.86	0.93
Parities											
Sex*Parities*Diet	0.97	0.90	0.56	0.90	0.93	1.00	0.90	0.72	0.60	0.88	0.90
Breed* Sex*	0.98	0.72	0.99	0.99	0.79	0.40	0.91	0.80	0.97	0.60	0.94
Parities* Diet											

^{a,b,c} Means on the same column having different superscripts are significantly different (P<0.05). 10g, 20g and 30g = 10grams, 20grams and 30grams Tiger nut inclusion level; HYL = Hyla Max; NZW = New Zealand White; DUT = Dutch Belted; BW = Body weight; BL = Body length; HW= Height at withers; EL= Ear length; HG = Heart girth; ST= shoulder to tail length; HSL = Head to shoulder length; FL= Fore limb; TL = Tail length; HL = Head length.

Table 4. Effects of breed, sex, parity, diet and their interactions on body weight (kg) and linear body measurements (cm) of three breeds of rabbits at week 2 old

Variations	BW	BL	HW	EL	HG	ST	SL	FL	TL	HL	RUMP
Breeds											
DUT	0.16±0.01	20.77±0.26	13.70±0.13	4.83±0.06	11.75±0.17	15.92±0.23	6.01±0.08 ^b	7.68±0.1	2.85±0.04	6.84±0.06	10.76±0.13
HYLA	0.15±0.00.	21.15±0.24	13.61±0.14	4.77±0.08	11.94±0.16	16.13±0.19	6.25±0.08 ^a	7.63±0.1	2.81±0.05	6.88±0.07	10.84±0.10
NZW	0.15±0.00	20.68±0.21	13.67±0.12	4.67±0.06	11.43±0.16	15.93±0.19	6.16±0.08 ^{ab}	7.39±0.1	2.82±0.03	6.88±0.07	11.03±0.10
Sex											
Female	0.15±0.00 ^b	20.55±0.15 ^b	13.46±0.09 ^b	4.72±0.05	11.52±0.11 ^b	15.74±0.13 ^b	6.04±0.06 ^b	7.43±0.07 ^b	2.79±0.03 ^b	6.80±0.05 ^b	10.76±0.08 ^b
Male	0.17±0.00 ^a	21.34±0.25 ^a	14.00±0.13 ^a	4.80±0.06	11.95±0.16 ^a	16.41±0.21 ^a	6.32±0.08 ^a	7.76±0.1 ^a	2.89±0.04 ^a	6.98±0.07 ^a	11.11±0.11 ^a
Parities											
P1	0.15±0.00	21.35±0.21 ^a	13.82±0.12 ^a	4.81±0.06	12.3±0.09 ^a	16.24±0.19 ^b	6.32±0.06 ^a	7.95±0.06 ^b	2.67±0.04 ^b	7.08±0.05 ^a	10.93±0.11 ^{ab}
P2	0.16±0.01	21.45±0.21 ^a	13.98±0.11 ^a	4.79±0.06	12.37±0.1 ^a	16.57±0.18 ^a	6.45±0.06 ^a	8.04±0.06 ^a	3.01±0.02 ^a	7.09±0.05 ^a	11.12±0.1 ^a
P3	0.15±0.00	18.74±0.18 ^b	12.75±0.12 ^b	4.56±0.09	9.19±0.18 ^b	14.42±0.14 ^c	5.21±0.07 ^b	5.85±0.07 ^c	2.81±0.05 ^{ab}	6.01±0.09 ^b	10.39±0.11 ^b
Diets											
10g	0.15±0.00	20.27±0.26 ^b	13.33±0.14 ^c	4.64±0.07 ^b	11.23±0.2 ^c	15.79±0.25	5.97±0.1 ^b	7.36±0.12 ^c	2.74±0.05 ^b	6.75±0.09 ^b	10.87±0.13
20g	0.16±0.01	20.72±0.23 ^b	13.51±0.09 ^b	4.84±0.07 ^a	11.75±0.1 ^b	15.93±0.2	6.14±0.08 ^{ab}	7.68±0.09 ^a	2.88±0.04 ^{ab}	6.94±0.06 ^a	10.87±0.13
30g	0.16±0.00	21.22±0.25 ^a	13.86±0.14 ^a	4.89±0.07 ^a	11.99±0.17 ^a	16.06±0.2	6.33±0.08 ^a	7.67±0.11 ^a	2.90±0.05 ^a	6.96±0.06 ^a	10.90±0.11
CNTRL	0.16±0.00	21.17±0.31 ^a	13.92±0.19 ^a	4.63±0.08 ^b	11.76±0.24 ^b	16.16±0.28	6.12±0.1 ^{ab}	7.51±0.14 ^b	2.79±0.04 ^b	6.81±0.10 ^{ab}	10.93±0.15
Breed											
Sex	0.66	0.66	0.59	0.38	0.45	0.71	0.04	0.74	0.20	0.07	0.15
Parities	0.04	0.01	0.00	0.19	0.01	0.01	0.01	0.00	0.03	0.02	0.04
Diets	0.24	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Breed*Sex	0.59	0.01	0.04	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.57
Breed*	0.51	0.74	0.67	0.80	0.72	0.50	0.54	0.71	0.69	0.44	0.92
Parities											
Breed*Diet	0.66	0.94	0.54	0.90	0.70	0.98	0.47	0.79	0.60	0.59	0.39
Sex* Parities	0.59	0.52	0.64	0.74	0.17	0.65	0.84	0.43	0.26	0.14	0.61
Sex * Diet	0.87	0.06	0.33	0.71	0.19	0.08	0.26	0.06	0.32	0.13	0.69
Parities *	0.48	0.33	0.56	0.86	0.76	0.78	0.63	0.85	0.89	0.69	0.48
Diets											
Breed * Sex *	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parities											
Breed * Sex	0.95	0.94	0.79	0.97	0.96	0.65	0.59	0.94	0.83	1.00	0.64
* Diet											
Breed	0.73	0.77	0.87	0.63	0.80	0.68	0.42	0.54	0.51	0.67	0.70
*Parities *											
Diets											
Sex * Parities	0.95	0.15	0.63	0.18	0.01	0.28	0.17	0.02	0.28	0.92	0.48
* Diet											
Breed * Sex	0.69	0.90	0.50	0.74	0.97	0.99	0.56	0.83	0.72	0.71	0.91
*Parities *											
Diets											

^{a,b,c} – Means on the same column having different superscripts are significantly different (P<0.05). 10g, 20g and 30g = 10grams, 20grams and 30grams Tiger nut inclusion level; HYL = Hyla Max; NZW = New Zealand White; DUT = Dutch Belted; BW = Body weight; BL = Body length; HW= Height at withers; EL= Ear length; HG = Heart girth; ST= shoulder to tail length; HSL = Head to shoulder length; FL= Fore limb; TL = Tail length; HL = Head length; RUMP = Rump

Table 5. Effects of breed, sex, parity, diet and their interactions on body weight (kg) and linear body measurements (cm) of three breeds of rabbit at week 3 old

Variations	BW	BL	HW	EL	HG	ST	SL	FL	TL	HL	RUMP
Breeds											
DUT	0.21±0.01	22.13±0.27	14.77±0.14	5.83±0.07	12.72±0.18	17±0.24	6.9±0.1	8.62±0.12	3.56±0.06	7.68±0.08	11.71±0.14
HYLA	0.3±0.10	22.39±0.28	14.56±0.14	5.7±0.08	12.94±0.18	17.2±0.23	7.06±0.09	8.46±0.12	3.54±0.06	7.65±0.08	11.78±0.13
NZW	0.2±0.00	21.94±0.23	14.24±0.19	5.63±0.06	12.36±0.17	16.98±0.21	6.85±0.09	8.29±0.12	3.59±0.05	7.57±0.08	12.03±0.12
Sex											
Female	0.24±0.04	21.79±0.17 ^b	14.28±0.12 ^b	5.66±0.05	12.47±0.13 ^b	16.75±0.15 ^b	6.85±0.07	8.33±0.09 ^b	3.5±0.04 ^b	7.58±0.06	11.7±0.09 ^b
Male	0.22±0.01	22.71±0.27 ^a	14.87±0.16 ^a	5.8±0.06	12.94±0.18 ^a	17.56±0.24 ^a	7.06±0.09	8.64±0.12 ^a	3.68±0.06 ^a	7.72±0.08	12.11±0.13 ^a
Parities											
P1	0.21±0.01	22.71±0.22 ^a	14.75±0.13 ^{ab}	5.89±0.06 ^a	13.34±0.10 ^a	17.44±0.21 ^a	7.19±0.07 ^a	8.99±0.07 ^a	3.41±0.05 ^{ab}	7.89±0.05 ^a	11.98±0.12 ^{ab}
P2	0.21±0.01	22.87±0.22 ^a	15.03±0.12 ^a	5.80±0.05 ^a	13.41±0.10 ^a	17.68±0.20 ^a	7.30±0.06 ^a	8.95±0.07 ^a	3.91±0.04 ^a	7.91±0.05 ^a	12.22±0.11 ^a
P3	0.32±0.14	19.6±0.21 ^b	13.05±0.27 ^b	5.21±0.10 ^b	9.84±0.20 ^b	15.12±0.15 ^b	5.72±0.08 ^b	6.44±0.09 ^b	3.25±0.05 ^b	6.59±0.10 ^b	10.94±0.12 ^b
Diets											
10g	0.3±0.11	21.41±0.29 ^{ab}	13.93±0.25 ^c	5.57±0.09 ^b	12.17±0.21 ^b	16.84±0.27	6.7±0.12 ^b	8.21±0.15 ^b	3.46±0.06	7.48±0.10 ^b	11.82±0.16
20g	0.2±0.01	22.01±0.23 ^b	14.44±0.11 ^b	5.88±0.06 ^a	12.70±0.11 ^{ab}	16.99±0.22	7.03±0.1 ^a	8.56±0.11 ^a	3.58±0.05	7.77±0.06 ^a	11.86±0.13
30g	0.21±0.01	22.63±0.28 ^a	14.89±0.16 ^a	5.85±0.06 ^a	12.98±0.19 ^a	17.2±0.23	7.14±0.09 ^a	8.59±0.13 ^a	3.71±0.07	7.78±0.07 ^a	11.84±0.12
CNTRL	0.21±0.01	22.47±0.35 ^a	14.76±0.2 ^a	5.57±0.09 ^b	12.73±0.26 ^{ab}	17.17±0.3	6.84±0.11 ^b	8.44±0.16 ^b	3.52±0.06	7.50±0.11 ^b	11.9±0.18
Breed	0.13	0.86	0.49	0.14	0.58	0.70	0.76	0.90	0.50	0.31	0.07
Sex	0.31	0.00	0.01	0.12	0.00	0.01	0.08	0.01	0.01	0.10	0.02
Parities	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diets	0.11	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.59
Breed * Sex	0.12	0.63	0.87	0.95	0.99	0.52	0.42	0.78	0.89	0.58	0.61
Breed * Parities	0.21	0.96	0.80	0.89	0.61	0.97	0.43	0.33	0.89	0.31	0.75
Breed* Diet	0.04	0.79	0.08	0.42	0.22	0.83	0.91	0.49	0.38	0.80	0.84
Sex * Parities	0.20	0.09	0.34	0.90	0.18	0.05	0.22	0.18	0.31	0.04	0.42
Sex * Diet	0.04	0.49	0.78	0.97	0.53	0.68	0.39	0.85	0.69	0.57	0.60
Parities * Diets	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Breed * Sex * Parities	0.13	0.95	0.86	0.77	0.77	0.77	0.35	0.92	0.68	0.87	0.91
Breed * Sex* Diet	0.04	0.83	0.86	0.96	0.58	0.72	0.35	0.51	0.87	0.86	0.38
Breed * Parities * Diet	0.03	0.61	0.62	0.16	0.02	0.28	0.90	0.50	0.30	0.97	0.65
Sex*Parities*Diet	0.06	0.99	0.81	0.70	1.00	0.98	0.38	0.54	0.67	0.98	0.97
Breed* Sex* Parities* Diet	0.03	0.98	0.85	0.94	0.95	0.82	0.97	0.96	0.66	0.98	0.99

^{a,b,c} – Means on the same column having different superscripts are significantly different (P<0.05). 10g, 20g and 30g = 10grams, 20grams and 30grams Tiger nut inclusion level; HYL = Hyla Max; NZW = New Zealand White; DUT = Dutch Belted; BW = Body weight; BL = Body length; HW= Height at withers; EL= Ear length; HG = Heart girth; ST= shoulder to tail length; HSL = Head to shoulder length; FL= Fore limb; TL = Tail length; HL = Head length; RUMP = Rump

Table 6. Effects of breed, sex, parity, diet and their interactions on body weight (kg) and linear body measurements (cm) of three of rabbit breeds at weeks 4 old

Variations	BW	BL	HW	EL	HG	ST	SL	FL	TL	HL	RUMP
Breeds											
DUT	0.28±0.01	24.1±0.25	15.93±0.15	6.67±0.06	14.23±0.12	18.5±0.23	8.05±0.08	9.73±0.09	4.24±0.06	8.79±0.07	13.13±0.13
HYLA	0.29±0.01	24.62±0.22	16.03±0.14	6.58±0.06	14.62±0.11	18.86±0.21	8.15±0.07	9.6±0.09	4.30±0.06	8.72±0.07	13.22±0.12
NZW	0.27±0.01	24.17±0.18	16.06±0.13	6.47±0.05	14.31±0.1	18.56±0.19	8.08±0.07	9.53±0.07	4.34±0.05	8.59±0.06	13.34±0.1
Sex											
Female	0.27±0.01 ^b	23.97±0.14 ^b	15.78±0.09 ^b	6.51±0.04 ^b	14.18±0.08 ^b	18.34±0.14 ^b	8.00±0.05 ^b	9.49±0.06 ^b	4.23±0.04 ^b	8.58±0.04 ^b	13.07±0.08 ^b
Male	0.29±0.01 ^a	24.81±0.22 ^a	16.39±0.14 ^a	6.66±0.06 ^a	14.7±0.11 ^a	19.11±0.21 ^a	8.25±0.07 ^a	9.83±0.08 ^a	4.4±0.060 ^a	8.88±0.07 ^a	13.52±0.11 ^a
Parities											
P1	0.28±0.01	24.49±0.2 ^a	15.65±0.13 ^b	6.5±0.05 ^b	14.37±0.1 ^b	18.61±0.21 ^b	8.06±0.07 ^{ab}	9.75±0.06 ^b	4.03±0.05 ^c	8.70±0.06 ^b	13.00±0.11 ^b
P2	0.28±0.01	24.61±0.22 ^a	16.24±0.14 ^a	6.75±0.06 ^a	14.63±0.11 ^a	18.9±0.21 ^a	8.37±0.07 ^a	9.92±0.07 ^a	4.61±0.05 ^a	8.93±0.05 ^a	13.35±0.12 ^a
P3	0.26±0.01	23.24±0.15 ^b	16.30±0.14 ^a	6.37±0.05 ^c	13.92±0.1 ^c	18.16±0.13 ^c	7.65±0.04 ^b	8.79±0.07 ^c	4.25±0.07 ^b	8.24±0.08 ^c	13.49±0.07 ^a
Diets											
10g	0.25±0.01 ^b	23.79±0.22 ^b	15.76±0.16 ^b	6.55±0.08	14.24±0.14	18.31±0.24	8.03±0.09	9.5±0.09	4.23±0.06 ^b	8.52±0.09 ^b	13.16±0.14
20g	0.26±0.01 ^b	23.78±0.19 ^b	15.38±0.09 ^b	6.63±0.08	14.07±0.09	18.24±0.22	8.01±0.1	9.46±0.08	4.24±0.06 ^b	8.78±0.07 ^a	13.07±0.13
30g	0.29±0.01 ^a	24.87±0.26 ^a	16.39±0.17 ^a	6.55±0.05	14.53±0.13	18.99±0.24	8.19±0.08	9.68±0.1	4.51±0.08 ^a	8.78±0.07 ^a	13.20±0.13
CNTRL	0.29±0.01 ^a	24.62±0.28 ^a	16.45±0.17 ^a	6.55±0.07	14.64±0.13	18.94±0.25	8.13±0.08	9.8±0.09	4.19±0.05 ^c	8.71±0.07 ^a	13.51±0.12
Breed	0.46	0.42	0.86	0.29	0.21	0.53	0.70	0.92	0.96	0.63	0.81
Sex	0.01	0.01	0.01	0.03	0.00	0.01	0.01	0.00	0.01	0.00	0.01
Parities	0.06	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.02
Diets	0.00	0.00	0.00	0.35	0.05	0.11	0.55	0.05	0.00	0.00	0.32
Breed * Sex	0.91	0.84	0.64	0.83	1.00	0.55	0.39	0.70	0.82	0.75	0.82
Breed * Parities	0.91	0.98	0.51	0.77	0.29	0.97	0.57	0.36	0.86	0.22	0.55
Breed* Diet	0.94	0.95	0.83	0.44	0.73	0.83	0.24	0.89	0.41	0.44	0.86
Sex * Parities	0.28	0.08	0.12	0.50	0.22	0.03	0.29	0.25	0.13	0.55	0.51
Sex * Diet	0.28	0.79	0.37	0.94	0.69	0.72	0.90	0.81	0.83	0.93	0.74
Parities * Diets	0.01	0.00	0.00	0.00	0.01	0.05	0.01	0.56	0.00	0.00	0.04
Breed * Sex *	0.55	0.77	0.31	0.62	0.66	0.52	0.80	0.83	0.63	0.84	0.71
Parities											
Breed * Sex* Diet	0.69	0.93	0.92	0.91	0.96	0.85	0.93	0.38	0.87	0.67	0.82
Breed * Parities *	0.22	0.54	0.37	0.27	0.03	0.50	0.25	0.13	0.41	0.38	0.61
Diet											
Sex*Parities*Diet	0.96	0.97	0.65	0.99	0.98	0.99	0.50	0.81	0.91	0.74	0.81
Breed* Sex*	0.94	0.89	0.96	0.62	0.98	0.92	1.00	0.89	0.82	0.90	0.91
Parities* Diet											

^{a,b,c} – Means on the same column having different superscripts are significantly different (P<0.05). 10g, 20g and 30g = 10grams, 20grams and 30grams Tiger nut inclusion level; HYL = Hyla Max; NZW = New Zealand White; DUT = Dutch Belted; BW = Body weight; BL = Body length; HW= Height at withers; EL= Ear length; HG = Heart girth; ST= shoulder to tail length; HSL = Head to shoulder length; FL= Fore limb; TL = Tail length; HL = Head length; RUMP = Rump

Table 7. Effects of breed, sex, parity, diet and their interactions on body weight (kg) and linear body measurements (cm) of three of rabbit breeds at weeks 5 old

Variations	BW	BL	HW	EL	HG	ST	SL	FL	TL	HL	RUMP
Breeds											
DUT	0.37±0.01	25.97±0.24	17.38±0.17	7.55±0.1	15.52±0.14	24.56±4.42 ^a	9.08±0.11	10.63±0.09	5.16±0.08	9.88±0.09	14.43±0.13
HYLA	0.38±0.01	26.26±0.22	17.23±0.16	7.48±0.06	15.66±0.14	20.16±0.22 ^{ab}	9.12±0.08	11.52±0.93	5.25±0.06	9.83±0.07	14.57±0.12
NZW	0.35±0.01	25.82±0.20	17.39±0.15	7.35±0.06	15.34±0.12	19.8±0.19 ^b	9.04±0.07	10.47±0.07	5.31±0.06	9.7±0.07	14.6±0.10
Sex											
Female	0.35±0.01 ^b	25.68±0.15 ^b	17.1±0.11 ^b	7.36±0.04 ^b	15.38±0.08	19.77±0.15 ^b	8.92±0.05 ^b	10.87±0.44	5.13±0.05 ^b	9.66±0.05 ^b	14.36±0.08 ^b
Male	0.38±0.01 ^a	26.54±0.23 ^a	17.75±0.16 ^a	7.61±0.08 ^a	15.68±0.15	24.18±3.75 ^a	9.33±0.1 ^a	10.77±0.09	5.45±0.07 ^a	10.03±0.08 ^a	14.84±0.11 ^a
Parities											
P1	0.37±0.01 ^a	26.34±0.2 ^a	17.07±0.15 ^b	7.39±0.06 ^{ab}	15.46±0.13 ^{ab}	20.16±0.21 ^{ab}	8.98±0.07 ^b	10.58±0.06	4.97±0.06 ^c	9.83±0.07 ^a	14.35±0.11
P2	0.38±0.01 ^a	26.36±0.23 ^a	17.56±0.16 ^a	7.62±0.09 ^a	15.73±0.13 ^a	20.33±0.23 ^{ab}	9.45±0.09 ^a	11.67±0.71	5.6±0.06 ^a	10.02±0.06 ^a	14.58±0.12
P3	0.32±0.01 ^b	24.65±0.14 ^b	17.47±0.15 ^a	7.26±0.06 ^b	15.12±0.09 ^b	25.89±6.75 ^a	8.58±0.06 ^b	9.76±0.08	5.15±0.06 ^b	9.33±0.09 ^b	14.83±0.06
Diets											
10g	0.34±0.01 ^b	25.51±0.21 ^b	17.15±0.17 ^{ab}	7.45±0.08	15.43±0.14	25.08±5.37 ^a	8.98±0.1 ^b	11.49±1.05	5.13±0.07 ^b	9.72±0.11	14.42±0.13
20g	0.35±0.01 ^b	25.62±0.23 ^b	16.64±0.11 ^b	7.43±0.12	15.18±0.09	19.8±0.23 ^c	8.89±0.09 ^b	10.39±0.09	5.23±0.06 ^a	9.84±0.08	14.4±0.14
30g	0.39±0.01 ^a	26.43±0.26 ^a	17.71±0.2 ^a	7.58±0.07	15.52±0.19	20.27±0.25 ^b	9.29±0.11 ^a	10.7±0.1	5.54±0.09 ^a	9.84±0.07	14.56±0.15
CNTRL	0.38±0.01 ^a	26.39±0.29 ^a	17.8±0.21 ^a	7.35±0.08	15.82±0.15	20.26±0.27 ^b	9.12±0.1 ^a	10.68±0.09	5.09±0.07 ^b	9.8±0.07	14.76±0.11
Breed	0.43	0.58	0.72	0.30	0.69	0.00	0.91	0.69	0.69	0.33	0.73
Sex	0.01	0.00	0.01	0.01	0.06	0.00	0.00	0.90	0.00	0.00	0.01
Parities	0.00	0.00	0.04	0.01	0.01	0.00	0.00	0.09	0.00	0.00	0.13
Diets	0.00	0.01	0.00	0.06	0.29	0.00	0.01	0.86	0.00	0.07	0.43
Breed * Sex	0.93	0.89	0.67	0.88	1.00	0.00	0.29	0.78	0.69	0.40	0.80
Breed * Parities	0.98	1.00	0.67	0.93	0.45	0.00	0.11	0.82	0.54	0.20	0.76
Breed* Diet	0.99	0.81	0.98	0.31	0.93	0.00	0.14	0.91	0.67	0.77	0.86
Sex * Parities	0.36	0.19	0.25	0.57	0.44	0.00	0.17	0.80	0.39	0.75	0.36
Sex* Diet	0.18	0.72	0.81	0.79	0.99	0.00	0.80	0.75	0.81	0.97	0.85
Parities * Diets	0.00	0.02	0.02	0.00	0.12	0.00	0.00	0.88	0.10	0.00	0.13
Breed * Sex * Parities	0.56	0.79	0.18	0.90	0.26	0.00	0.57	0.80	0.63	0.94	0.68
Breed* Sex* Diet	0.81	0.87	0.87	0.97	0.92	0.00	0.96	0.90	0.98	0.76	0.94
Breed * Parities * Diet	0.64	0.43	0.65	0.07	0.39	0.00	0.17	0.96	0.10	0.22	0.78
Sex*Parities*Diet	0.97	0.98	0.89	0.16	0.97	0.00	0.38	0.83	1.00	0.95	0.94
Breed* Sex* Parities* Diet	0.98	0.96	0.98	0.78	0.51	0.00	0.93	0.93	0.60	0.90	0.92

^{a,b,c} – Means on the same column having different superscripts are significantly different ($P<0.05$). 10g, 20g and 30g = 10grams, 20grams and 30grams Tiger nut inclusion level; HYL = Hyla Max; NZW = New Zealand White; DUT = Dutch Belted; BW = Body weight; BL = Body length; HW= Height at withers; EL= Ear length; HG = Heart girth; ST= shoulder to tail length; HSL= Head to shoulder length; FL= Fore limb; TL = Tail length; HL = Head length.

DISCUSSION

The results confirmed that both genetic and environmental factors significantly influence rabbit morphometric traits. The superior performance of New Zealand White and Hyla Max rabbits aligns with findings by Sivakumar et al. (2013), who reported higher skeletal and muscular development in commercial breeds due to selective breeding for growth efficiency.

Sexual dimorphism was evident, with males outperforming females in nearly all parameters. This difference can be attributed to androgenic effects that promote protein deposition and muscle development (Oke et al, 2026). Females may divert more energy toward reproduction, leading to smaller linear measurements (Cheeke, 1987).

Parity significantly affected offspring growth. Kits from second-parity does show higher morphometric values, likely due to improved maternal experience, increased milk yield, and more efficient nutrient allocation (Maertens et al., 2006) This suggests that reproductive maturity and maternal behavior play crucial roles in offspring development.

The dietary inclusion of tiger nut positively influenced growth, particularly at 20–30 g/kg. Tiger nut's high oleic acid and fiber content enhance energy utilization and gut health, explaining the improved morphometric traits (Belewu & Belewu, 2007). Similar results were observed by Adeyemi (2018), who found that energy-dense diets enhanced growth and muscle deposition in rabbits.

Parity $\times$ diet interactions revealed that second-parity dams fed 30 g/kg tiger nut produced kits with superior body conformation. This finding supports the role of maternal nutrition and physiological efficiency during mid-reproductive stages in optimizing offspring growth (Hernandez & Dallezotte, 2010).

CONCLUSION

Breed, sex, parity, and tiger nut inclusion significantly affected rabbit morphometric and growth traits. New Zealand White and Hyla Max breeds, males, and second-parity offspring demonstrated superior performance. Optimal tiger nut inclusion (20–30 g/kg) improved body length, height at withers, and hind leg length. These findings highlight the combined effects of genetic and nutritional factors in rabbit production and suggest practical strategies for improving growth through breed selection and dietary enhancement.

REFERENCES

- Adeyemi A. A. (2018) Physiological response of rabbit does fed diets supplemented with Moringa oleifera leaf meal. *Nigerian J. Anim. Sci.* 2018, 20(4): 425-431
- Akanno EC, Ibe SN (2006). Prediction of body weight of the domestic rabbits at different stages of growth using linear body measurements. *Nig. J. Anim. Prod.* 33(1): 3-8
- Alves J. M, Carneiro M, Afonso et al., "Levels and patterns of genetic diversity and population structure in domestic rabbits," *PLoS One*, 10(12) 1–20, Article ID e0144687, 2015.
- Belewu, M. A. and Belewu, K. Y. (2007). Comparative physico-chemical evaluation of tigernut, soybean and coconut milk sources. *International Journal of Agricultural Biology*, 9: 785- 787.
- Cheeke, P. R. (1987). *Rabbit feeding and nutrition*. Academic Press Inc. Ed., 376p - Orlando, USA <http://books.google.fr/books?id=XpTYrB6Uv7sC>
- Chineke, C. A. (2000). Characterization of physical body traits of domestic rabbit in humid tropics.
- Chineke, C. A. (2000). Characterization of physical body traits of domestic rabbits in humid tropics. *Proceeding of the 25th annual conference of Nigeria Society for Animal production*, Umudike, 19 -23 March, 2000. Pp 237 – 239.
- Climate Data. (2018). Akure Weather Information. Available at <http://en.climate-data.org/location/385339/>. Retrieved on 24/07/2018.
- Hernandez, P. and DalleZotte, A. (2010). Influence of diet on rabbit meat quality. *Nutrition of Rabbit*, 2nd Edition.
- Lebas, F., Coudert, P., De Rochambeua, H. and Thébault, R. G. (1997). *The Rabbit Husbandry, Health and Production*. FAO Animal Production and Health Series 21(6) 234-342.
- Maertens, L, Lebas, F. and Szendro, Z. (2006). Rabbit milk: A review of quantity, quality and non-dietary affecting factors. *World rabbit science*, 14:205-30.
- Oke, P. P., Moreno, V., Olivari, F. A. and Allende, M. L. (2006). Sub-lethal concentrations of waterborne copper are toxic to lateral line neuromasts in zebrafish (*Danio rerio*) 16386394 Full text @ Here. Res.
- Szendrő, Z., Szendrő, K. and Dalle Zotte. A. (2012). Management of reproduction on small, medium and large rabbit farms: A review. *Asian-australasian Journal of Animal Sciences* 25(5):738-748.
- SAS (2018). *Statistical analysis system multiple incorporation. Users' Guide Statistical version* Cary, NC. USA