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HERITABILITY AND REPEATABILITY ESTIMATES OF PRE-WEANING, REPRODUCTIVE AND MORPHOMETRIC TRAITS OF RABBIT BREEDS

[1]Ogunjesa, A. B., [2]Oyegunle, O. O., and [3]Chineke, C. A.

[1]Department of Animal Production and Health, Federal University of Technology Akure, Ondo state, Nigeria.
[2]Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria
[3]Department of Animal Production and Health, Federal University of Technology Akure, Ondo state, Nigeria
Correspondence: atinuke.awe@gmail.com

Abstract
The currently high rate of inflation in Nigeria necessitates the need to conduct more researches on rabbits for more affordability of animal proteins via accelerated improvement in rabbit production techniques. Therefore, this study was aimed at estimating heritability and repeatability for pre-weaning litter traits and body characteristics of 300 kits obtained from five rabbit breeds (Rex, California, New Zealand White, Dutch belted and locally adapted breeds) and their crosses. Data were taken weekly from 7 days to 28 days of age on pre-weaning body weights and reproductive traits using a Bench electronic scale while morphometric traits were measured using a Generic measuring tape and a 30-centimetre metric ruler. Data was analyzed using mixed model least squares and maximum likelihood computer program of Harvey (1987). Heritability for litter traits ranged from medium (0.12) to high (0.70) while for body weights and morphometric traits, it ranged from low (0.01) to high (0.95). The high heritability results indicated body weights may be improved through individual selection while traits with low heritability could be improved upon by crossbreeding. Furthermore, a combination of pedigree and individual selection could be done for moderately heritable traits.The repeatability estimates for all traits ranged from low (0.01) to medium (0.49). These showed low chances of these records being repeated. Therefore, assessment of several parities should be done before actual selection is carried out for rabbit breed improvement.

Key words: *Litter size, body weight, body length, gestation length, kits*

Introduction

Animal proteins are vital for human health (Elmadfa and Meyer, 2017). Although, they can be obtained from a variety of animals, they are still expensive and relatively unaffordable by many Nigerians (Sanusi and Adewoyin, 2014). Of the majority of animals that supply animal proteins, rabbits (micro-livestock species) possess exceptional attributes which make them economically suitable to meet human protein requirements if they are raised in commercial quantity, especially with the current level of inflation rates in Nigeria. These attributes include: affordable or low-cost management requirements, small-bodied size, short generation interval, high fecundity and rapid growth rate, ability to utilize forage and agricultural by-products and adaptation to a wide range of ecological environment (Biobaku and Oguntona, 1997).

Although hundreds of rabbit breeds exist across the world, California, New Zealand White, Chinchilla, Dutch and Rex have outstanding quality for meat production (Lebas *et al.,* 1997; Mailafia *et al.,* 2010; David, 2011). Crossing these breeds has increased efficiency in rabbit meat production (Wanjala *et al.,* 2016). This has been successfully done in Europe (Marin-Garcia and Llobat, 2021) and could also be practiced in a developing country like Nigeria. However, for the breeding programme to be successful, practices such as selection based on use of breed diversity (cross breeding) and genetic parameter estimates such as heritability and repeatability are vital (Wanjala *et al.,* 2016). Estimates of heritability and repeatability are reliable tools used in selection of animals and prediction of future performance for rapid improvement in animal production (Kabir *et al*., 2006). According to Lewer (2005), heritability estimates are basically described as high, medium or low according to the following convention: high (greater than 0.30); medium (0.10 to 0.30); and low (less than 0.10), while according to Falconer and Mackay (1996), repeatability is categorized as low (< 0.30), medium (≥ 0.30 - < 0.50) and high (≥ 0.50 - 1.00). Studies on heritability and repeatability estimates have been done by Kabir *et al.* (2012) using rabbit breeds such as New Zealand White, California and Chinchilla while Okoro *et al.* (2012) used unselected nondescript rabbits. Their studies generally showed medium to high heritability traits for litter size and litter weight from birth till weaning. Kabir *et al.* (2012) reported moderate to high repeatability for the same traits. Their results may be improved if breeds with good mothering ability were included in the experiment. This would improve pre-weaning performance and consequently lead to better weaning and post weaning performance. This study was therefore designed at estimating heritability and repeatability of pre-weaning traits and body measurements in rabbit breeds and their crosses in a tropical environment. The findings from this study will provide additional information on rabbit breeding and production strategies.

Materials And Methods

Study Location

The research was carried out at the Rabbit Unit of the Teaching and Research Farm, the Federal University of Technology, Akure, Ondo State, Nigeria. Akure is located 350.52m above sea level at Latitude 7018'12"N and Longitude 508'4"E (Adekayode, 2014) with a mean annual rainfall of about 1500mm (Barbour et al., 1982; Uluocha and Ekop, 2002). A bimodal rain period with a short break in August and mean annual relative humidity of 75% with temperature varying from 28°C - 30°C .

Duration of Study

This study was carried out between December 2011 and October 2012, covering a period of 10 months.

Experimental Animals and their Management

Foundation stock of forty rabbits, comprising five breeds namely Rex (RX), California (CF), New Zealand White (NZW), Dutch-belted (DT) and the Locally-adapted breed (LAB) and having six does and two bucks per breed were subjected to pure mating, cross mating and reciprocal mating to generate three hundred (300) kits used for this study. The breeds of the kits obtained were NZW x NZW (23), RX x RX (20), DT x DT (21), CF x CF (17), LAB x LAB (21), NZW x RX (18), DT x CF (23), LAB x NZW (18), CF x RX (22), DT x LAB (18), RX x NZW (22), CF x DT (19), NZW x LAB (19), RX x CF (15) and LAB x DT (24).

All the rabbits were subjected to the same dietary and management conditions. The houses had floors made of concrete and short walls to ensure proper ventilation. The hutches were made of wood and wire mesh, fitted with feeders and drinkers. They were fed a formulated diet having a proximate composition of 16.23% CP, 2280kcal/kg ME and 10.27% CF together with sun-dried greens (*Aspilia Africana* and *Tridax procumbens*) for supplementary fibre. Water was supplied *ad-libitum*.

At 16 weeks, the does were taken to the buck for mating. Ten days after, palpation was done to ascertain pregnancy. The mating process was repeated for does that failed to conceive. Kindling boxes were placed in the hutches of pregnant does 25 days after conception was confirmed. Litters were raised on milk of the doe from birth till they were weaned at 28 days although they started taking concentrates and leafy supplements provided in the does cages at this period.

Data Collection and Analysis

All body weights (Individual kit weight (IKT), Litter weight (LWT) and Average litter weight (ALT)) were determined in the morning before animals were fed. The weights of the 300 kits were taken at birth, 7, 14, 21 and 28 days of age using a Bench electronic scale of 10kg maximum weight with 0.01kg accuracy. Morphometric traits studied were ear length (EL), chest girth (CG), nose-to-shoulder length (NSL), trunk length (TRL), tail length (TLL), body length (BL), abdominal circumference (AC) and height at withers (HWT). Height at withers was measured with a 30-centimetre metric ruler while all other linear traits were measured using Generic measuring tape calibrated in centimeters. The following morphometric traits were studied as described by Chineke (2005):

Length of ear: The distance from the base of the attachment of the ear to the tip of the ear.
Heart girth: This is measured as body circumference just below the fore leg.
Nose-to-shoulder length: The distance from the nose to the point of the shoulder.
Trunk length: The longitudinal distance from the point of the shoulder to the tuberosity of the ischium.
Tail length: This is the distance from the tip of the tail to the base of the tail.
Body length: This is the distance from the nose through the shoulder to the posterior end.
Abdominal circumference: This is measured as body circumference just above the hind leg.
Height at withers: The dorsal midline at the highest point on the withers.

Statistical analysis

Data collected were analyzed to analysis of variance (ANOVA) for unequal subclass numbers, using Harvey's (1987) Least Squares and Maximum Likelihood computer programme.

Heritability (h^2) and repeatability (r) estimates were obtained using the following formula:

$$h^2 = \frac{4\sigma^2 d}{\sigma^2 s + \sigma^2 d + \sigma^2 e};$$

while repeatability estimates were obtained as:

$$r = \frac{\sigma^2 B}{\sigma^2 B + \sigma^2 w}$$

Where h^2 = heritability estimate
r = repeatability estimate
$\sigma^2 s$ = variance component due to sire
$\sigma^2 d$ = variance component due to dam
$\sigma^2 e$ = variance component due to error
$\sigma^2 B$ = variance between individuals
$\sigma^2 w$ = variance within individuals

Results

Heritability Estimates for Reproductive Traits among Different Rabbit Breeds

Table 1 showed the heritability estimates for reproductive traits among the different rabbit breeds. Heritability estimates were high for litter size at birth (LSB) in all breeds except for DT, CF, CF_m x RX_f and DT_m x LAB_f which had medium heritability estimates of 0.34 ± 0.21, 0.25 ± 0.16, 0.24 ± 0.12 and 0.24 ± 0.12 respectively. All the breeds also had high heritability estimates for GSL except for NZW, NZW_m x LAB_f and RX_m x CF_f which had medium heritability estimates of 0.21 ± 0.10, 0.19 ± 0.20 and 0.28 ± 0.12 respectively. For IKT, LWT and ALW, heritability estimates ranged from medium (0.12±0.42) to high (0.56±0.27) with LAB, DT and Rx having the highest estimates of 0.51 ± 0.20, 0.56 ± 0.27 and 0.52 ± 0.21 respectively.

Heritability estimates for body weights and morphometric traits are shown in Table 2. Heritability estimates for IKT across the breeds were low (0.09±0.04), medium

(0.13±0.16 to 0.26±0.16) and high (0.33±0.16 to 0.95±0.34). LAB had the highest heritability estimate for IKT (0.95±0.34) while NZW had the lowest (0.09±0.04). For EL, high heritability estimates were recorded for all the breeds except for NZW which had medium (0.23±0.09) heritability. However, DT had the highest heritability value (0.86 ± 0.82). Dutch belted had the highest heritability value (0.73±0.76) for TRL while CF had the lowest (0.09±0.50). REX had the highest (0.55±0.21) heritability for CG while CF had the lowest (0.01±0.25). However, NZW, LAB, NZW$_m$ x RX$_f$, RX$_m$ x NZW$_f$, RX$_m$ x CF$_f$ $_{and}$ LAB$_m$ x DT$_f$ also had high heritability estimates (0.40±0.14, 0.51±0.22, 0.40±0.04, 0.32±0.22, 0.50±0.22 and 0.39±0.12 respectively). The estimate for HW ranged from 0.11±0.31 to 0.57±0.43 indicating medium to high heritability. Abdominal circumference proved to be highly heritable in all the breeds except DT$_m$ x LAB$_f$, NZW$_m$ x LAB$_f$ and LAB$_m$ x DT$_f$ which had medium heritability (0.28±0.50, 0.23±0.06, and 0.26±0.32 respectively).

Heritability estimates for BL ranged from 0.17±0.95 to 0.65±0.18. High heritability values were recorded for BL in all the breeds except in DT which had low heritability (0.17±0.95). For the NSL, heritability estimates were high except in NZW, CF, CF$_m$ x DT$_f$, NZW$_m$ x LAB$_f$ and LAB$_m$ x DT$_f$ which had medium heritability (0.17±0.07, 0.18±0.67, 0.15±0.17, 0.19±0.17 and 0.28±0.15 respectively). The estimate for TLL ranged from medium (0.16±0.06 for NZW$_m$ x LAB$_f$) to high (0.52±0.11 for LAB).

Table 1. Estimates of Heritability for Reproductive Traits among Different Rabbit Breeds

Genotype	LSB	GSL	IKT	LWT	AL
NZW	0.34 ± 0.21	0.21 ± 0.10	0.49 ± 0.11	0.32 ± 0.13	0.42 ± 0.22
Rx	0.42 ± 0.14	0.44 ± 0.32	0.52 ± 0.21	0.54 ± 0.23	0.43 ± 0.25
DT	0.21 ± 0.14	0.53 ± 0.12	0.56 ± 0.27	0.15 ± 0.10	0.47± 0.33
CF	0.25 ± 0.16	0.42 ± 0.23	0.20 ± 0.52	0.37 ± 0.22	0.22 ± 0.53
LAB	0.70 ± 0.44	0.52 ± 0.12	0.51 ± 0.20	0.49 ± 0.25	0.53 ± 0.23
NZW$_m$ x Rx	0.43 ± 0.17	0.54 ± 0.32	0.45 ± 0.21	0.34 ± 0.24	0.40 ± 0.14
DT$_m$ x CF$_f$	0.32 ± 0.43	0.45 ± 0.20	0.28 ± 0.20	0.31 ± 0.17	0.34 ± 0.22
LAB$_m$ x NZW$_f$	0.49 ± 0.24	0.53 ± 0.17	0.40 ± 0.10	0.35 ± 0.12	0.53 ± 0.13
CF$_m$ x Rx$_f$	0.24 ± 0.12	0.41 ± 0.17	0.19 ± 0.32	0.21 ± 0.05	0.22 ± 0.10
DT$_m$ x LAB$_f$	0.24 ± 0.12	0.43 ± 0.30	0.50 ± 0.24	0.31 ± 0.23	0.42± 0.21
Rx$_m$ x NZW$_f$	0.34 ± 0.14	0.37 ± 0.23	0.26 ± 0.31	0.12 ± 0.42	0.33 ± 0.20
CF$_m$ x DT$_f$	0.34 ± 0.22	0.43 ± 0.13	0.24 ± 0.10	0.26 ± 0.15	0.30 ± 0.10
NZW$_m$ x LAB$_f$	0.47 ± 0.23	0.19 ± 0.20	0.32 ± 0.13	0.34 ± 0.12	0.50 ± 0.34
Rx$_m$ x CF$_f$	0.31 ± 0.14	0.28 ± 0.12	0.23 ± 0.15	0.34 ± 0.25	0.33 ± 0.35
LAB$_m$ x DT$_f$	0.44 ± 0.32	0.32 ± 0.21	0.39 ± 0.25	0.29 ± 0.10	0.53 ± 0.17

26B: NZW = New Zealand White; DT = Dutch-Belted; CF = California; LAB = Locally-adapted Breed; LSB = Litter size at birth; GSL = Gestation length; IKT = Individual kit weight; LWT = Litter weight and ALW = Average litter weight; $_m$ = male; $_{f=}$ female

Table 2: Heritability Estimates of Morphometric Traits among Different Rabbit Breeds from Weeks 1 to 4

Genotype	IKT	EL	TRL	CG	HW	AC	BL	NSL	TLL
NZW	0.09 ± 0.04	0.23 ± 0.09	0.29 ± 0.11	0.40 ± 0.14	0.34 ± 0.12	0.45 ± 0.16	0.33 ± 0.12	0.17 ± 0.07	0.21 ± 0.08
Rx	0.60 ± 0.19	0.51 ± 0.22	0.51 ± 0.21	0.55 ± 0.21	0.49 ± 0.23	0.48 ± 0.23	0.65 ± 0.18	0.53 ± 0.22	0.32 ± 0.21
DT	0.18 ± 0.36	0.86 ± 0.82	0.73 ± 0.76	0.10 ± 0.30	0.11 ± 0.31	0.35 ± 0.50	0.17 ± 0.95	0.49 ± 0.60	0.20 ± 0.40
CF	0.23 ± 0.76	0.55 ± 0.03	0.09 ± 0.50	0.01 ± 0.25	0.20 ± 0.72	0.43 ± 0.14	0.40 ± 0.94	0.18 ± 0.67	0.34 ± 0.11
LAB	0.95 ± 0.34	0.64 ± 0.17	0.56 ± 0.20	0.40 ± 0.04	0.49 ± 0.23	0.46 ± 0.22	0.51 ± 0.21	0.38 ± 0.25	0.52 ± 0.11
NZW$_m$ x Rx	0.39 ± 0.14	0.33 ± 0.19	0.49 ± 0.21	0.40 ± 0.04	0.44 ± 0.13	0.43 ± 0.33	0.56 ± 0.18	0.63 ± 0.20	0.23 ± 0.11
DT$_m$ x CF$_f$	0.26 ± 0.16	0.64 ± 0.22	0.37 ± 0.26	0.30 ± 0.13	0.32 ± 0.12	0.34 ± 0.14	0.41 ± 0.54	0.38 ± 0.60	0.44 ± 0.31
LAB$_m$ x NZW$_f$	0.52 ± 0.14	0.40 ± 0.27	0.43 ± 0.10	0.17 ± 0.22	0.57 ± 0.43	0.62 ± 0.32	0.42 ± 0.22	0.54 ± 0.22	0.32 ± 0.12
CF$_m$ x Rx$_f$	0.33 ± 0.16	0.45 ± 0.13	0.29 ± 0.52	0.13 ± 0.25	0.24 ± 0.22	0.32 ± 0.14	0.34 ± 0.49	0.43 ± 0.60	0.30 ± 0.10
DT$_m$ x LAB$_f$	0.13 ± 0.16	0.62 ± 0.20	0.53 ± 0.64	0.30 ± 0.33	0.21 ± 0.41	0.28 ± 0.50	0.32 ± 0.50	0.34 ± 0.30	0.25 ± 0.34
Rx$_m$ x NZW$_f$	0.46 ± 0.11	0.41 ± 0.13	0.39 ± 0.31	0.32 ± 0.22	0.24 ± 0.26	0.56 ± 0.33	0.43 ± 0.12	0.35 ± 0.32	0.36 ± 0.31
CF$_m$ x DT$_f$	0.22 ± 0.21	0.51 ± 0.33	0.19 ± 0.10	0.21 ± 0.25	0.24 ± 0.20	0.33 ± 0.16	0.34 ± 0.32	0.15 ± 0.17	0.24 ± 0.16
NZW$_m$ x LAB$_f$	0.56 ± 0.34	0.43 ± 0.19	0.34 ± 0.22	0.24 ± 0.16	0.40 ± 0.11	0.23 ± 0.06	0.43 ± 0.19	0.19 ± 0.17	0.16 ± 0.06
Rx$_m$ x CF$_f$	0.46 ± 0.29	0.33 ± 0.12	0.31 ± 0.25	0.50 ± 0.22	0.23 ± 0.05	0.44 ± 0.24	0.39 ± 0.41	0.33 ± 0.18	0.44 ± 0.32
LAB$_m$ x DT$_f$	0.50 ± 0.24	0.36 ± 0.11	0.45 ± 0.20	0.39 ± 0.12	0.35 ± 0.22	0.26 ± 0.32	0.41 ± 0.21	0.28 ± 0.15	0.34 ± 0.19

NB: IKT = Individual kit weight; EL = Ear length; TRL = Trunk length; CG = Chest girth; HW = Height at withers; AC = Abdominal circumference; BL = Body length; NSL = Nose-to shoulder length; TLL = Tail length; NZW, New Zealand White; DT, Dutch-Belted; CF, California; LAB, Locally-adapted breed; $_m$= male; $_f$= female

Repeatability Estimates for Reproductive Traits among the Different Rabbit Breeds

The estimates of repeatability for reproductive traits are shown in Table 3. Most of the breeds had low repeatability estimates (ranging from 0.12±0.11 to 0.29±0.24) for LSB except for NZW, CF, LAB, DT_m x CF_f, NZW_m x LAB_f and LAB_m x DT_f which had values of 0.31 ± 0.12, 0.34 ± 0.13, 0.30 ± 0.11, 0.31 ± 0.12, 0.33 ± 0.22 and 0.49 ± 0.12 respectively. Repeatability estimates for IKT ranged from low (< 0.30), to moderate (≥ 0.30 - < 0.50) with DT having the highest repeatability estimate (0.49 ± 0.18) and Rex the lowest (0.03 ± 0.20).

Gestation length had repeatability estimates ranging from low (0.12 ± 0.11) in NZW_m x RX_f to medium (0.42 ± 0.92) in DT. Litter weight had low repeatability estimates (< 0.30) for all the breeds, except for NZW which had medium repeatability estimate (0.30 ± 0.11).

Table 4 showed the repeatability estimates for body weights and morphometric traits among the different rabbit breeds across weeks 1-4. Among the breeds, repeatability estimates for IKT ranged from low (0.05±0.02 to 0.23±0.11) to moderate (0.30±0.11 to 0.49±0.12) with LAB having the highest repeatability estimate and NZW the lowest. For ear length, most of the breeds had low repeatability estimates (ranging from 0.12±0.11 to 0.29±0.24) except for DT, LAB, DT_mx CF_f, DT_m x $LAB_f$and CF_m x DT_fwhich had moderate estimates of 0.42±0.92, 0.34±0.12, 0.31±0.13, 0.32±0.12 and 0.32±0.17 respectively. Dutch belted and DT_m x LAB_fhad moderate repeatability estimates (0.49 ± 0.18 and 0.31 ± 0.23 respectively) for TRL while all other breeds recorded low estimates ranging from 0.03 ± 0.20 (CF) to 0.29±0.10 (LAB). Generally, all the breeds had low to moderate repeatability estimates (ranging from 0.01±0.03 to 0.39±0.14) for CG, HW, AC, BL, NSL and TLL.

Table 3. Estimates of repeatability for reproductive traits among the different rabbit breeds

Genotype	LSB	GSL	IKT	LWT	AL
NZW	0.31 ± 0.12	0.22 ± 0.12	0.20 ± 0.15	0.30 ± 0.11	0.14 ± 0.07
Rx	0.09 ± 0.16	0.24 ± 0.03	0.03 ± 0.20	0.01 ± 0.03	0.09 ± 0.12
DT	0.08 ± 0.06	0.42 ± 0.92	0.49 ± 0.18	0.01 ± 0.04	0.10 ± 0.01
CF	0.34 ± 0.13	0.22 ± 0.13	0.24 ± 0.23	0.21 ± 0.13	0.20 ± 0.12
LAB	0.30 ± 0.11	0.29 ± 0.24	0.28 ± 0.20	0.29 ± 0.14	0.24 ± 0.13
NZW_m x Rx	0.19 ± 0.11	0.12 ± 0.11	0.21 ± 0.10	0.19 ± 0.04	0.21 ± 0.14
DT_m x CF_f	0.31 ± 0.12	0.29 ± 0.17	0.28 ± 0.13	0.09 ± 0.20	0.32 ± 0.21
LAB_m x NZW_f	0.11 ± 0.05	0.32 ± 0.17	0.09 ± 0.10	0.12 ± 0.10	0.13 ± 0.10
CF_m x Rx_f	0.13 ± 0.12	0.22 ± 0.09	0.19 ± 0.12	0.04 ± 0.02	0.10 ± 0.22
DT_m x LAB_f	0.10 ± 0.12	0.31 ± 0.13	0.19 ± 0.16	0.17 ± 0.11	0.20 ± 0.09
Rx_m x NZW_f	0.23 ± 0.11	0.22 ± 0.23	0.24 ± 0.17	0.19 ± 0.12	0.13 ± 0.20
CF_m x DT_f	0.09 ± 0.10	0.32 ± 0.12	0.31 ± 0.23	0.17 ± 0.20	0.11 ± 0.11
NZW_m x LAB	0.33 ± 0.22	0.28 ± 0.12	0.21 ± 0.11	0.13 ± 0.16	0.23 ± 0.17
Rx_m x CF_f	0.05 ± 0.02	0.20 ± 0.10	0.22 ± 0.13	0.24 ± 0.12	0.26 ± 0.08
LAB_m x DT_f	0.49 ± 0.12	0.34 ± 0.12	0.29 ± 0.10	0.24 ± 0.12	0.22 ± 0.23

NB: NZW = New Zealand White; DT = Dutch-Belted; CF = California; LAB = Locally-adapted Breed; $_m$ = male; $_f$ = female; LSB = Litter size at birth; GSL = Gestation length; IKT = Individual kit weight; LWT = Litter weight and ALW = Average litter weight

Table 4. Estimates of repeatability of morphometric traits among the different rabbit breeds across weeks 1-4

Genotype	IKT	EL	TRL	CG	HW	AC	BL	NSL	TLL
NZW	0.05 ± 0.02	0.20 ± 0.10	0.22 ± 0.13	0.24 ± 0.12	0.26 ± 0.08	0.25 ± 0.19	0.13 ± 0.12	0.11 ± 0.02	0.12 ± 0.18
Rx	0.30 ± 0.11	0.29 ± 0.24	0.28 ± 0.20	0.29 ± 0.14	0.24 ± 0.13	0.30 ± 0.17	0.34 ± 0.12	0.23 ± 0.19	0.17 ± 0.21
DT	0.08 ± 0.06	0.42 ± 0.92	0.49 ± 0.18	0.01 ± 0.04	0.10 ± 0.01	0.15 ± 0.21	0.11 ± 0.25	0.39 ± 0.29	0.16 ± 0.21
CF	0.09 ± 0.16	0.24 ± 0.03	0.03 ± 0.20	0.01 ± 0.03	0.09 ± 0.12	0.21 ± 0.09	0.19 ± 0.51	0.11 ± 0.21	0.21 ± 0.07
LAB	0.49 ± 0.12	0.34 ± 0.12	0.29 ± 0.10	0.24 ± 0.12	0.22 ± 0.23	0.21 ± 0.19	0.31 ± 0.20	0.17 ± 0.22	0.39 ± 0.14
NZW_m x Rx	0.19 ± 0.11	0.12 ± 0.11	0.21 ± 0.10	0.19 ± 0.04	0.21 ± 0.14	0.29 ± 0.17	0.31 ± 0.15	0.34 ± 0.20	0.11 ± 0.13
DT_m x CF_f	0.10 ± 0.12	0.31 ± 0.13	0.19 ± 0.16	0.17 ± 0.11	0.20 ± 0.09	0.17 ± 0.11	0.22 ± 0.14	0.18 ± 0.30	0.23 ± 0.11
LAB_m x NZW_f	0.31 ± 0.12	0.29 ± 0.17	0.28 ± 0.13	0.09 ± 0.20	0.32 ± 0.21	0.37 ± 0.22	0.24 ± 0.13	0.32 ± 0.18	0.15 ± 0.11
CF_m x Rx_f	0.13 ± 0.12	0.22 ± 0.09	0.19 ± 0.12	0.04 ± 0.02	0.10 ± 0.22	0.14 ± 0.08	0.19 ± 0.10	0.21 ± 0.50	0.19 ± 0.12
DT_m x LAB_f	0.09 ± 0.10	0.32 ± 0.12	0.31 ± 0.23	0.17 ± 0.20	0.11 ± 0.11	0.12 ± 0.20	0.19 ± 0.11	0.20 ± 0.14	0.15 ± 0.15
Rx_m x NZW_f	0.23 ± 0.11	0.22 ± 0.23	0.24 ± 0.17	0.19 ± 0.12	0.13 ± 0.20	0.34 ± 0.23	0.29 ± 0.12	0.20 ± 0.22	0.19 ± 0.11
CF_m x DT_f	0.11 ± 0.05	0.32 ± 0.17	0.09 ± 0.10	0.12 ± 0.10	0.13 ± 0.10	0.19 ± 0.13	0.20 ± 0.32	0.09 ± 0.11	0.13 ± 0.11
NZW_m x LAB_f	0.33 ± 0.22	0.28 ± 0.12	0.21 ± 0.11	0.13 ± 0.16	0.23 ± 0.17	0.11 ± 0.08	0.22 ± 0.13	0.07 ± 0.12	0.10 ± 0.12
Rx_m x CF_f	0.31 ± 0.12	0.22 ± 0.12	0.20 ± 0.15	0.30 ± 0.11	0.14 ± 0.07	0.25 ± 0.13	0.26 ± 0.19	0.18 ± 0.14	0.23 ± 0.18
LAB_m x DT_f	0.34 ± 0.13	0.22 ± 0.13	0.24 ± 0.23	0.21 ± 0.13	0.20 ± 0.12	0.11 ± 0.16	0.19 ± 0.21	0.16 ± 0.10	0.22 ± 0.13

NB: NZW, New Zealand White; Rx, Rex; DT, Dutch-Belted; CF, California; LAB, Locally-adapted Breed; $_m$ = male; $_f$ = female; IKT = Individual kit weight; EL = Ear length; TRL = trunk length; CG = Chest girth; HW = Height at withers; AC = Abdominal circumference; BL = Body length; NSL = Nose-to shoulder length; TLL = tail length

Discussion

In this study, the estimates of heritability for Litter size at birth and Litter weight at birth ranged from medium to high. Kabir *et al.* (2014) reported similar results using Chinchilla and California White rabbit breeds. Individual kit weight at birth and weaning had medium to high heritability as well. The results were similar to that of Adeolu and Ogunnupebi (2019) who reported high heritability estimates. Generally, the results corroborate those of Khalil *et al.* (2000); Okoro *et al.* (2011); Kabir *et al.* (2012) and Okoro *et al.* (2012). For linear body measurements, medium to high heritability estimates were recorded across the traits except for trunk length which had low to moderate repeatability estimates. Akanno and Ibe (2005) recorded low heritability estimates for ear length at 6 weeks. The results of this present study showed strong additive gene contributions to the expression of linear traits with high heritability while the environment has great influence on linear traits with low heritability. The results of heritability obtained in this study showed that there are very strong tendencies of does passing these traits to their offspring due to strong additive gene actions. The wide range of heritability estimates could be due to the method used in data analysis as well as differences in breed and population size.

The results of low to medium repeatability estimates for litter size at birth (LSB), gestation length (GSL) and litter weight at birth (LWT) obtained in this study are similar to that of Zaharaddeen and Kabir (2018) who reported low repeatability for LSB (0.27), medium repeatability for GSL (0.44) and high repeatability for LWT (0.50), although there were differences in the breeds used. Okoro *etal* (2012) also reported low repeatability estimates for LWT (0.03) and litter weight at weaning (-0.13). However, Kabir *et al.* (2012) reported moderate (0.50) to high (0.86) repeatability estimates for LSB, LWT and GSL in Chinchilla, New Zealand White and California White breeds of rabbit. Akpa and Alphonsus (2008) and Kabir *et al.* (2012) had similar results of high repeatability estimates. The low repeatability estimates obtained across weeks 1 to 4 for IKT is slightly in line with results by Adeolu and Ogunnupebi (2019) who reported low estimates for kit weight at week 2 and high estimates at week 4 (0.05 and 0.58 respectively). Repeatability estimates for linear traits studied were low to moderate.

Traits with low to medium repeatability estimates indicate that in any experimental population, many records must be considered before correct evaluation of doe's performance can be done. It could also be that for traits which displayed wide variation in repeatability estimates, a larger-sized data is required for a more reliable estimate.

Conclusion

Since individual kit weight, litter size at birth and ear length are highly heritable in the locally adapted breed, the locally adapted breed should be utilized optimally through grading up with New Zealand White or California so as to improve ear length which would help in thermoregulation, especially in a tropical region like Nigeria. This could also improve the individual kit weight, thus increasing market yield. In terms of selection, individual selection for improvement of body weights should be done. Traits with low heritability can be improved upon through crossbreeding and for traits with medium heritability, a combination of pedigree and individual selection should be adopted.

Low repeatability estimates indicate that selection based on a single production record cannot be sufficient for improvement of the productive potential in rabbit does. Therefore, it could potentially be used as a culling criterion to improve doe herd productivity in terms of litter mass production.

Based on high heritability estimates, individual selection for improvement of body weights should be done. Traits with low heritability can be improved through cross breeding and for traits with medium heritability, a combination of pedigree and individual selection should be adopted.

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