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Genetic and Non-genetic Effects on Weaning and Post-weaning Traits in Rabbit Breeds and Crosses

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Abstract: Data on 259 rabbits from 73 litters representing 8 genotypes were monitored for genetic and non-genetic effects on Individual Kit weight (Ikt), Litter weight (Lwt), Average litter weight (Alt) and Litter size (Ltz) at weaning and post-weaning ages of 35 and 56 days. The least squares model included main effects of genotype, sex, parity of dam, litter size, season of birth of the litter and first-order interactions between genotype, parity and season. Genotype differences were detected for 35-day Ikt ($p<0.01$), 35-day Lwt ($p<0.05$), 56-day Ikt ($p<0.01$) and 56-day Lwt ($p<0.05$).Crossbred NZWDBD x NZWDBD litters were significantly ($p<0.01$) superior over other genotypes in Ikt and Lwt.Sex differences ($p<0.05$) were obtained for 35- day Lwt. The males weighed heavier than females in Lwt at 35 and 56 days. Litter size differed ($p<0.01$) in Ikt, Lwt and Alt.Litters of seven rabbits outweighed other litters. Parity of dam was significantly important for Ikt ($p<0.01$), 56-day Ikt and Alt ($p<0.05$).All the traits were consistent with parity. Season mean values for 35- day Lwt and 56- day Ikt were different with dry season rabbits weighing more than wet seasons'. In this study, genetic and non-genetic effects were important in post- weaning performance of rabbit genotype. As such, these effects should be given appropriate attention in improvement programme for expansion of commercial rabbit industry in the humid tropics.

Key words: Genetic, post-weaning, breeds, crosses

INTRODUCTION

Rabbits in humid tropics have not been subjected to intensive selection pressure for genetic improvement of commercial production traits. In Europe and North America, cross breeding and selection among available breeds have been used extensively to improve rabbit productive[1]. Ozimba and Lukefahr[2] showed that crossbreeding improved fecundity, prolificacy, litter traits at weaning as well as post- weaning growth rate of rabbits. Crossbreeding brings together either the overall characters relative to the mother and the offspring or a favourable combination of additive effects on the components of an overall character. Crosses can exploit high growth potential of buck breed and good prolificacy, maternal performance and tolerance of the production environment of doe breed, a high ovulation rate and strong embryo viability in the crossbred doe. Thus, ovulation rate and egg and embryo viability are components of litter size at birth (prolificacy). Prolificacy and birth-weaning viability are components of litter size at weaning[3].

Rouvier[4], cited by Lebas *et al.*[3] reported that concerning the litter characters of the crossed doe California x New Zealand white, there was a favourable combination of direct genetic effect on the ovulation rate transmitted by the sire and the dam effects of the maternal line of the dam. Rouvier *et al.*[5] also observed that the crossed does with Small Himalayan dams showed heterosis and a doe with a California sire and a Small Himalayan dam has a bigger and heavier litter at weaning. In another experiment by Fayeye and Ayorinde[6], two-breed crossing improved the litter size and weight, pre-weaning livability, mean kit weight and rate of body weight increase in the New Zealand white x Chinchilla, California white x Chinchilla and New Zealand x California. Crosses produced from distantly versus closely related breeds, examples-Californian x Sichuan whites, Californian x New Zealand white may express more hybrid vigor than crosses from closely related animals. This is because of greater genetic differences represented in the cross, the basis of hybrid vigor[7]. In general, hybrid vigor has a positive influence on production traits especial those related to reproduction, health and disease resistance. However the potential economic benefits associated with crossbreeding using optimal breed combinations with respect to post- weaning litter traits of commercial importance have not been adequately investigated in Nigeria. Accordingly, the objectives of this study were to compare purebred and crossbred for weaning and post-weaning performance and evaluate possible effects of genetic and non- genetic factors on the production traits.

MATERIALS AND METHODS

Location of study: The study was conducted (between 1998 and 2001) in the rabbit unit of the Teaching and Research Farm of the Federal University of Technology, Akure, Nigeria. Akure is situated on 350.52 m above sea level at latitude 7°14'N and at longitude 5°14'E. The city falls within the rainforest zone of the humid tropics which is characterized by hot and humid climate. The mean annual rainfall is 1500 mm and the rains period is bimodal with a short break in August. The mean annual relative humidity is 75% and that of temperature is 20°C.

Animal and their management: A total of 259 rabbit kits from 73 litters obtained from a cross breeding experiment (1998-2001) involving 13 bucks and 49 does were used in the study. The 49 does representing 15 New Zealand white (NZW) and 13 Chinchilla (CHA) purebreds, 11 New Zealand white x Dutch belted (NZWDBD), 10 New Zealand white x Croel (NZWCRL) crossbreds were randomly assigned to 13 bucks (3 NZW and 5 CHA purebreds and 3 NZWDBD and 2 NZWCRL crossbreds) for mating early in the morning. The litters produced, representing 8 genotypes from the mating were monitored for genetic and non-genetic effects on weaning and post-weaning performance characteristics. The kits were sexed at 21 days. Litters were weaned at 35 days when each kit was individually ear-tagged and weighed. Litter mates were kept together in the same cage to 56 days of age.

Housing: The rabbits were housed in cages. Each cage or hutch has the following dimensions: length - 105 cm, width - 85 cm and height - 60 cm. The hutches were raised on wooden or metallic legs about 60 cm above the ground. The rabbits in hutches were placed inside a low walled house built with concrete block and corrugated iron sheets as roofing material. The wooden and metallic hutches were covered to some extent with mesh that would permit inspection, ventilation and dropping of rabbit faeces onto the cemented floor. Kindling boxes (each having the following dimensions: length -40 cm, width -30 cm and height -25 cm with a small hole measuring 15 cm by 15 cm) were provided inside the cages. Also supplied in each cage were feeding and watering troughs, which were made from tins.

Feeding and watering: The rabbits were given *ad libitum* access to commercial diet in the morning, supplemented with sweet potato leaves and *Aspillia africana* in the evening over the course of the experiment. The chemical composition of the commercial diet consisted of 2300 kcal kg^{-1} metabolisable energy, 15% crude protein, 8.0% ash, 7.2% fibre, 0.67% ether extract, 8.24% moisture content and 91.76% dry matter. The chemical composition of the sweet potato leaf was 11.68% crude protein, 7.68% ash, 3.22% fibre, 0.72% ether extract, 93.12% moisture content and 6.88% dry matter while that of *Aspillia africana* was 17.41% crude protein, 12.98% ash, 6.65% fibre, 0.87% ether extract, 93.33% moisture content and 6.67% dry matter. Clean water was supplied regularly.

Sanitation and health management: The rabbit house and its surroundings were kept clean. Practices such as sweeping and washing of the floor and troughs were done regularly. The incidence of diarrhea was combated with antibiotics such as embassin forte^{R}. To ensure absence of haemoparasites, internal and external parasites, the animals were treated with IVOMEC^{R} injection.

Data collection and traits studied: Basic information of genotype, parity, sex, litter size, birth season, sire and dam were kept on each litter in addition to body weight records at weaning age of 35 and post-weaning age of 56 days. The traits studied were individual kit weight (Ikt), litter weight (Lwt) average litter weight (Alt) and litter size (Ltz). All body weights were determined in the morning before feeding the animals, using electronic weighing scale. The weights for genotype, sex, parity, litter size and season at 35 and 56 days were used for the analyses.

Analytical procedures: The effects of genotype, sex, parity, litter size and season on body weight at 35 and 56 days of age were estimated from least square procedures of unequal sub-class numbers[8]. Where, significant differences were observed, differences between means were tested using Duncan's multiple range test outlined in the Harvey statistical package. The models used were:

For individual kit weight at 35 and 56 days of age

$$Y_{ijklmn} = U + B_i + C_j + P_k + S_l + R_n + (BC)_{ij} + (BP)_{ik} + (BS)_{il} + (CP)_{jk} + (PS)_{kl} + (CS)_{jl} + (BCP)_{ijk} + (BCS)_{ijl} + (CPS)_{jkl} + (BCPS)_{ijkl} + E_{ijklmn}$$

Where:

Y_{ijklmn} = The observation of the dependent variable on the $_m{}^{th}$ kit of the $_i{}^{th}$ genotype of the $_j{}^{th}$ sex of kth parity of l^{th} season of birth of $_n{}^{th}$ litter size.

U = Overall mean of all observations

B_i = Effect of the genotype of kit, I = 1, 2, 3, 4, 5, 6, 7, 8 (NZW x NZW, CHA x CHA, NZW x CHA, NZWDBD x NZWDBD, NZW x NZWDBD, NZWCRL x NZWCRL, CHA x NZWDBD and CHA x NZWCRL)

C_j = Effect of the $_j^{th}$ sex of kit; $_j$= 1, 2 (male, female)

P_k = Effect of the $_k^{th}$ parity, $_k$ = (1, 2, 3, 4, 5, 6)

S_l = Effect of the $_l^{th}$ season, 1, 2 (dry, wet)

R_n = Effect of the $_n$th litter size, $_n$ = (2, 3, 4, 5, 6)

$(BC)_{ij}$ = Effect of interaction between i^{th} genotype of kit and $_j^{th}$ sex of kit.

$(BP)_{ik}$ = Effect of interaction between i^{th} genotype and $_k^{th}$ parity.

$(BS)_{il}$ = Effect of interaction between i^{th} genotype and $_l^{th}$ season.

$(CP)_{ji}$ = Effect of interaction between i^{th} sex and $_k^{th}$ parity

$(CS)_{jl}$ = Effect of interaction between $^{th}_j$ sex and $^{th}{}_l$ season

$(PS)_{kl}$ = Effect of interaction between $^{th}_k$ parity and l^{th} season.

$(BCP)_{ijk}$ = Effect of interaction between $_i^{th}$ genotype, $_j^{th}$ sex and $_k^{th}$ parity.

$(BCS)_{ijl}$ = Effect of interaction between $_i^{th}$ genotype, $_j^{th}$ sex and $_l^{th}$ season.

$(CPS)_{jkl}$ = Effect of interaction between $_j^{th}$ sex, $_k^{th}$ parity $_l^{th}$ season.

$(BCPS)_{ijkl}$ = Effect of interaction between $_i^{th}$ genotype, $_j^{th}$ sex, $_k^{th}$ parity and $_l^{th}$ season.

E_{ijklmn} = Random error normally, identically and dependently distributed with zero mean and variance σ^2 e.

For litter weight, average litter weight and litter size at 35 and 56 days

Y_{ijklmn} = $U + B_i + C_j + P_k + S_l + R_n + (BC)_{ij} + (BP)_{ik} + (BS)_{il} + (CP)_{jk} + (CS)_{jl} + (PS)_{kl} + (BCP)_{ijk} + (BPS)_{ikl} + (BCS)_{ijl} + (CPS)_{jkl} + E_{ijklmn}$

Where:

Y_{ijklmn} = The observation of the dependent variable on the $_m^{th}$ kit of the $_i$th genotype of the $_j$th sex of the $_k$th parity of $_l$th of season of birth of the $_n$th litter size.

U = Overall mean of all observations

B_i = Effect of the $_i^{th}$ genotype of kit ($_I$= NZW x NZW, CHA x CHA, NZW x CHA, NZWDBD x NZWDBD, NZW x NZWDBD, NZWCRL x NZWCRL, CHA x NZWDBD and CHA x NZWCRL.

C_j = Effect of $_j^{th}$ sex of kit ($_j$ = male, female)

P_k = Effect of $_k^{th}$ parity ($_k$ = 1,2,3,4,5,6)

S_i = Effect of $_l^{th}$ season ($_l$ = dry, wet)

R_n = Effect of nth litter size $_n$ = (2,3,4,5,6)

$(BC)_{ij}$ = Effect of interaction between $_i^{th}$ genotype and $_j^{th}$ sex.

$(BP)_{ik}$ = Effect of interaction between $_i^{th}$ genotype and $_k^{th}$ parity.

$(BS)_{il}$ = Effect of interaction between $_i^{th}$ genotype and $_l^{th}$ season.

$(CP)_{jk}$ = Effect of interaction between $_j^{th}$ sex and $_k^{th}$ parity.

$(PS)_{kl}$ = Effect of interaction between $_k^{th}$ parity and $_l^{th}$ season.

$(BCP)_{ijk}$ = Effect of interaction between $_i^{th}$ genotype, $_j^{th}$ sex and $_k^{th}$ parity.

$(BPS)_{ikl}$ = Effect of interaction between $_i^{th}$ genotype, $_k^{th}$ parity and $_l^{th}$ season.

$(CPS)_{jkl}$ = Effect of interaction between $_j^{th}$ sex, $_k^{th}$ parity and $_l^{th}$ season.

E_{ijklmn} = Random error normally, identically and independently distributed with zero mean and variance σ^2e.

RESULTS

Reproductive traits at 35 days of age (weaning age): The overall means are indicated as 326.50±5.55 g, 351.17±10.59 g, 1097.43±47.27 g and 3.36±0.16 for individual kit weight (Ikt), average litter weight (Alt), litter weight (Lwt) and litter size (Ltz), respectively (Table 1).

Genotype and parity had significant ($p<0.001$) influences on individual kit weight (Ikt) but not on average litter weight (Alt) and litter size (Ltz). The litter weight (Lwt) was significantly ($p<0.05$) affected by genotype, sex, litter size and season. Litter size also influenced Ikt and Alt ($p<0.05$). Sex and season had no significant effects on Ikt, Alt and Ltz. The interactions involving genotype, parity and season showed that genotype x parity, genotype x season, parity x season and genotype x parity x season significantly ($p<0.001$) affected Ikt. Parity x season interaction was also an important source of variation ($p<0.05$). Other interactions were not significant (Table 2).

The individual kit weight (Ikt) and litter weight (Lwt) means values by genotype and parity differed significantly ($p<0.001$). The New Zealand White-Dutch belted x New Zealand White-Dutch belted (NZWDBD x NZWDBD) kits were superior in Ikt (381.47±14.0 g) compared to the other genotypes. The kits of New Zealand White x New Zealand White (NZW x NZW) recorded lighter Ikt means than others. The Lwt and Ltz means for New Zealand White-Dutch belted x New

Table 1: Least square means for reproductive traits at 35 days

Variables	No.	Individual kit wt (g)	No.	Litter wt (g)	Average litter wt (g)	Litter size
Genetic Groups						
NZW x NZW	50	289.18±11.20^{c}	14	950.46±97.72^{ab}	339.52±28.13	3.18±0.37
CHA x CHA	61	371.76±13.20^{ab}	18	1204.09±106.96^{ab}	387.70±24.94	3.24±0.33
NZW x CHA	30	366.51±13.00^{ab}	10	1045.83±132.77^{ab}	378.06±21.28	2.93±0.46
NZW.DBD x NZW.DBD	24	381.47±14.00^{a}	6	1439.93±191.34^{a}	393.50±29.08	4.15±0.65
NZW x NZW.DBD	19	327.63±17.33^{abc}	6	889.30±136.62^{b}	349.45±26.08	2.71±0.52
NZWCRL x NZWCRL	18	321.77±20.13^{abc}	5	1158.75±117.44^{ab}	375.80±30.44	3.84±0.58
CHA x NZW.DBD	38	307.39±9.72^{c}	9	1048.40±124.30^{ab}	305.25±17.49	3.75±0.28
CHA x NZWCRL	19	321.89±19.02^{abc}	5	1012.60±136.59^{ab}	339.32±41.41	3.18±0.58
Parity 1	37	317.24±11.87	11	1076.00±116.49	339.12±21.25	3.36±0.43
2	50	349.96±15.84	14	1146.70±96.31	391.13±28.90	3.19±0.36
3	50	333.80±13.63	15	1064.10±109.62	362.75±24.48	3.72±0.33
4	67	322.88±8.56	17	1162.90±107.11	334.99±15.94	3.72±0.31
5	42	302.33±11.52	11	1049.80±121.01	312.44±25.12	3.50±0.38
6	13	317.43±29.55	5	740.70±176.61	359.17±58.77	2.33±0.88
Litter size 2	24	451.21±27.93^{a}	24	638.07±39.63^{e}	462.2±25.46^{a}	-
3	20	391.38±27.14^{ab}	20	817.47±41.86^{d}	408.6±20.95^{b}	-
4	10	324.27±29.33^{bc}	10	1031.13±84.19^{cd}	350.38±27.17^{ab}	-
5	7	309.63±13.97^{bc}	7	1213.67±58.02^{dc}	310.74 + 11.00^{b}	
6	8	282.46±17.98^{c}	8	1486.08±77.43^{ab}	297.22±15.49^{b}	-
7	4	269.33±41.33^{c}	4	1767.6±204.39^{a}	294.61±34.07^{b}	-
Sex						
Male	117	324.24±8.76	34	1193.33±63.13^{a}	355.80±14.22	3.05±0.21
Female	142	328.36±7.12	39	988.68±67.10^{b}	346.41±15.88	3.67±0.22
Season						
Dry	116	351.95±11.07	31	1246.00±77.13^{a}	376.24±21.61	3.50±0.23
Wet	143	314.28±6.07	43	1022.75±57.05^{b}	339.82±11.69	3.30±0.20
Overall mean	259	326.50±5.55	73	1097±47.27	351.17±10.59	3.36±0.16

Mean with different superscripts in the same column are significantly different ($p<0.05$, $p<0.01$ and $p<0.001$)

Table 2: Mean square (ms) for reproductive traits at 35 days of age

Variables	Individual kit weight (g)		Litter weight (g)		Average litter weight (g)		Litter size	
Source of variation	df	MS	df	MS	df	MS	df	MS
Genotype	7	49404.84***	7	177581.54*	7	11978.75	7	1.35
Sex	1	7114.49	1	40919.26*	1	13526.24	1	1.42
Parity	5	4193.54***	5	51422.39.39	5	8806.88	5	0.92
Litter size	5	45271.55**	5	386408.53***	5	28468.80**	-	-
Season	1	3921.02	1	5511.51	1	5504.50	1	2.29
Genotype x Parity	18	14108.11***	13	143229.71	13	6301.31	13	1.27
Genotype x Season	4	27876.71***	3	308221.46	3	4349.69	3	2.39
Genotype x Sex	7	3564.27	4	73127.19	4	3841.63	4	0.77
Parity x Season	3	51241.81***	3	548131.50*	3	11932.60	3	3.29
Sex x Parity	5	259.35	2	99722.72	2	8485.31	2	1.70
Sex x Season	1	3.23	1	22240.29	1	17657.70	1	2.57
Genotype x Sex x Parity	11	3009.67	-	-	-	-	-	-
Genotype x Sex x Season	3	1692.69	-	-	-	-	-	-
Genotype x Parity x Season	1	121843.46***	-	-	-	-	-	-
Sex x Parity x Season	2	13644.23	-	-	-	-	-	-
Genotype x Sex x Parity x Season	1	11898.81	-	-	-	-	-	-
Error	183	4785.30	31	158704.14	31	8191.32	36	2.12

*$p<0.05$, **$p<0.01$ and ***$p<0.001$

Zealand White-Dutch belted (NZWDBD x NZWDBD) (1439.93±91.34 g and 4.15±0.65 g) were higher than the means of the same traits for other genotypes. The least Lwt mean was observed for New Zealand White x New Zealand White (NZW x NZWDBD) (889.30±136.62 g). There were no significant ($p>0.05$) differences in the Alt and Ltz means among the genotypes (Table 1).

The mean values for all the traits by sex were not significantly ($p>0.05$) different except litter weight (Lwt, $p<0.05$) where, males proved to be superior over females (1193.33±63.31 g versus 988.68±67.10 g). However, females performed better in individual kit weight (Ikt: 328.36±7.12 g versus 324.24±8.76 g) than males with no significant difference. The average litter weight (Alt) by were in favour of the males

The mean values for individual kit weight (Ikt), average litter weight (Alt) litter weight (Lwt) and Litter size (Ltz) by parity of dam were not different ($p>0.05$). The kits of the second parity were heaviest in Ikt and Alt (349.96±15.84 and 391.13±28.90 g), whereas parity 4 kits assumed superiority in Lwt (1162.90±107.11 g) and Ltz (3.72±0.31) over other parities. The least means values

Table 3: Least square means for reproductive traits at 56 days

Variables	No.	Individual kit wt (g)	No.	Litter wt (g)	Average litter wt (g)	Litter size
Genetic groups						
NZW x NZW	50	566.18±17.29^{b}	14	1666.63±173.21^{ab}	598.67±38.93	3.08±0.37
CHA x CHA	61	542.41±16.18^{ab}	19	1733.84±155.47^{ab}	565.18±27.19	3.22±0.30
NZW x CHA	13	533.85±17.10^{ab}	4	1445.87±370.62^{ab}	527.96±32.58	2.75±0.63
NZW.DBD x NZW.DBD	23	624.20±33.56^{a}	5	2051.33±280.65^{a}	635.45±63.39	3.56±0.75
NZW x NZW.DBD	19	480.91±19.26^{abc}	6	1177.98±237.69^{b}	481.19±30.81	2.34±0.52
NZWCRL x NZWCRL	14	531.82±20.33^{ab}	4	1819.81±297.82^{ab}	524.44±27.25	3.68±0.66
CHA x NZW.DBD	22	411.82±16.99^{bc}	6	1224.36±200.05^{b}	415.13±28.72	2.98±0.40
CHA x NZWCRL	13	398.02±8.83^{c}	4	1190.33±289.86^{b}	410.66±39.00	2.78±0.68
Parity 1	30	484.42±19.23^{b}	10	1343.36±182.09^{ab}	508.36±27.56	2.73±0.42^{b}
2	50	505.26±20.02^{b}	14	1697.48±195.57^{ab}	525.64±37.59	3.27±0.44^{ab}
3	46	504.32±20.76^{b}	14	1371.57±184.45^{ab}	513.89±38.26	2.67±0.32^{ab}
4	50	460.16±13.87^{b}	13	1557.24±156.22^{ab}	467.30±125.21	3.32±0.30^{ab}
5	32	501.24±13.87^{b}	8	2211.31±377.43^{a}	500.61±26.73	4.48±0.23^{a}
6	7	611.51±46.38^{a}	3	1051.66±81.28^{d}	603.21±80.93	2.83±0.88^{b}
Litter size 2	20	551.89±41.63^{ab}	20	988.47±91.74^{d}	586.47±42.02^{a}	-
3	19	562.69±40.87^{a}	19	1151.54±86.77^{c}	575.85±43.39^{a}	-
4	9	530.07±36.37^{ab}	9	1579.40±103.44^{b}	526.47±34.48^{ab}	-
5	5	437.25±18.09^{b}	5	1844.00±54.28^{b}	461.00±13.57^{abc}	-
6	6	489.71±33.69^{ab}	6	2511.00±167.40^{a}	502.20±34.48^{ab}	-
7	3	440.33±56.63^{b}	3	2634.67±333.70^{a}	439.12±55.96^{c}	-
Sex						
Male	92	503.12.36±12.36	30	1724.18±118.42	517.44±17.17	2.69±0.25
Female	123	519.03±10.72	32	1353.36±108.68	522.23±23.32	3.41±0.22
Season						
Dry	73	515.54±16.13^{a}	27	1652.23±163.78	525.36±30.41	3.19±0.29
Wet	142	506.76±8.79^{b}	35	1425.31±91.02	514.31±15.61	2.90±0.20
Overall mean	215	496.67±8.08	62	1581.93±81.28	513.47±14.58	3.18±0.17

Mean with different superscripts in the same column are significantly different (p<0.05,p<0.01 and p<0.001)

Table 4: Mean square (ms) for reproductive traits at 56 days of age

Variables	Individual kit wt (g)		Litter weight (g)		Average litter weight (g)		Litter size	
Source of variation	df	MS	df	MS	df	MS	Df	MS
Genotype	7	57563.77***	7	953699.33*	7	20893.13	7	2.13
Sex	1	157.42	1	1648817.86	1	1123.30	1	6.37
Parity	5	20152.18*	5	722222.49*	5	4087.52	5	3.18*
Litter size	5	27945.64*	5	1045846.00***	5	32370.94*	-	-
Season	1	72183.68**	1	525045.27	1	23802.50	1	0.14
Genotype x Parity	13	21712.17**	12	263950.97	12	12944.41	12	0.92
Genotype x Season	2	5807.99	2	1402543.42	2	20095.22	2	4.82
Genotype x Sex	7	4069.03	4	122557.53	4	10465.52	4	0.72
Parity x Season	3	58474.02**	3	1408252.11	3	12370.80	3	2.90
Sex x Parity	5	8237.03	4	376304.14	4	12325.51	4	1.47
Sex x Season	1	254.44	1	376304.14	1	5476.81	1	0.32
Genotype x Parity x Season	3	41770.50**	1	70083.33	1	2004.101	1	0.53
Genotype x Sex x Parity	9	7029.66	2	1278030.73	2	143.98	2	5.76
Genotype x Sex x Season	2	3872.72	-	-	-	-	-	-
Sex x Parity x Season	3	27839.18*	1	796331.57	1	796331.57	1	8.04*
Error	147	9034.14	17	245271.22	17	245271.22	36	1.69

*p<0.05, **p<0.01 and ***p<0.001

of 740.70±176.61 g and 2.33±0.88 for Lwt and Ltz respectively were observed for parity 6. Parity 5 kits had the lowest Ikt and Alt means of 302.33±11.52 g and 312.44±25.12 g.

There were differences in mean values of individual kit weight (Ikt), average litter weight (Alt) and litter weight (Lwt) by litter size. The Ikt and Alt means decreased as litter size increased. Whereas the Lwt increased as the litter size increased. The litter of 2 rabbits was heaviest in Ikt (451.21±27.93 g) and in Alt (462.25±25.46 g), while the litter of 7 rabbits was superior in Lwt (1967.67±203.39 g).

The traits by season were similar except for Lwt that was different (p<0.05). The dry season witnessed better performance in all traits than the wet season.

Reproductive traits at 56 days of age: The overall means for individual kit weight (Ikt), average litter weight (Alt), litter weight (Lwt) and litter size (Ltz) were 496.67±8.08 g, 513.47±14.58 g, 1581.93±81.28 g and 3.18±0.17 respectively (Table 3).

Genotype effect on individual kit weight (Ikt) was highly significant (p<0.001) as evidenced by analysis of variance (Table 4). Parity exerted significant influence ($p<0.05$) on individual kit weight (Ikt), litter weight (Lwt) and litter size (Ltz). Season and litter size had significant ($p<0.01$) effects on Ikt. The average litter weights (Alt) and litter weight (Lwt) were as well influenced by litter size. The interactions between genotype x parity, parity x season, genotype x parity x season and sex x parity x season significantly ($p<0.01$, $p<0.001$, $p<0.01$ and <0.05 respectively) influenced Ikt at 56 days of age. Also sex x parity x season significantly ($p<0.05$) influenced Ltz. The effects of genotype, sex, season and other interactions on Ikt, Lwt, Alt and Ltz were assumed not to be important sources of variation except for genotype effect ($p<0.05$) on Lwt.

Genotype means for individual kit weight (Ikt) and litter weight (Lwt) were statistically different ($p<0.001$) (Table 3). The New Zealand White-Dutch belted x New Zealand White-Dutch belted (NZWDBD x NZWDBD) was consistently superior in mean values for Ikt (624.20±33.56 g) Lwt (2051.33±280.65 g) and average litter weight (Alt: 635.45±63.39 g) over other genotypes. The Chinchilla x New Zealand White- Croel (CHA x NZWCRL) and New Zealand White x New Zealand White-Dutch belted (NZW x NZWDBD) recorded the lowest Ikt (398.02±8.83 g) and Lwt (1177.98±237.69 g) respectively. The genotypes were similar in average litter weight (Alt) and litter size (Ltz). The least Alt (410.66±39.00 g) and Ltz (2.34±0.52) were obtained for Chinchilla x New Zealand White- Croel (CHA x NZWCRL) and New Zealand White x New Zealand White-Dutch belted (NZW x NZWDBD) respectively.

The individual kit weight (Ikt), average litter weight (Alt), litter weight (Lwt) and litter size (Ltz) by sex did not differ statistically ($p>0.05$). The females were heavier in Ikt (519.03±10.73 g versus 503.27±12.36 g) and in Alt (522.23±23.32 g versus 517.44±17.17 g) than males. The males performed better than females in Lwt (1724.18±118.42 g versus 1353.36±108.68 g)

The parity means (Table 3) for individual kit weight (Ikt), litter weight (Lwt) and litter size (Ltz) differed significantly ($p<0.05$). Parity 6 had highest Ikt value (611.51±46.38) and smallest Ltz value (2.83±0.88). Parity 5 recorded the heaviest Lwt (2211.31±377.43) while the lowest value of the same trait was observed for parity 6 (1051.66±81.28 g). There was no mean difference for average litter weight (Alt) by parity at 56 days.

There were differences in mean values of individual kit weight (Ikt), average litter weight (Alt) and litter weight (Lwt) by litter size. The Ikt and Alt declined consistently with litter size from litter of 2 to 5, then increased in litter of 6 and dropped in litter of 7 rabbits. The Lwt increased with litter size. The highest mean values for Ikt (562.69±40.87 g) Alt (586.47±42.02 g) and Lwt (2634.67±335.70 g) were recorded in litter size of 3, 3 and 7, respectively (Table 3).

Seasonal means for Ikt were different ($p<0.01$) but similar for Lwt, Alt and Ltz ($p>0.05$). Kits born in the dry season were heavier in Ikt (515.54±16.13 g versus 506.76±8.79 g), Lwt (1652.23±163.78 g versus 1425.31±91.02 g) and Alt (525.36±30.41 g versus 514.31±15.61 g) than those born in the wet season. There were more Ltz in the dry season than in the wet season (3.19±0.29 versus 2.90±0.20).

DISCUSSION

The analytical results showed differences in performance characteristics of the genotypes. The differences in performance might be due to set of genes received from parents and environment provided for gene expression. This had been envisaged earlier[9] and also could be attributed to strong maternal effects of litter size and milk production more than genetic effects[2]. Crossbred does had been reported to produce more milk to cater for their kits than the purebred does[3,10].

This study considered individual kit weight (Ikt) although litter weight (Lwt) has been a trait for emphasis in rabbit production. However, the significant genotype ($p<0.01$) effect suggested Ikt as a trait of economic importance for consideration in rabbit breeding programme. This finding corroborated[11] who reported significant breed ($p<0.05$) influence on Ikt at birth. New Zealand White-Dutch belted x New Zealand White-Dutch belted (NZW.DBD x NZW.DBD) were superior in Ikt over other genotypes in this study. It has been shown early that crossbreeding improved litter trait at weaning as well as post-weaning growth rates of rabbits[1].

Genotype effect ($p<0.05$) on litter weight (Lwt) was obvious. Similarly, breed differences for Lwt[2,10,12-14] had been reported. The range and mean values for Lwt in this study were in line with the figures reported in the tropics[10,15-18], though typically lower than reports in the temperate regions[2,12]. The NZWDBD x NZWDBD was consistently superior over other genotypes in Lwt.

The non significant genotype influence on average litter weight (Alt) was observed. The Alt reported by Iyeghe-Erakpotobor *et al.*[10] compared fabourably with Alt mean and range values obtained in the present study. The similarities in Alt values by genotype at 35 and 56 days had been observed elsewhere[19].

The litter size (Ltz) among the genotypes was similar at both ages. The similarity in Ltz at weaning among rabbit breed-types had been confirmed in reports by different workers[20-22]. The Ltz obtained in the study was within the range values for the tropics[13]. New Zealand White-Dutch belted x New Zealand White-Dutch belted (NZWDBD x NZWDBD) had larger Ltz than other genotypes. Breed, strain and breeding techniques influence Ltz as well as environmental effect such as nutrition of the doe[23]. Generally, litter size in rabbit varied between breeds and strain and within breeds[24]. Also differences in litter size due to doe effect might be attributed to differences in ovulation rate and pre-implantation viability[25].

Besides, litter size (Ltz) as a source of variation was significantly ($p<0.01$) important for individual kit weight (Ikt), litter weight (Lwt) and average litter weight (Alt). There was a consistent increase in Ikt and Alt with litter size at 35 days where litter size of two rabbits recorded better performance, corroborating observation made in goat by Akpan[26] that kids born twins were heavier than triplets but their growth rate was slower. The Ltz of 7 rabbits maintained a consistent significant ($p<0.05$) heavier Lwt than other Ltz at both ages. The result of this study compared favourably with reports in available literature[3,16]. The litter size depends on the number of egg produced after mating and this number depends on the body size of the breed[3]. The significant influence by litter size in the present study would suggest that the maternal environment exerted significant influence on the traits studied. It might be further ascribed to the doe's mothering ability and available food for litter size.

The reproductive traits assumed undulating trend with parity. In contrast to the present findings, Ozimba and Lukefahr[2] reported that parity effect was never a significant source of variation. But, Rollins *et al.*[27] found parity to influence litter size and litter weight at 56 days. Rouvier *et al.*[5] reported parity effects for litter size, survival rate and total litter weight and average fryer weight at 56 days. In addition, Lukefahr *et al.*[28] reported parity influences on litter feed in take, feed efficiency and litter weight at 56 days. Residual maternal effects of parity might have influenced the performances observed in this study.

The effect of season on litter size (Ltz) at weaning had been reported[2,10]. Yahaya[29] and Abdul-malik *et al.*[30] reported no significant influence of season on litter size at weaning. These authors also reported significant influence of season on Lwt at weaning. The dry periods kits had higher mean values for Ikt and Alt at 35 and 56 days. This was contrary to reports by Casady *et al.*[31], Sitlman *et al.*[32] and McNitt and Likefahk[33]. Also, kits in the dry periods survived and performed better than those of wet seasons corroborating Iyeghe-Erakpotobor *et al.*[10] and Iyeghe[34]. In the present results, weaning and post-weaning performance favoured dry season rabbits. This could be due to low incidence of diarrhea, which was associated with consumption of succulent green vegetation of wet period.

Sex effect was similar except for Lwt at 35 days where males significantly ($p<0.05$) weighed more than the females. Apart from this, females generally performed better than the males and this agreed with the findings of Lebus *et al.*[3].

This study considered NZW x NZW, CHA x CHA, NZW x CHA, NZWDBD x NZWDBD, NZW x NZWDBD, NZWCRL x NZWCRL, CHA x NZWDBD and CHA x NZWCRL kits for weaning and post-weaning performance characteristics namely individual kit weight (Ikt), litter weight (Lwt), average litter weight (Alt) and litter size (Ltz). Overall, NZWDBD x NZWDBD was superior, particularly for 35 - day Ikt, Alt and Ltz; 56 - day Ikt, Alt, Lwt and Ltz. Such superiority is likely to enhance faster genetic gain enabling faster rate of improvement in total herd productivity. The NZW, well recognized as a suitable breed for meat production, occupied last position in some of the traits considered in the study. The genotype differences in performance observed indicate that a breeding programme for selection and improvement is imperative for the establishment of breeds suitable for intensive commercial rabbit production in the tropics. The differences could be associated with the introduction of heterotic advantage resulting from breed combination systems. However, not all crossbred kits were superior in production traits over the purebred kits. This was in agreement with the findings of Oseni *et al.*[35]. Crossbreeding combined differences in genetic merit for specific characters to synchronize effective performance characteristics and adaptability resources that were most economical[36]. The choice of breeds for commercial production should however be based on weaning and post-weaning kit performance. In addition, the genotype, sex, litter size, parity and season as important sources of variation should be considered in improvement programme to increase meat yield from these rabbit breeds and crosses. Results of this study provide corroborative evidence in support of the adoption of crossbreeding in the commercial rabbit industry in Nigeria.

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