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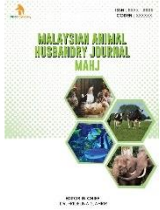

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RESEARCH ARTICLE

GENOTYPE × FEEDING REGIME INTERACTION: INFLUENCE ON BODY MEASUREMENTS AND GROWTH RATES OF WEANED RABBITS

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ABSTRACT

An experiment was conducted to determine the interaction effect of four genotypes: purebred New Zealand White (NZW×NZW) and Chinchilla (CH×CH) and their reciprocal crossbreds (NZW×CH, CH×NZW) and four quantitative feeding regimes: *ad libitum* concentrate + *ad libitum* forage (A), *ad libitum* concentrate + 30% restricted forage (B), 30% restricted concentrate + *ad libitum* forage (C) and 30% restricted concentrate + 30% restricted forage (D) on post-weaning body measurements and growth rates of 70 F_1 rabbits. Body weight (BW), body length (BL), head-to-shoulder length (HTSL), ear length (EL) and shoulder-to-tail tip (STTT) were measured weekly from 7 to 11 weeks. The body measurements were evaluated by analysis of variance. Absolute growth and instantaneous relative growth rates were determined from linear regression equations and Brody's model, respectively. Body measurements differed significantly ($p < 0.05$) among the interactions at different weeks. Higher final mean BW (1333.33 ± 60.09 g), BL (39.67 ± 0.33 cm), HTSL (11.77 ± 0.29 cm), EL (11.60 ± 0.06 cm) and STTT (37. 00 ± 0.09 cm) were recorded from the interactions of CH×CH with D, CH×NZW with B, CH×CH with D, CH×NZW with D and NZW×NZW with B, respectively. Absolute and instantaneous relative growth rates were significantly higher for BW (182.00 g/wk, 0.09), HTSL (0.63 g/wk, 0.01), EL (0.70 g/wk, 0.03) from the interaction of CH×CH with D and for BL (3.38 g/wk, 0.05) and STTT (3.43 g/wk, 0.06) from the interactions of CH×NZW with B and NZW×NZW with C, respectively. Feeding of CH×CH with D best improved growth in this study and should be recommended for profitable rabbit production.

KEYWORDS

Rabbits, breeding, feed restriction, quantitative traits, growth models

1. INTRODUCTION

Rabbits (*Oritilagus cuniculus*) are micro livestock that serve as a good and affordable source of animal protein. Small body size, small space requirement, noiseless nature, high fecundity and prolificacy, less cholesterol content in meat and ability to thrive on a number of forages with concentrates make rabbits preferable to many livestock species both in research and commercial production (Mailafia et al., 2012). Despite these attributes, lack of good breed and high cost of commercial feed have been a major constraint to rabbit production (Cherwon et al., 2020). Feed accounts for 60-70% of the total cost of livestock production, and constitutes a major determinant of profitability in livestock enterprise (Yesef et al., 2020). Rabbits depend both on concentrates and forages for healthy growth and reproduction. These feed materials are mainly obtained from the rural and semi-urban areas. It is however, observed that forages are fast disappearing due to increase in non-agricultural land use while the cost of commercial concentrates are exorbitantly high, especially in this post-covid 19 era (Van Zanten et al., 2005; Elleby et al., 2020). The phenomenal rise in feed cost has necessitated a search for alternative feeding practice such as quantitative feed restriction that is capable of minimizing cost and maximizing productivity and profit in livestock enterprise.

Quantitative feed restriction has been practised in poultry, pig and rabbits to achieve different purposes (Oliveira et al., 2012; Nwachukwu et al., 1990; Njoku et al., 2018). Yakubu et al. (2007) reported that restricted fed rabbits did better in body weight and linear body measurements than non-restricted fed group. Isaac et al. (2022) reported that a combination of *ad libitum* forage and restricted concentrate fed to purebred Chinchilla rabbits and a combination of restricted concentrate and *ad libitum* forage fed to purebred New Zealand White rabbits significantly reduced their feed intake without depressing growth. Body weight and linear body measurements are important quantitative traits used in estimation of body size and conformation in animals (Ibe and Ezekwe, 1994). They serve as indices for selection and improvement of meat animals, and hence determine the overall economic value of the animals (Agamy et al., 2015). These quantitative traits are, however, greatly influenced by genotype and environment, which should be properly improved to improve the growth of animals.

Growth is an increase in size and dimension resulting from complex interaction of both genetic and non-genetic factors in the animal. Growth models are useful in estimation of growth rates of animals. Narine et al. (2010) used Brody's model and other non-linear models to describe growth in Japanese quails. Brody's two parameter function is a non-linear growth model for determination of instantaneous relative growth rate, defined as the rate of growth at time, t within the animal's growing phase (Brody, 1994; Nwaogwugwu and Udoh, 2019). Many authors have studied growth in animals on the basis of genotype differences alone (Ibe, 1993; Eleroglu et al, 2014; Nwaogwugwu and Udoh, 2019). Since good environment is essential in realising the full genetic potential of animals, the study of genotype × feeding regime interaction effect on the growth performance of rabbits is quite germane (Rauw et al., 2015). The objectives of this study were to evaluate the body measurements and determine growth rates of four rabbit genotypes fed four different feeding regimes.

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2. Materials and Methods

2.1 Experimental Location

The experiment was conducted at the Rabbitry Unit of the Teaching and Research Farm, Abia State University, Umuahia Campus. The campus is located at Latitude 05° 29′ N, Longitude 07° 33′ E and altitude of 122 m. The area lies within the tropical rainforest zone of Nigeria, is characterized by an annual rainfall approximating to 2,177 mm, an ambient temperature ranging from 27 to 36° C and from 20 to 26° C during hot, dry seasons and cold, rainy seasons respectively. It has a relative humidity of 57–97%.

2.2 Experimental Animals and Their Management

Twelve healthy parent rabbits, six from each of Chinchilla (CH) and New Zealand White (NZW) breed, were mated in the ratio of 1 buck to 2 does per breed to produce a total of 70 day-old kits belonging to four genotypes. The genotypes and their numbers produced were 20 purebred New Zealand White (NZW×NZW), 16 purebred Chinchilla (CH×CH), 17 crossbred New Zealand White by Chinchilla (NZW×CH) and 17 crossbred Chinchilla by New Zealand White (CH×NZW) rabbits. The rabbits were weaned at 6 weeks old. The surviving rabbits from each genotype were randomly assigned to the following four feeding regimes: *ad libitum* concentrate + *ad libitum forage* (A), *ad libitum* concentrate + 30% restricted forage (B), 30% restricted concentrate + *ad libitum forage* (C) and 30% restricted concentrate + 30% restricted forage (D). Determination of the percentage concentrate and forage fed the restricted groups was based on total intake of full fed animals the previous day. The experiment lasted for five weeks from 7 to 11 weeks post-weaning. The rabbits were handled in accordance with animal ethics.

2.3 Experimental Design

A 4 × 4 factorial experiment was conducted in a completely randomised design. There were two factors: genotype and feeding regime, each having four levels, i.e. NZW×NZW, CH×CH, NZW×CH, CH×NZW genotypes and A, B, C and D feeding regimes. The design is summarized in equation (1)

$$Y_{ijk} = \mu + F_i + G_j + (F \times G)_{ij} + \Sigma_{ijk} \quad (1)$$

where Y_{ijk} is the observation made on the k-th progeny of the j-th genotype in the i-th feeding regime, F_i is the feeding regime effect (i = 1, 2, 3 and 4), G_j is the genotype effect (j = 1, 2, 3 and 4), $(F \times G)_{ij}$ is the interaction effect between the feeding regime and the genotype, and Σ_{ijk} is the random error.

2.4 Data Collection and Measurements of Traits

Data were collected weekly on individual body weight (BWT), measured in grams (g); body length (BL), taken as the distance from the middle of the head to the base of the tail; head-to-shoulder length (HTSL), taken as the distance from the tip of the head to the shoulder; ear length (EL), taken as the distance from the base to the tip of the ear and shoulder-to-tail tip (STTT), taken as the distance from the shoulder to the tail tip. All linear measurements were taken in centimeters (cm) using a tape.

2.5 Analytical Procedure

A two-way analysis of variance was carried out to determine whether or not significant differences existed among the genotype × feeding regime interactions on the body measurements at 5% significance level. The analysis was done at biweekly (7, 9 and 11 weeks) intervals. A simple linear regression of body measurements on age was performed in each genotype × feeding regime sub-class to determine the absolute growth rate in g/week. The regression model used is specified in equation (2).

$$Y_i = a + b\,(Age)_i + e_i, \quad (2)$$

where Y_i is any of the body measurements from i-th genotype × feeding regime interaction, a is initial growth constant, b is regression coefficient, which is the required growth rate (g/week), ie. increase in any of the body measurements per week and e_i is random error. Log-linear regression of log transformed body measurements on time (age) was performed to obtain equation (3).

$$LnY = LnA + kt \quad (3)$$

where Ln is the natural or Naperian logarithm. Antilog of the constant, A in (3) was numerically obtained to base e. Instantaneous relative growth rate was then determined using Brody's two parameter function (Brody, 1949) expressed in equation (4).

$$Y_t = Ae^{kt} \quad (4)$$

where Y_t is body measurement at time t and A is a constant. The coefficient, k is the required instantaneous relative growth rate, which was a measure of increase in any of the body measurements at time, t. Regression analysis was performed using pooled data for the 7- 11weeks period of growth. All analyses were carried out with IBM SPSS Statistics (2015) computer programme.

3. Results

Table 1 indicates significant differences ($p < 0.05$) in BW, BL, EL and STTT among the genotype × feeding regime interactions. The highest mean BW and BL were obtained from the interaction of CH×NZW with D while those of EL and STTT were from the interactions of CH×CH with A and NZW×CH with A and B feeding regimes. The mean HTSL did not differ significantly ($p > 0.05$) among the interactions. The mean BW from the interaction of NZW×CH with B (966.67 ± 8.33 g) was slightly smaller but did not differ significantly from that of CH×NZW with D feeding regime (1025.00±19.87 g). In Table 2, significant differences were observed only in BL and STTT at 9 weeks post-weaning with highest mean values obtained from the interaction of CH×NZW with D. Mean BW, HTSL and EL did not differ significantly ($p > 0.05$) among the interactions. However, the means of these traits obtained from the interaction between CH×CH and C were numerically higher than the others. In Table 3, significant differences ($p < 0.05$) were observed among the interactions in all the traits. Highest mean BW and HTSL were obtained from the interaction of CH×CH with D while those of EL and STTT were from the interactions of CH×NZW with D and NZW×NZW with B, respectively. However, the mean BW from the interaction of CH×CH with D (1333.33 ± 60.09 g) did not differ significantly from that of the interaction between NZW×NZW and C (1300.00 ± 28.87 g). Body weight means from the restricted groups were higher than those of *ad libitum* fed groups. The BL and STTT showed significant growth throughout the period of growth (Tables 1-3).

Table 4 gives the absolute growth and instantaneous growth equations for body weight in different genotype × feeding regime interactions. The absolute growth rates, measured by regression coefficients (b's) were positive, highly significant ($p < 0.05$) with higher coefficients of determination (R^2). The exception was the interaction between NZW×NZW and B feeding regime which had smaller R^2 and was not significant ($p > 0.05$). The highest absolute growth rate of 182 g/week was obtained from the interaction between CH×CH and D. This was followed by the next three higher rates (165, 164, 151 g/week) from the interactions between NZW×NZW and each of C and D and NZW×CH and C. The instantaneous relative growth rates with their percentages varied into seven groups of 0.09 (10.71%), 0.08 (9.52%), 0.07 (8.33%), 0.06 (7.14%), 0.04 (4.76%), 0.02 (2.38%) and 0.01 (1.19%) for the various genotype × feeding regime interactions. The highest percentage growth rate (10.71%) was obtained from the interaction between CH× CH and D while the lowest rate (1.19 %) was obtained from the interactions between NZW×CH and B and CH×NZW and D.

In Table 5, the absolute growth rates were all positive and highly significant ($p < 0.05$). They had high R^2 values and small standard errors except for the interaction between CH×NZW and C. The instantaneous relative growth rates for the various interactions were grouped into 0.02, 0.03 and 0.05 corresponding to 4.65%, 6.98% and 11.63%. The interaction between CH×NZW and B had both the highest absolute growth and instantaneous relative growth rates. In Table 6, the initial growth constants for head-to-shoulder length both for absolute and instantaneous relative growth equations did not vary. Absolute growth rates were positive and significant ($p < 0.05$) except for the interaction between CH×NZW and B. The R^2 values for most of the interactions in both equations were high. The interaction between CH×CH and D feeding regime also had the greatest absolute growth rate while the instantaneous relative growth rates were similar for all the groups.

Table 7 presents similar results for ear length of the rabbits for the 5 weeks growing period. The absolute growth rates were all positive and highly significant ($p < 0.05$) as in other traits. The R^2 values in both absolute and instantaneous relative growth equations were all high. Standard errors were small in all the groups. The instantaneous relative growth rates ranged from 0.02 (40%) to 0.03 (60 %) among the interactions. This meant that the ear grew at the rate of 40% in rabbits whose instantaneous relative growth rate was 0.02 and 60% in rabbits having 0.03 rate. Table 8 presents similar results for shoulder-to-tail length. The absolute growth rates were positive, significant ($p < 0.95$) and the R^2 values were high except for the interactions between CH×NZW and B, C and D feeding regimes.

Table 1: Genotype × Feeding Regime Interaction Effect on Body Measurements of Rabbits at 7 Weeks of Age.

Trait	**NZW x NZW**				**NZW x CH**				**CH x CH**				**CH x NZW**				P-value
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	
BW (g)	700.00 ± 14.43	825.00 ±18.34	716.67 ±8.66	575.00 ±14.43	800.00 ±22.05	966.67 ±8.33	758.33 ±14.43	725.00 ±50.69	741.67 ±80.36	650.00 ±8.33	791.67 ±14.43	575.00 ±109.29	716.67 ±22.05	566.67 ±36.32	666.67 ±14.43	1025.00 ±19.87	0.00
BL (cm)	28.67 ±1.33	29.67 ±0.33	30.50 ±0.29	28.17 ±0.44	30.67 ±0.33	30.33 ±0.33	28.00 ±0.58	29.67 ±0.33	31.00 ±0.58	29.83 ±0.60	31.00 ±0.58	29.47 ±0.29	29.33 ±1.67	26.67 ±9.33	31.00 ±0.58	32.67 ±0.33	0.00
HTSL (cm)	10.33 ±0.33	10.17 ±0.17	10.33 ±0.33	10.37 ±±0.19	10.30 ±0.15	10.30 ±0.06	10.20 ±0.12	10.20 ±0.12	10.33 ±0.33	10.17 ±0.09	10.40 ±0.61	10.50 ±0.29	10.33 ±0.33	11.00 ±0.58	10.50 ±0.29	10.67 ±0.33	0.95
EL (cm)	8.67 ±0.33	9.50 ±0.29	9.33 ±0.17	9.23 ±0.12	8.63 ±0.09	9.33 ±0.18	8.93 ±0.41	8.30 ±0.25	9.50 ±0.50	9.03 ±0.32	9.10 ±0.15	8.43 ±0.12	9.00 ±0.29	8.50 ±0.06	9.33 ±0.24	9.23 ±0.12	0.02
STTT (cm)	25.00 ±0.58	26.00 ±0.58	23.33 ±0.33	23.33 ±0.33	26.33 ±0.33	26.33 ±0.33	23.67 ±0.33	23.37 ±0.19	23.67 ±0.88	23.67 ±0.88	25.00 0.58	23.67 ±0.33	21.00 0.58	21.00 ±0.58	24.27 ±0.37	24.13 ±0.13	0.00

A = *ad libitum* concentrate + *ad libitum* forage, B = *ad libitum* concentrate + 30% restricted forage, C = 30% restricted concentrate + *ad libitum* forage, D = 30% restricted concentrate + 30% restricted forage, BW = Body weight, BL = Body length, HTSL = Head-to-shoulder length, EL = Ear length, STTT = Shoulder-to-tail tip

Table 2: Genotype × Feeding Regime Interaction Effect on Body Measurements of Rabbits at 9 Weeks of Age

Trait	**NZW x NZW**				**NZW x CH**				**CH x CH**				**CH x NZW**				P-value
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	
BW (g)	933.33 ±93.91	1066.67 ±133.33	1033.33 ±116.67	1075.00 ±52.04	1008.33 ±50.69	1033.33 ±8.33	975.00 ±66.67	1091.67 ±101.04	1066.67 ±22.05	1116.67 ±44.10	1075.00 ±72.65	925.00 ±52.04	925.00 ±25.00	850.00 ±14.43	966.67 ±88.19	1033.33 ±8.33	0.83
BL (cm)	31.67 ±2.08	31.67 ±1.53	31.67 ±1.53	31.33 ±0.58	32.67 ±0.58	33.33 ±0.58	31.33 ±0.58	33.33 ±1.53	33.33 ±0.58	32.93 ±0.12	32.83 ±0.76	32.67 ±2.08	33.10 ±0.17	37.67 ±0.58	36.33 ±2.52	31.67 ±0.58	0.00
HTSL (cm)	10.23 ±0.03	10.23 ±0.03	10.33 ±0.09	10.23 ±0.03	10.40 ±0.12	10.37 ±0.19	10.17 ±0.03	10.30 ±0.06	10.10 ±0.06	10.33 ±0.09	10.50 ±0.17	10.27 ±0.07	10.13 ±0.07	10.37 ±0.09	10.27 ±0.07	10.33 ±0.33	0.51
EL (cm)	9.80 ±0.25	9.70 ±0.15	9.67 ±0.18	10.07 ±0.07	9.73 ±0.18	9.83 ±0.17	9.90 ±0.21	9.83 ±0.27	10.07 ±0.07	9.77 ±0.15	10.33 ±0.33	9.80 ±0.31	10.03 ±0.03	10.23 ±0.12	10.17 ±0.17	10.07 ±0.07	0.50
STTT (cm)	28.83 ±0.44	29.33 ±0.88	28.00 ±2.08	29.00 ±0.58	28.00 ±1.15	29.67 ±1.33	27.33 ±0.88	28.00 ±1.53	30.00 ±0.58	27.00 ±1.15	28.33 ±1.20	28.67 ±1.86	30.00 ±0.58	37.00 ±0.58	24.00 ±1.53	30.33 ±1.33	0.00

A = *ad libitum* concentrate + *ad libitum* forage, B = *ad libitum* concentrate + 30% restricted forage, C = 30% restricted concentrate + *ad libitum* forage, D = 30% restricted concentrate + 30% restricted forage, BW = Body weight, BL = Body length, HTSL = Head-to-shoulder length, EL = Ear length, STTT = Shoulder-to-tail tip

Table 3: Genotype × Feeding Regime Interaction Effect on Body Measurements of Rabbits at 11 Weeks of Age

Trait	NZW x NZW				NZW x CH				CH x CH				CH x NZW				P-value
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	
BW (g)	1141.67 ±22.05	1283.33 ±44.10	1300.00 ±28.87	1191.67 ±74.07	1200.00 ±28.87	1050.00 ±38.19	1266.67 ±22.05	1166.67 ±22.05	116.67 ±71.20	1225.00 ±52.04	1225.00 ±38.19	1333.33 ±60.09	1088.33 ±44.10	1050.00 ±28.87	1100.00 ±57.74	1141.67 ±30.05	0.020
BL (cm)	37.5 ±0.29	38.67 ±0.33	36.67 ±0.33	35.67 ±0.88	37.67 ±0.33	36.33 ±0.67	36.67 ±0.33	33.87 ±0.13	37.60 ±0.31	38.00 ±0.58	38.67 ±0.33	38.53 ±0.29	35.6 ±0.67	39.67 ±0.33	36.00 ±1.00	37.67 ±0.33	0.000
HTSL (cm)	11.43 ±0.33	11.40 ±0.33	11.20 ±0.33	11.20 ±0.58	11.37 ±0.58	11.10 ±0.58	11.03 ±0.33	11.20 ±0.58	11.27 ±0.58	11.17 ±0.58	11.30 ±0.58	11.77 ±0.29	11.20 ±0.33	11.53 ±0.29	11.53 ±0.58	11.60 ±0.58	0.003
EL (cm)	10.73 ±0.15	10.87 ±0.12	11.10 ±0.12	10.83 ±0.12	11.43 ±0.09	11.00 ±0.21	10.73 ±0.06	10.67 ±0.12	11.17 ±0.07	11.10 ±0.09	10.60 ±0.09	10.20 ±0.13	10.90 ±0.20	11.17 ±0.09	11.13 ±0.03	11.60 ±0.06	0.000
STTT (cm)	32.00 ±0.09	37.00 ±0.09	36.67 ±0.06	32.67 ±0.17	32.67 ±0.22	34.67 ±0.23	36.60 ±0.09	31.00 ±0.12	34.67 ±0.09	33.47 ±0.06	34.00 ±0.06	33.77 ±0.12	33.67 ±0.21	33.67 ±0.09	35.33 ±0.13	32.67 ±0.06	0.000

A = *ad libitum* concentrate + *ad libitum* forage, B = *ad libitum* concentrate + 30% restricted forage, C = 30% restricted concentrate + *ad libitum* forage, D = 30% restricted concentrate + 30% restricted forage, BW = Body weight, BL = Body length, HTSL = Head-to-shoulder length, EL = Ear length, STTT = Shoulder-to-tail tip

Table 4: Absolute Growth and Instantaneous Relative Growth Equations for Body Weight of Rabbits Influenced by Genotype × Feeding Regime Interaction for 7-11 Weeks Period

[1]Group	Absolute	R^2 (%)	SE	P value	Instantaneous	R^2 (%)
G_1xA	BW =159.27+122.50A	80.70	91.10	0.000	BW=11.50e$^{0.06t}$	80.50
G_1xB	BW = 166.33+89.33A	17.80	292.00	0.118	BW=15.80e$^{0.02t}$	1.20
G_1xC	BW = -432.50+164.17A	80.80	116.28	0.000	BW=10.60e$^{0.07t}$	83.00
G_1xD	BW = -566.67+165.00A	82.90	113.86	0.000	BW = 9.01e$^{0.08t}$	83.20
G_2xA	BW = 102.67+101.67A	86.50	58.51	0.000	BW=13.52e$^{0.04t}$	86.90
G_2xB	BW = 790.33+24.67A	51.60	36.32	0.003	BW=18.36e$^{0.01t}$	51.70
G_2xC	BW = -333.33+151.67A	84.00	100.67	0.000	BW=11.16e$^{0.06t}$	85.30
G_2xD	BW = -171.67+125.00A	80.70	88.72	0.000	BW=11.53$^{e0.06t}$	83.50
G_3xA	BW = 170.00+93.33A	67.50	98.42	0.000	BW=13.59e$^{0.04t}$	65.70
G_3xB	BW = -379.33+151.00A	70.00	150.33	0.000	BW = 9.94e$^{0.08t}$	59.70
G_3xC	BW = 135.83+102.50A	79.60	78.10	0.000	BW=13.74e$^{0.04t}$	79.00
G_3xD	BW = -588.67+182.00A	86.50	109.32	0.000	BW = 9.40e$^{0.09t}$	79.70
G_4xA	BW = 143.17+86.33A	67.40	91.70	0.000	BW=12.94e$^{0.04t}$	58.00
G_4xB	BW = -220.00+116.67A	95.50	38.65	0.000	BW=10.31e$^{0.06t}$	92.40
G_4xC	BW = 391.17+148.33A	67.00	158.24	0.000	BW=10.14e$^{0.07t}$	71.30
G_4xD	BW = 755.00+35.00A	59.80	43.63	0.002	BW=18.23e$^{0.01t}$	60.80

G_1 = NZW×NZW, G_2 = NZW×CH, G_3 = CH×CH, G_4 = CH×NZW,
[1]see foot note of Table 1 for definitions of A, B, C and D
BW = Body weight, R^2 = Coefficient of determination, SE = Standard error, P = Probability

Table 5: Absolute Growth and Instantaneous Relative Growth Equations for Body Length of Rabbits Influenced by Genotype × Feeding Regime Interaction for 7-11 Weeks Period

[1]Group	Absolute	R^2	SE	P value	Instantaneous	R^2 (%)
G_1xA	BL = 12.33+2.30A	80.90	1.79	0.000	BL = 3.46e$^{0.03t}$	78.10
G_1xB	BL = 14.57+2.17A	79.60	1.67	0.000	BL = 3.60e$^{0.03t}$	78.80
G_1xC	BL = 15.87+1.82A	74.90	1.61	0.000	BL = 3.63e$^{0.02t}$	73.20
G_1xD	BL = 13.133+2.03A	85.30	1.28	0.000	BL = 3.46e$^{0.03t}$	86.30
G_2xA	BL = 18.37+1.70A	91.50	0.79	0.000	BL = 3.78e$^{0.02t}$	92.20
G_2xB	BL = 18.83+1.63A	89.20	0.86	0.000	BL = 3.78e$^{0.02t}$	89.70
G_2xC	BL = 12.93+2.13A	95.00	0.74	0.000	BL = 3.49e$^{0.03t}$	95.00
G_2xD	BL = 22.01+1.12A	74.50	0.99	0.000	BL = 3.94e$^{0.02t}$	75.20
G_3xA	BL = 18.24+1.72A	81.20	1.26	0.000	BL = 3.78e$^{0.02t}$	80.30
G_3xB	BL = 13.25+2.23A	90.50	1.10	0.000	BL = 3.53e$^{0.03t}$	90.40
G_3xC	BL = 15.07+2.09A	87.80	1.19	0.000	BL = 3.63e$^{0.03t}$	87.80
G_3xD	BL =12.95+2.28A	90.60	1.11	0.000	BL = 3.53e$^{0.03t}$	91.00
G_4xA	BL = 18.02+1.60A	64.00	1.82	0.000	BL = 3.71e$^{0.02t}$	62.10
G_4xB	BL = 3.24+3.38A	82.70	2.35	0.000	BL = 3.06e$^{0.05t}$	82.80
G_4xC	BL = 16.40+1.83A	42.90	3.20	0.008	BL = 3.63e$^{0.03t}$	41.80
G_4xD	BL =21.79+1.41A	63.40	1.62	0.000	BL = 3.97e$^{0.02t}$	62.10

G_1 = NZW×NZW, G_2 = NZW×CH, G_3 = CH×CH, G_4 = CH×NZW,
[1]see foot note of Table 1 for definitions of A, B, C and D
BL = Body length, R^2 = Coefficient of determination, SE = Standard error, P = Probability

Table 6: Absolute Growth and Instantaneous Relative Growth Equations for Head-To-Shoulder Length of Rabbits Influenced by Genotype × Feeding Regime Interaction for 7-11 Weeks Period

[1]Group	Absolute	R^2 (%)	SE	P value	Instantaneous	R^2 (%)
G_1xA	HTSL = 8.06+0.29A	56.60	0.38	0.001	HTSL = 2.51e$^{0.01t}$	56.70
G_1xB	HTSL = 8.55+0.23A	35.90	0.49	0.018	HTSL = 2.57e$^{0.01t}$	35.70
G_1xC	HTSL = 8.18+0.27A	57.50	0.36	0.001	HTSL = 2.52e$^{0.01t}$	57.60
G_1xD	HTSL = 8.30+0.20A	62.00	0.31	0.000	HTSL = 2.54e$^{0.01t}$	66.60
G_2xA	HTSL = 8.46+0.25A	66.50	0.27	0.000	HTSL = 2.56e$^{0.01t}$	66.20
G_2xB	HTSL = 8.48+0.24A	63.70	0.27	0.000	HTSL = 2.56e$^{0.01t}$	63.60
G_2xC	HTSL = 7.80+0.31A	74.10	0.27	0.000	HTSL = 2.49e$^{0.01t}$	73.90
G_2xD	HTSL = 8.14+0.27A	63.70	0.31	0.000	HTSL = 2.52e$^{0.01t}$	64.50
G_3xA	HTSL = 8.34+0.25A	54.30	0.37	0.003	HTSL = 2.54e$^{0.01t}$	50.90
G_3xB	HTSL = 7.84+0.30A	78.60	0.24	0.000	HTSL = 2.49e$^{0.01t}$	78.50
G_3xC	HTSL = 8.49+0.24A	36.10	0.49	0.028	HTSL = 2.55e$^{0.01t}$	37.40
G_3xD	HTSL = 7.48+0.36A	58.80	0.46	0.001	HTSL = 2.46e$^{0.01t}$	58.39
G_4xA	HTSL = 8.00+0.29A	46.60	0.47	0.005	HTSL = 2.51e$^{0.01t}$	47.10
G_4xB	HTSL = 9.02+0.20A	20.10	0.61	0.094	HTSL = 2.61e$^{0.01t}$	21.10
G_4xC	HTSL = 8.03+0.30A	57.10	0.40	0.001	HTSL = 2.51e$^{0.01t}$	56.60
G_4xD	HTSL = 8.05+0.32A	45.40	0.53	0.006	HTSL = 2.52e$^{0.01t}$	44.20

G_1 = NZW×NZW, G_2 = NZW×CH, G_3 = CH×CH, G_4 = CH×NZW
[1]see foot note of Table 1 for definitions of A, B, C and D
HTSL = Head-to-shoulder length, R^2 = Coefficient of determination, SE = Standard error, P = Probability

Table 7: Absolute Growth and Instantaneous Relative Growth Equations for Ear Length of Rabbits Influenced by Genotype × Feeding Regime Interaction for 7-11 Weeks Period

[1]Group	Absolute	R^2 (%)	SE	P value	Instantaneous	R^2 (%)
G_1xA	EL = 4.89+0.54A	87.30	0.31	0.000	EL = $2.16e^{0.02t}$	84.40
G_1xB	EL = 6.63+0.37A	74.40	0.33	0.000	EL = $2.35e^{0.02t}$	74.00
G_1xC	EL = 5.54+0.49A	83.90	0.33	0.000	EL = $2.24e^{0.02t}$	83.60.
G_1xD	EL = 6.06+0.43A	90.00	0.22	0.000	EL = $2.29e^{0.02t}$	89.90
G_2xA	EL = 3.72+0.68A	94.30	0.25	0.000	EL = $2.06e^{0.03t}$	95.60
G_2xB	EL = 6.03+0.44A	82.50	0.31	0.000	EL = $2.29e^{0.02t}$	83.00
G_2xC	EL = 5.55+0.48A	82.80	0.33	0.000	EL = $2.23e^{0.02t}$	80.90
G_2xD	EL = 4.33+0.60A	88.10	0.33	0.000	EL = $2.10e^{0.03t}$	86.90
G_3xA	EL = 6.15+0.44A	71.80	0.42	0.000	EL = $2.30e^{0.02t}$	71.50
G_3xB	EL = 4.94+0.55A	87.90	0.31	0.000	EL = $2.17e^{0.02t}$	87.30
G_3xC	EL = 6.07+0.44A	75.90	0.37	0.000	EL = $2.28e^{0.02t}$	76.60
G_3xD	EL = 3.50+0.70A	95.00	0.24	0.000	EL = $2.03e^{0.03t}$	94.70
G_4xA	EL = 4.8+0.56A	82.10	0.40	0.000	EL = $2.16e^{0.03t}$	81.00
G_4xB	EL = 3.94+0.66A	95.60	0.22	0.000	EL = $2.07e^{0.03t}$	94.90
G_4xC	EL = 5.50+0.51A	83.80	0.34	0.009	EL = $2.24e^{0.02t}$	83.19
G_4xD	EL = 4.13+0.68A	90.10	0.34	0.000	EL = $2.12e^{0.03t}$	90.00

G_1 = NZW×NZW, G_2 = NZW×CH, G_3 = CH×CH, G_4 = CH×NZW
[1]see foot note of Table 1 for definitions of A, B, C and D
EL = Ear length, R^2 = Coefficient of determination, SE = Standard error, P = Probability

Table 8: Absolute Growth and Instantaneous Relative Growth Equations for Shoulder-To-Tail Tip of Rabbits Influenced by Genotype × Feeding Regime Interaction for 7-11 Weeks Period

[1]Group	Absolute	R^2 (%)	SE	P value	Instantaneous	R^2 (%)
G_1xA	STTT =11.48+1.86A	88.90	0.89	0.000	STTT = $3.29e^{0.03t}$	88.00
G_1xB	STTT = 4.03+2.90A	85.30	1.83	0.000	STTT = $3.02e^{0.04t}$	86.10
G_1xC	STTT = -5.30+3.90A	85.10	2.48	0.000	STTT = $2.59e^{0.06t}$	85.30
G_1xD	STTT = 1.42+3.02A	78.40	2.41	0.000	STTT = $2.80e^{0.05t}$	79.60
G_2xA	STTT =12.10+1.86A	81.00	1.37	0.000	STTT = $3.35e^{0.03t}$	80.40
G_2xB	STTT = 9.90+2.16A	80.60	1.61	0.000	STTT = $3.25e^{0.03t}$	80.40
G_2xC	STTT = -0.46+3.22A	90.30	1.60	0.000	STTT = $2.77e^{0.05t}$	92.40
G_2xD	STTT = 5.89+2.41A	78.40	1.92	0.000	STTT = $2.97e^{0.04t}$	78.90
G_3xA	STTT = 5.43+2.63A	89.00	1.41	0.000	STTT = $3.03e^{0.04t}$	88.10
G_3xB	STTT = 5.69+2.46A	88.70	1.33	0.000	STTT = $3.00e^{0.04t}$	88.60
G_3xC	STTT = 7.08+2.42A	89.20	1.28	0.000	STTT = $3.10e^{0.04t}$	89.10
G_3xD	STTT = 3.25+2.84A	87.60	1.62	0.000	STTT = $2.92e^{0.04t}$	87.10
G_4xA	STTT = -0.32+3.06A	86.00	1.88	0.000	STTT = $2.66e^{0.05t}$	86.10
G_4xB	STTT = -2.83+3.43A	47.30	5.50	0.005	STTT = $2.54e^{0.06t}$	51.10
G_4xC	STTT = 7.09+1.99A	43.70	3.44	0.007	STTT = $3.03e^{0.03t}$	42.00
G_4xD	STTT = 16.04+1.20A	41.60	2.17	0.000	STTT = $3.48e^{0.02t}$	45.30

G_1 = NZW×NZW, G_2 = NZW×CH, G_3 = CH×CH, G_4 = CH×NZW
[1]see foot note of Table 1 for definitions of A, B, C and D
STTT = Should-to-tail tip, R^2 = Coefficient of determination, SE = Standard error, P = Probability

4. Discussion

The highest mean body weight obtained from the interaction between CH×NZW and D at 7 weeks which was finally surpassed by the interaction between CH×CH and D at 11 weeks post-weaning indicated that the difference was due to genotype and not feeding regime. This suggested that purebred Chinchilla rabbit had greater genetic potential for faster growth than its crossbred with New Zealand White rabbits in the same environment. This result collaborates with the findings of Mallam et al. (2018), who reported that purebred Chinchilla was superior to other rabbit genotypes in most of the growth traits studied. The result indicated further that the D feeding regime, i.e. 30% restricted concentrate + 30% restricted forage, was adequate for the growth of the rabbits. The body weight means obtained from the interaction of CH×CH with D which did not differ significantly from that of the interaction of NZW×NZW with C at 11 weeks implied that either of the two interacting groups could be used to improve body weight at this age. The outstanding performance of these breeds explains why they are commonly used in rabbit breeding within this study area (Oke et al., 2004; Obike and Ibe, 2010). It is clearly evident from the result that the restricted fed rabbits consumed lesser quantity of feed than the *ad libitum* fed. This implies that quantitative feed restriction improves growth and reduces cost of rabbit production. This result collaborates with the findings of Isaac et al. (2022). Onyiro et al. (2005), in a similar experiment used 20% as basis of restriction and reported no significant genotype × feeding regime interaction effect on the body weight and linear body measurements of rabbits throughout the 11-18 weeks period of their study. Since significant genotype × feeding regime interaction effect was recorded in the present study, the result indicated that restricting the intake of growing rabbits to 30 % concentrate and *ad libtum* forage and vice versa or using 30% restriction for both feed materials could result in differential growth among the genotypes which could serve as basis for selection and improvement.

The positive and highly significant absolute growth rates obtained in Tables 4 - 8 indicated that the animals increased in size and dimension throughout the experimental period. The magnitude of the rates indicated the amount of increase in size and dimension in gram per week imparted to the rabbits by the genotype × feeding regime interactions. Differences in the growth rates, both in absolute and instantaneous terms suggested that the different interactions had different effects on the growth of the animals. The greatest instantaneous relative growth rates obtained from the interaction of the purebred Chinchilla rabbits with D feeding regime for body weight was an indication that Chinchilla rabbits might reach sexual maturity at earlier age and might have higher average daily gain since the relative accuracy of regression of weight as an estimator of absolute growth rate had been found to compare with average daily gain (Fayeye et al., 2005; Liu et al., 1991). The general higher means of the body measurements (Tables 1-3) recorded by the restricted fed rabbits than the non-restricted ones, which also reflected on their growth rates are in agreement with the previous studies (Gidenne et al., 2009; Adeyemu et al., 2019). This indicated that the quantitative feed restriction employed in this study was beneficial to the growth and health of the rabbits with reduced feed intake. This supports previous findings (Onu et al., 2013; Isaac et al., 2022). Higher coefficients of determination and smaller values of standard errors were an indication that greater variation in the observed growth was mainly due to the combined effect of genotypes and feeding regimes, thus supporting the view that both genetic and environmental factors are essential for improvement of quantitative traits (Remington, 2009). The percentage variations in the instantaneous relative growth rates indicated the amount of genetic variance for the different growth traits. Wider variations in growth rates would mean greater genetic response to selection for growth. This is in agreement with the work of Estany et at. (1992). It therefore suggested that body weight and shoulder-to-tail tip, followed by body length, had greater additive genetic variance, and as such, would respond rapidly to individual selection. These traits can serve as good selection indices for rabbit improvement. The uniform growth rates observed for ear length and head-to-shoulder length among the interactions was an indication of low genetic variance for these traits. Such traits do not have faster genetic response to selection and should be improved by family or sib selection with proper feeding (El Nagar et al., 2020; Ellen et al., 2007). The percentage instantaneous relative growth rates helped to amplify the growth rates which were generally small, so that appreciable differences could be easily detected. This was the case of ear length with the 0.02 and 0.03 rates giving 40 % and 60%, respectively, indicating that with long term selection, significant differences in the growth of these two traits could be realized in the animals.

5. Conclusion

Purebred Chinchilla fed 30 % restricted concentrate + 30% restricted forage had comparably higher growth rates of body weight, head-to-shoulder length and ear length whereas Chinchilla × New Zealand White crossbred fed *ad libitum* concentrate + 30% restricted forage or the reverse had higher growth rates of body length and shoulder-to-tail tip. New Zealand White × Chinchilla crossbred fed *ad libitum* concentrate + 30% restricted forage and Chinchilla × New Zealand White crossbred fed 30 % restricted concentrate + 30% restricted forage had the lowest growth rate for body weight. In addition, Chinchilla × New Zealand White crossbred fed 30 % restricted concentrate + 30% restricted forage had the lowest growth rate for shoulder-to-tail tip. Body weight, shoulder-to-tail tip and body length had greater growth rates among the traits studied. It was concluded that purebred Chinchilla rabbits fed a combination of 30 % restricted concentrate and 30% restricted forage best improved growth traits, especially body weight, shoulder-to-tail tip and body length in this study. Purebred Chinchilla rabbits should therefore, take prior position, followed by Chinchilla × New Zealand White crossbreds in rabbit breeding for improved growth.

Conflict of Interest

The authors declare that there is no conflict of interest in this study.

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