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Sexual Dimorphisms and Phenotypic Correlation among Growth Traits in Three Rabbit Strains.

[1]H. M. Ideozu*; [2]S. I. Omeje; [2] Udeh; [2]P.O Akporhuarho

[1]Department of Animal Science, Rivers State University,
Nkpolu-Oroworukwo, P.M.B. 5080, Port Harcourt, Rivers State, Nigeria
Corresponding author's Orcid: 0000-0001-9763-0495
[2]Department of Animal Science, Delta State University, Abraka, Nigeria.

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***Corresponding Author**

H.M. Ideozu

E-mail: *hansino@rocketmail.com; hanson.ideozu1@ust.edu.ng*

Phone: *+234 803 8903327*

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ABSTRACT

This study addressed Sexual dimorphisms and phenotypic correlation among growth traits in three rabbit strains. 150 weaner rabbits of three different strains comprising 50 New Zealand white, 50 Dutch and 50 Hylamax were used. The 30 weeks experiment evaluated sexual dimorphisms and phenotypic correlation among growth traits in three rabbit strains. The sexual dimorphism considered the disparities between males and females. The growth traits studied were; Body weight (BW), Body length (BL), Chest Girth (CG), Ear Length (EL), Abdominal circumference (AC), Thigh Length (TL), Tail Length (TAL). The study was conducted to ascertain strain, sex, age (weeks 6, 10, 14, 18, 22, 26 and 30) effect and the interaction of both strain and age effect. Data were subjected to a multivariate analysis in the General Linear model using IBM SPSS (Version 22, 2013). The results indicate that significant disparity existed in body weight amongst the three strains by age and sex. The effect of strain was significant at 6 and 8 weeks of age with New Zealand white having significantly ($P<0.05$) higher body weight than Dutch and Hylamax rabbits. These high levels of significance indicate that the differences between individuals were attributed to the genotype effect. There were significant ($P<0.05$) disparities in all three rabbit strains across the various ages except week 10 that had no significant difference, though numerical variation existed. BL had a positive phenotypic correlation with LBW and EL at ($P<0.05$) level, TAL was highly substantial ($P<0.01$) with EL (0.01) and moderate in TL (0.02) at (0.01 and 0.05 levels).

INTRODUCTION

Recent development in the field have shown that domestic rabbit (*Oryctolagus cuniculus*) has been associated with man and has contributed to his well-being for many centuries. Rabbits are small mammals in the family Leporidae of the order Lagomorpha. There are about 305 strains of domestic rabbit. Best known for being prolific, rabbits are also herbivores which efficiently convert fodder to food (El-Sabrout and Aggag, 2017). The only limiting factor reported to be affecting growth and productivity of rabbits in tropical and arid climates according to McNitt *et al*. (2010) is calorie stress associated with high ambient temperature. Rabbit meat provides a cheap source of meat which is characterized by a high protein and low-fat cholesterol content (Aduku and Olukosi, 2010). Rabbits have the potentials to supply good and high-quality animal proteins, and are comparable to domestic chickens which have short gestation and generation interval, highly prolific, lack of taboos to its production and consumption, and can subsist on domestic waste and succulent leaves. In the tropics where there is stiff competition for grains and legumes between man and animals, rabbits can conveniently be reared in small or large scale since they can survive on forages and agricultural by-products not consumed by man.

Rabbit meat is characterized by high protein, low fat and low cholesterol contents and it is considered as a delicacy and a healthy food product (Dalle Zotte, 2012). Rabbits have a number of other characteristics that might be advantageous to subsistence farming system, such as their small body size, short generation interval with a relatively short gestation period average of 30-31 days. They have high growth rate, high feed efficiency, an early marketing age and require small land area. It is used as a food, for fur, as an experimental subject in research, and as a source of much pleasure as a pet and fancy animal in some countries. Rabbit farming is increasing in most of the developing countries due to their smaller body size, short gestation period, high production potential, rapid growth rate and the ability to utilize forage and by-products as major diet components (Cheeke, 2016).

When selection for a trait differs in direction we have antagonistic selection; this often leads to sexual conflicts since the two sexes share most of their genetic architecture. Sexual dimorphism is often seen as a resolution to sexual conflict, a way to decouple the genetic basis of traits under conflict and allow sex-specific expression (Cornwallis and Birkhead 2002). One way to better understand the evolution of sexual dimorphism is using a life history theory framework; where traits linked to growth, reproduction and survival are studied and quantified (Cooper, 2014).

Sexual dimorphisms are thought to have evolved in response to selection pressures that differ between males and females. In turn, variation in sexual selection pressures may be influenced by ecological conditions. Variation in predation, parasitism, or the distribution and abundance of resources can shift the balance between the benefits of ornamental plumage and the cost of maintaining such traits; such environmental conditions can act on male and female plumage with varying degrees of independence (Clutton-Brock and Vincent, 1991). Ecological factors may also affect the expression of condition-dependent traits in different environments. Thus, diversity of ecological conditions often leads to extensive intra- and interspecific variability in sexual dimorphisms. While correlation between sexual dichromatism and ecological factors has been thoroughly documented (Cooper, 2014), major questions remain. First, it is unclear why some groups of rabbit species show extensive variation in sexual dichromatism while other groups, often apparently subjects to similar variation in ecological conditions, are remarkably conservative in their sexual ornamentation and degree of dimorphisms. Second, given high genetic correlation between sexes that is often found in morphological traits. We need more information on how fast sexual dimorphisms can evolve following an ecological change and whether taxa or trait groups differ in their ability to evolve dimorphisms. Third, it is unclear to what degree ancestral dimorphic traits (such as pigment type and pigmentation distribution) and ontogenetic sequences of plumage traits may "set the stage" or bias the evolution of derived dimorphic traits, and whether such constraints differ between species groups (Cory, 2009). Finally, the role of sexual selection versus other selective forces, and the roles of various mechanisms of sexual selection in the production of sexual dimorphisms are highly debated issues.

Sexual dimorphism means that the two sexes of a species differ in external appearance. Although some sexual dimorphism is the result of natural selection, most is thought to have evolved through sexual selection. Sexual dimorphism in body size is common yet highly variable among marine mammals (Gencheva *et al*, 2017).

Sexual dimorphism has fascinated biologists since before the time of Darwin. Darwin considered that most sexual dimorphism was due to sexual selection, in which evolutionary forces acted separately on the sexes Gencheva *et al*, 2017. Females might choose to mate with highly ornamented males (e.g., the peacock's tail) or males might develop characters useful for fighting with other males to win in contests for access to females (e.g., large body size and antlers in deer). Today, these two processes are often referred to as female choice and contest competition, respectively. More recently, scientists have learned that males compete not only by physical fighting and display but also, in species where females mate with more than one male, by sperm competition within the female reproductive tract. Recent reviews have both questioned the very notion of sexual selection (Roughgarden *et al.,* 2006), and reaffirmed it, albeit with acknowledgment of much greater complexity than described by Darwin (Clutton-Brock, 2007).

The objectives were to determine the productive performance of the three strains of rabbit at different ages and to ascertain the effects of sex and phenotypic correlationship on the growth traits of the three rabbit strains.

Sexual dimorphism has been the subject of wonder and scientific studies for centuries, being present in most animal species since prehistoric times. According to Aristotle (fourth century BC), differences in the semen temperature at the time of copulation resulted in sexual dimorphism, with hot semen generating males and cold semen generating females. In the Historia Animalium (IV, 11), Aristotle reported that in all the species where differences between males and females occur, nature has clearly differentiated the character of females from that of males. Aristotle claimed that females are less muscular, have less sturdy joints and finer hair, moist flesh, thinner legs, and more delicate feet with respect to males, and their voice is higher-pitched. As to bones, Aristotle stated that females have smaller skulls, tighter faces, thinner necks, weaker chests, and minute femurs. Differences in morphology are associated with different behavior, from which Aristotle derives a judgment on the inferiority of the females compared to males. This idea of sexual dimorphism promoting the superiority of males has been kept throughout ancient times and the Middle Ages at least. In modern times, Charles Darwin suggested that sexual dimorphism may result from sexual selection when individuals of one sex compete for access to members of the other sex (Darwin 1871/1958).

Sexual Size Dimorphism (SSD)

Sexual size dimorphism (SSD) is a difference in body length or mass of sexually mature organisms and has been demonstrated in a great variety of animals including invertebrates and vertebrates with male-biased dimorphism being the more common, but certainly not the exclusive pattern (Isaac, 2005). In the last three decades, evolutionary biologists have developed a large body of theory for explaining the evolution of sexual size dimorphism in terms of sex-specific differences in the selection of mates, in food preferences, or in response to environmental factors including competitions and population density (Hedrick and Temeles, 2004). SSD, which is usually measured in adults, can result from differences between sex in growth patterns or selection and pressures during ontogeny (Merila *et al*., 1997). In addition, theoretical and empirical works indicate that SSD can evolve and be maintained when selection acts to maintain size differences between sexes, provided that variation in the trait of interest has a heritable component, and the genetic correlation between the sexes is less than one (Merila *et al.,* 1998). Multifactorial analyses of morphological traits have been proved to be suitable in assessing the variation within a population and can discriminate different population types when all morphological variables are considered simultaneously (Yakubu and Ibrahim, 2011).

Sexual size dimorphism in mammals

In most sexually reproducing animals, females are larger than males, a pattern often explained by fecundity selection on females (Darwin 1871). This is because more space is required for keeping eggs than keeping sperm and because egg production increases with body size. Energetic demands on female mammals are comparatively higher than on females in other animal groups since mammals not only need energy for egg production but also for gestation and lactation. Female mammals should therefore be expected to develop a larger energy store and should consequentially be expected to exhibit even larger size differences with males than other animals without such demands. However, even though there are numerous mammalian species where females are larger than males, earlier studies have reported that mammals are generally dimorphic, with a bias toward males, as is also commonly the case in birds. In explaining this male size bias, sexual selection is often cited as a possible driver (Darwin 1871). This is especially likely in species where males provide little or no parental investment, as males in these species can increase their reproductive success directly by competing for matings. Sexual selection through male–male competition as an explanation for male-biased size dimorphism has found support in several comparative studies that have shown correlations between different estimates of polygyny and dimorphism. Such correlations have been reported for mammals in general, but also separately for primates (Lindenfors *et al*. 2002). Although it is improbable that sexual selection on males is the sole causal agent behind mammal size dimorphism (Isaac 2015), these empirical studies indicate that sexual selection can be the important determinant in a significant fraction if not the majority of cases where male-biased sexual size dimorphism has evolved in mammals.

Body Size and Sexual Dimorphism

Sexual dimorphism refers to any systematic difference in form between males and females of a species. By definition, males and females differ in the size of their gametes: males make many small sperm, whereas females make fewer and larger eggs. This fundamental difference in gamete size, or anisogamy, predisposes the sexes to different reproductive organs, which are termed primary sexual characters. However, sexual dimorphism typically refers to traits that are not directly associated with reproduction, termed secondary sexual characters (Fontanesi *et al,* 2016). Although sexual dimorphism explicitly refers to morphology, such morphological differences are typically associated with sexual differences in behavior, physiology, and life history.

Sexual dimorphism holds a special place in the history of evolutionary biology. While developing his theory of sexual selection, Charles Darwin amassed a vast catalogue of sexual dimorphisms. He described dimorphisms ranging from the enlarged horns and mandibles of male beetles to the extravagant plumage and song of male birds and concluded with a detailed discussion of secondary sexual characteristics in humans (Fontanesi *et al,* 2014). Darwin argued that these dimorphisms evolve because extravagant ornaments and songs are preferred by the opposite sex (intersexual selection), whereas weaponry and large body size confer an advantage in competition with members of the same sex (intrasexual selection). In either scenario, the key outcome is that individuals with a particular trait achieve greater mating success. Sexual selection has since been defined as selection arising through variation in mating success.

MATERIALS AND METHODS

Study Location

The experiment was carried out at the Rabbitry Unit of the Teaching and Research farm of Rivers State University, Nkpolu Oroworukwo, Port Harcourt, Rivers State. Port Harcourt lies between longitude 6^0 59’ 54”E and latitude 4^0 47’ 21”N with average monthly temperature and relative humidity of 22.54 – 31.03^{0}C and 69.08 – 112.47% respectively. The average rainfall in Port Harcourt is 200.45mm (Uko and Tamunobereton-Ari, 2013).

Experimental Animals

The experiment was conducted using a total of 150 weaned rabbits belonging to three strains as follows: New Zealand White (25 males and 25 females), Dutch (25 males and 25 females) and Hylamax (25 males and 25 females), respectively. The rabbits were obtained from O. G farms Ogbomosho Oyo State, Lautech Teaching and Research farm Ogbomosho Oyo State and O. G. Farms, Egbeda Ibadan respectively. These were introduced into the Rabbitry Unit of the Teaching and Research Farm of Rivers State University, Port Harcourt, Rivers State. The experimental animals were randomly allocated into separate hutches according to sex and strain. They were allowed to acclimatize in the new environment for two weeks.

Individual body weight and morphometric traits of 150 (50/strain) weaner rabbits from the 3 strains were recorded at the end of every 4 weeks from week 6 to 30 weeks of age. The rabbits were housed individually in separate hutches according to their strain. Body weight was obtained using an electronic weighing balance (sensitive to the nearest 0.01g) other morphometric traits such as body length, ear length, chest girth, abdominal circumference, thigh length, leg length and tail length were obtained using a flexible measuring tape.
Data was collected on;

Body Weight: The body weight of each rabbit was taken using electronic balance, (LT 30KA, 30kg/1g; Jadesola weighing, ISO: 2001/UKAS 260 Accredited III U.K) with sensitivity of 0.01g. Weighing was done on 4-weekly basis from the 6th to the 30th week of age of the rabbits.

Body Morphometrics: Body morphometric measurements were taken using a flexible measuring tape. The measurements included:

(i) Body length: This was measured as the distance from the nose to the pin bone or to the end of the coccygeal vertebrae without tail from body surface.
(ii) Ear Length: This was measured as the distance from the point of attachment of the ear to the head to the tip of the ear.
(iii) Chest Girth: This was measured as the body circumference just behind the fore leg.
(iv) Abdominal circumference: This was measured as the body circumference just before the hind leg.
(v) Thigh Length: This was measured as the distance from the hip joint to the knee.
(vi) Leg length: It was measured vertically as distance from the hip joint to the toe.

All the above measurements were done according to the description of Gueye *et al.,*(1998), Teguia *et al*., (2008) and Yakubu, (2011).

Experimental Design and Data Analysis

For the assessment of the growth parameters the study was carried out under a 3 x 2 factorial in the completely randomized design. Accordingly, the data was subjected to a multivariate analysis outlined in the General Linear model using IBM SPSS (Version 22, 2013).

Strain type (NZW, DUT and HYL) and Sex type (male and female) as main effects. Interactions between the main effects were also analyzed. Significant means at $P<0.05$ were separated using the Turkey test technique. The linear model under the stated design for the study on the growth parameters were as follows:

$$X_{ijk} = \mu + A_i + S_j + AS_{ij} + e_{ijk}$$

Where

X_{ijk} = observation made on each trait evaluated
μ = the overall population mean
A_i = effect of the ith strain on the observed trait (i=1, 2, 3)
S_j = effect of the jth sex on the measured trait (j=1, 2)
AS_{ij} = effect of the interaction between strain and sex on the measured trait
e_{ijk} = random error.

RESULTS AND DISCUSSION

The proportion of each qualitative traits of the three strains viz; New Zealand White, Dutch and Hylamax are presented in table 4.1. The individual traits that can be classified into groups based on apparent and definitely distinct traits for each group. Colour variations, hair colour patterns and eye color are qualitative traits influenced by colour-coding genes, fur quality and softness are qualitative properties of commercial value (Mancini *et al.,* 2017). Qualitative traits are characters that can be seen only existence, not measured value or degree. There is a clear distinction between one trait with another and cannot be made discontinuous. According to their head index, New Zealand White, Dutch and Hylamax rabbits had oval head type because they had the index value of the width-size division to the head length > 0.50, and their body type are commercial. Commercial body type of rabbits is an expression of broiler rabbit that has a larger body size and shape (Abo-Eid *et al.,* 2016). Eye colour of three breeds of rabbit were red, the eye color is determined by the distribution and pigment content of melanocytes and melanosomes in the iris of eye. Covrig *et al*. (2013) reported that the red eyes that appear in white-haired rabbits are the expression of cc genes that cause albino on the surface of the body and red on the eyes. Whereas the absence of pigment on the skin of white-haired rabbits usually make them have red eyes.

Table 4.1: Qualitative characteristics of the three rabbit strains

Traits	Phenotype	Strains (%)		
		New Zealand White	Dutch	Hylamax
Head type	Oval	100	100	100
Body type	Commercial	100	100	100
Eye colour	Red	100	100	100
Hair colour	White/Brown	100	100	100
Colour variation in Hair	Single	100	100	100
	Mixed	90	90	90
Hair type	Normal	100	100	100
Hip type	Compact	91	77.1	72.2
	Slim	11	23.2	18.6

Body weight, age and sex of the three rabbit strains

The body weight by age and sex of the three rabbit strains are presented in table 4.2. The results indicated that significant disparity existed in body weight amongst the three strains by age and sex. The effect of strain was significant at 6 and 8 weeks of age with New Zealand white having significantly ($P<0.05$) higher body weight than Dutch and Hylamax rabbits. Although, the effect of sex was significant only at 30 weeks of age with the females having a competing higher body weight. A similar trend occurred in week 26. Same was noticed in week 22 although there was no significant disparity, only numerical differences.

Table 4.2: Body weight, age and sex of the three strains of rabbit genotype.

Body weight	New Zealand White		Dutch		Hylamax		P-value
	Males	Females	Males	Females	Males	Females	
BW6	855.3± 53.5^{a}	787.7±54.0^{a}	601.0± 53^{b}	498.5±53^{c}	652.1±53.5^{b}	512.5±54.0^{c}	0.002
BW10	1211.1±45^{a}	1096.5±45^{a}	868.8±44^{b}	798.6±44^{c}	874.6±44^{b}	818.7±44^{b}	0.013
BW14	1766.5a±68^{a}	1493.7±67^{b}	1460.7±67^{b}	1145.6±67^{c}	1481.7b±67^{b}	1245.5±67^{c}	0.005
BW18	2287.7±118^{a}	2048.6±119^{ab}	1697.8±119^{bc}	1504.5±118^{c}	17913.7±119b^{c}	1609.5±118^{c}	0.024
BW22	2877.5±172	2901.6±173	2053.5±173	2312.6±173	2103.5±172	2412.5±172	0.611
BW 26	3232.5± 202^{a}	3365.6±201^{a}	2515.1± 201^{b}	2706.4±202^{b}	2544.1±201^{b}	2831.5b±202^{b}	0.045
BW30	4213.4±45^{a}	3595.7±45^{a}	2969.7±45^{b}	3496.8±45^{b}	2976.7±45^{b}	3399.7±45^{b}	0.000

Means with different superscript on the same row are significantly different ($P<0.05$).

Table 4.3 presents the least square means showing strains and age effect on body weight and body morphometrics. Results from the study indicates that there was no significant ($P>0.05$) difference among the strains for body weight and body morphometric although numerical differences existed.

Table 4.3 Least square means showing strains and age effect on body weight and body morphometrics

Age	Strains	Body weight	Body Length	Ear length	Chest Girth	Thigh length	Abdominal circumfrence	Leg Length	S-Level
6	New Zealand	0.8	28.1	8.35	9.55	5.75	10.83	9.02	N.S
	Dutch	0.6	27.61	8.97	9.46	5.66	10.11	9.76	N.S
	Hylamax	0.50	26.1	8.11	9.11	5.03	10.13	9.04	N.S
10	New Zealand	1.2	28.7	9.01	11.60	6.55	11.92	9.88	N.S
	Dutch	0.8	29.12	9.08	10.99	6.13	12.11	10.11	N.S
	Hylamax	0.8	28.41	9.13	11.05	6.77	11.01	11.46	N.S
14	New Zealand	1.7	35.50	10.15	14.04	7.70	14.06	11.03	N.S
	Dutch	1.5	33.61	10.18	14.16	7.61	13.11	11.91	N.S
	Hylamax	1.4	35.13	10.21	14.22	7.13	14.11	12.06	N.S
18	New Zealand	2.2	37.17	11.45	14.90	8.37	16.04	12.56	N.S
	Dutch	1.7	34.14	11.17	15.03	8.15	15.21	12.91	N.S
	Hylamax	1.8	35.12	10.96	14.44	8.23	16.09	12.04	N.S
22	New Zealand	2.8	40.40	11.31	16.44	9.15	17.12	13.06	N.S
	Dutch	2.3	39.12	11.09	16.11	9.60	16.45	13.11	N.S
	Hylamax	2.3	38.12	11.02	16.32	9.22	17.11	14.03	N.S
26	New Zealand	3.2	42.12	12.51	16.77	10.13	18.43	14.18	N.S
	Dutch	2.5	41.04	12.03	17.11	9.86	18.22	14.24	N.S
	Hylamax	2.5	41.13	12.38	17.33	10.11	18.19	14.88	N.S
30	New Zealand	4.2	43.15	12.79	17.01	10.77	19.21	15.17	N.S
	Dutch	2.9	42.99	12.80	17.21	10.15	19.01	15.22	N.S
	Hylamax	2.9	44.56	12.14	17.43	10.44	19.51	15.71	N.S

Table 4.4 shows the sex effects of strain and age on growth traits at week 6. There were no significant ($P>0.05$) disparities in live body weight and body morphometrics at 6 weeks of age between the males and females of the three strains of rabbits. The weaner rabbits were of the same age and size at the commencement of the experiment. However, there were significant disparities among other measured traits, the three strains recorded significant differences in the sexes in other body morphometrics.

Table 4.4. Least square showing sex effects on body weight and body morphometrics of the three strains at 6 weeks of age

Parameters	Mean (+SE)		
	Male	Female	Overall
Live body weight (kg)	0.85 ± 0.02^{b}	0.89 ± 0.02^{a}	0.87± 0.01
Body length (cm)	25.17 ± 0.24^{b}	27.26 ± 0.35^{a}	26.22 ± 0.22
Ear length (cm)	8.92 ± 0.07^{b}	9.40 ± 0.07^{a}	9.16 ± 0.05
Tail length (cm)	9.79 ± 0.09^{b}	9.26 ± 0.10^{a}	9.56 ± 0.07
Thigh length (cm)	9.33 ± 0.17^{b}	9.51 ± 0.19^{a}	9.92 ± 0.13
Chest girth (cm)	11.68 ± 0.15^{b}	10.04 ± 0.14^{a}	10.36 ± 0.11
Abdominal circumference (cm)	10.01 ± 0.19^{b}	10.82 ± 0.18^{a}	10.91 ± 0.14

Means with different superscripts in the same column differ significantly ($p < 0.05$).

Table 4.5 shows the sex effects of strain and age on growth traits at week 30. There were significant ($P<0.05$) disparities in live body weight and body morphometrics at 30 weeks of age between the sexes. The adult rabbits showed differences in live body weight and body morphometrics, with the females having higher values in all the traits except for ear length and live body weight.

Table 4.5. Least square showing sex effects on body weight and body morphometrics of the three rabbit strains at 30 weeks of age

Parameters	Mean (+SE)		
	Male	Female	Overall
Live body weight (kg)	4.34 ± 0.02^{a}	4.21 ± 0.02^{b}	4.28 ± 0.04
Body length (cm)	12.17 ± 0.13^{b}	17.26 ± 0.35^{a}	14.71 ± 0.22
Ear length (cm)	14.15 ± 0.04^{b}	14.40 ± 0.07^{a}	14.16 ± 0.05
Tail length (cm)	10.77 ± 0.11^{a}	10.26 ± 0.10^{b}	10.02 ± 0.07
Thigh length (cm)	10.33 ± 0.12^{b}	11.51 ± 0.19^{a}	10.92 ± 0.13
Chest girth (cm)	18.68 ± 0.10^{b}	20.04 ± 0.14^{a}	19.36 ± 0.11
Abdominal circumference (cm)	20.01 ± 0.19^{b}	21.82 ± 0.18^{a}	20.91 ± 0.14

Means with different superscripts in the same column differ significantly ($p < 0.05$).

Table 4.6 presents the phenotypic correlation between body morphometrics using pooled facts of the three strains. BL had a positive phenotypic correlation with LBW and EL at ($P<0.05$) level. Furthermore, TAL was highly substantial ($P<0.01$) with EL (0.01) and moderate in TL (0.02) at (0.01 and 0.05 levels). CG was positively correlated to BL but damagingly correlated to LBW. For the three strains singly, strong positive phenotypic correlation was perceived between LBW, with TAL, TL and AC. This indicates that LBW, TAL, BL, TL and AC are strong aspects for predicting growth and body weight in rabbits.

Table 4.6 Phenotypic Correlation between body weight and body morphometrics of New Zealand, Dutch and Hylamax rabbit strains

	LBW	BL	EL	TAL	TL	CG	AC
LBW	1	0.621**	0.437**	0.581**	0.568**	0.765	0.753**
BL		1	0.426**	0.616*	0.703**	0.541**	0.652**
EL			1	0.581**	0.402**	0.406**	0.442**
TAL				1	0.646**	0.495**	0.583**
TL					1	0.531**	0.720**
CG						1	0.844**
AC							1

**. Correlation is significant at the 0.01 level (2-tailed), LBW = live body weight, BDL = body length, EL = ear length, TAL = tail length, TL = Thigh length, CG = chest girth, AC = abdominal circumference.

DISCUSSION

Body weight, age and sex of rabbits

In all the growth traits monitored in this study, the New Zealand White strain was significantly superior to the Dutch and Hylamax strains. This tends to suggest that New Zealand white strain have a growth advantage over the other strains. Furthermore, it may as well indicate that the underlying carotenoid pigmentation for white colour could possibly be linked with genes that favour the development of the various traits (Body weight, body length, chest girth, thigh length, abdominal circumference, etc) studied (Shanin and Hassan, 2002).

Body weight, body length, girth, and other morphometric traits were positively affected by sex in the three strains of rabbit, especially New Zealand White and this could be related to the fact that White plumaged rabbits are expected to reflect light very effectively thereby experiencing less heat stress and this in turn makes them adapt and grow well in tropical regions as compared to other coloured plumage strains (Reddy, *et al.,* 2016).

Body Weight

Body weight is considered a function of the framework or size of the animal and its condition (Phillip, 1970). The range of weaner rabbit body weight 400g to 950g of New Zealand White, Dutch and Hylamax strains in this experiment was slightly above that of 515g to 650g reported by Ekwe *et al.,* (2007) in a crossbred rabbit genotype. It also differed from the range 413g to 415g reported by Wafar, *et al* (2019) for light and heavy rabbits. The significantly higher body weight of the New Zealand White weaner suggests that the gene for white plumage may have the potential for rapid growth.

According to age, variation for body weight was noticed to be highest at week 30; this shows that among genetic groups, body weight varied more at 30 weeks old in the New Zealand White rabbits. The superior performance of New Zealand white for body weight agrees with the work of Galal (2000), in his experiment on effect of sex and genotype on double segregation genes on some phenotypic and genetic parameters.

Noting that rabbits and chickens fall under same non ruminant category, Dekhili and Aggoun (2013) noted that body weight expresses its usefulness in vital economic traits in the meat industry; hence most breeders would prefer selecting parents with such desirable character for the next generation. Difference in body weight within a flock can be attributed to genetic variation and environmental factors that affect individuals (Ayorinde and Oke, 1995). The NZW strain was observed to have superiority over the Dutch and Hylamax in body weight at specific ages; this attribute could be linked to the fact that it reflects light away thereby reducing stress.

Findings from this study show that body weight and morphometric traits are most often used to determine growth in farm animals. The New Zealand white rabbits had 87.45% body weight variation as compared to Dutch and Hylamax strains.

Body length

This current study revealed that the New Zealand white strains were generally superior to the other strains. For body length in particular, the NZW had longer body length than their Dutch and Hylamax counterparts. The larger body length of the NZW strains suggests that they have advantage over the Dutch and Hylamax strains in growth and development of this trait. This could also be traced to the rapid growth of the chest girth in the NZW rabbit strains. The values for body length were 37.3, 36.0 and 37.0 for NZW, Dutch and Hylamax respectively; this means that the body length of the rabbit strain is a good prediction for growth.

The disparity among the results above may be as a result of the strain and age of chickens used. However, there was a positive correlation between body length and body weight, as the strains with higher body length also had higher body weights.

Chest girth

There is an increase in the chest girth of rabbits at a more rapid rate as a result of breast depth and width (Shemeis and Abdallah, 2009). Ige, (2013) and Yunusa and Adeoti, (2014), noted that chest girth and body length can act as good indicators of growth. Oblakova (2006), recommended the use of chest girth for prediction of the likely body weight of turkey, in a study of phenotypic correlation between some morphological characteristics of eggs in basic turkey. From the current study the chest girth of New Zealand White strain was noticed to be larger than that of their Dutch and Hylamax counterparts. Rastogi *et al.* (2009) noted that chest girth has a strong correlation with body weight followed by body length and this may be due to the fact that the chest girth has vital muscles and bones.

Sex Effect of Strain and age

Table 4.4 and 4.5 shows the least square mean SE of body weights and linear body measurements as affected by sex. Sex had significant ($p < 0.05$) effects on all the body measurements studied. The mean live body weight recorded for the females was 0.89 kg at 6 weeks whereas that of the males was 0.85 kg for the males with an overall mean value of 0.87 kg for the two sexes. The LBW values obtained in this study is lower than the values recorded for dwarf rabbits by Dalle Zotte *et al.* (2012), who reported 1.630 kg and 1.542 kg for females and males, respectively. Values obtained for female rabbits were significantly ($p < 0.05$) higher than those for the males in BL, EL, TAL, TL, CG and AC.

The results obtained in this study agree with the report of Rotimi and Ati (2020), who also observed that female rabbits were significantly ($p < 0.05$) heavier than the males. However, Abdel-Azeem *et al.* (2007) reported that sex non significantly affected body weight at the different ages studied, although females were slightly heavier than males. The differences observed in this study for all the variables between the sexes of the rabbit could be attributed to sexual dimorphism. Sexual dimorphism was also reported in Dutch rabbits (Akpobasa, 2012).

Phenotypic correlation between body weight and morphometric

The correlation coefficients between live body weight and body morphometrics are presented in Table 4.4 There were positive and highly significant ($p < 0.01$) correlation coefficients among the variables. Correlation values ranged from 0.403 (between EAL and TL) to 0.845 (CG and AC). This result aligns with the work of Yakubu and Ayoade (2009) in New Zealand white × Chinchilla rabbits. However, values in this report are lower than those obtained by Chineke (2000) who reported a correlation coefficient range of 0.765 – 0.948 among traits in rabbits and Tiamiyu *et al.* (2000) who reported a high positive correlation coefficient range of 0.89 – 0.98. The results confirm high prediction ability among the variables.

The significant (P<0.05) strain differences recorded in all the traits evaluated between the three breeds suggest that the three strains may not have had similar genetic background. The obtained results agree with the findings of Oke *et al.* (2018) and Isaac *et al.* (2010) who found significant breed differences in linear measurements at different ages with the exception of shoulder to tail. The present study corroborates the findings of Ozimba and Lukefahr (2017) and Roberts and Lukefahr (2018) who asserted that there was small to non-significant strain differences for postweaning growth traits in breed comparison studies involving three strain. The three strains however, increased in body size and other body dimensions as the animals grew in age. The rate of change was high initially but slowed down from 16th week to 22nd week. This type of growth has been called a convex-shaped growth curve as reported in broilers (Marks, 1979).

The result of phenotypic correlation analyses implies that all body morphometrics are good determinants of body weight. That is, body weight could be predicted with greater accuracy using the values of anyone of body dimensions. In agreement with this study, Ige *et al.* (2015) found that linear body measurements are useful in live weight determination. The observed findings also presuppose that the growth in any body dimension will invariably result to increase in live weight. Similarly, the positive, significant phenotypic correlations recorded among body morphometrics indicate strong relationships between the various traits that are connected with animal growth. According to El-Labban (2009), positive relationships between these traits were as a result of pleiotrophic effects of genes and linkage effects which operate on these traits. Therefore, any attempt to perform phenotypic selection for one trait will consequently result in improvement of the other.

Strain-basis analyses indicate that three strains grew in size and body morphometrics with advancing age under normal conditions. Moreover, phenotypic correlation values between body weight and other linear parts were very high in the two breeds. This suggests possible strong and positive relationship between these traits, and the likelihood of pleiotrophic effect of genes operating on them. Therefore, any attempt to select for one trait in a breeding program will automatically result to improvement on other traits. Previous studies have indicated positive and significant correlations between live weight and body dimensions in farm animals, that is, body dimensions are good indicators and can be used to predict the body weight of an animal. The current study was in agreement with the findings of Ige *et al.* (2007) in local fowls, Kolawole and Salako (2010) in cane rat and Elamin and Yousif (2011) in Sudanese rabbits. In addition, age of the rabbits across the three strains were found to have significant positive correlation with body weight and body morphometrics. There were significant strain x age interaction effects on all the traits measured. This implies that growth traits in rabbits are strains and age dependent.

CONCLUSION

The study showed that sex had significant (P<0.05) effects on morphometric parameters measured in the rabbits, with females recording higher values than males at some ages and parameters. This result confirms the occurrence of sexual dimorphism in the rabbits studied. The information obtained from this study partly suggests that the use of rabbit for meat production should skew towards raising female rabbits.

Since there were modified significant strain disparities in live body weight and body morphometrics, anyone of the three strains could be used to cross with our local strains to improve their genetic potentials and productivity. The local strains are hardy and heat tolerant but low in mature body weight in comparison with exotic breeds. The crossbreds will no doubt combine the quality traits of both the local and exotic rabbit strains. Also, it was indicated in this study that body weight has significant positive phenotypic correlation with body morphometrics, that is, all the linear parts are good determinants of body weight in rabbits. The phenotypic correlations between body weight and morphometrics on one hand were high and positive. On the other hand, there were significant positive correlations among the various body morphometrics evaluated. This implies that improvement in any part will lead to increase in body weight and other body morphometrics.

The present investigation was therefore, undertaken to assess sexual dimorphisms, genetic correlations among growth traits and their association with the growth hormone receptor gene in three rabbit strains**.** The aim was to identify and recommend the strain and sex that can be used to upgrade and improve the growth potential of our local unimproved rabbits. The study also estimates the relationship between body weight and body morphometrics so as to be able to predict the value of the former from the latter using specific genes that favour growth.

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