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Comparative study of growth patterns of Kalahari Red goats and West African dwarf goats reared in Southwest Nigeria

[1]Omotosho, B. O., [1*]Bemji, M. N., [1]Bamisile, K., [1]Ozoje, M. O., [2]Oluwatosin, B. O.,[3]Sowande, O.S., [1]Wheto, M., [4]James, I. J.,[1]Lawal, A. M. and [5]Osinowo, O. A.

[1]*Department of Animal Breeding and Genetics,*
Federal University of Agriculture, Abeokuta, Nigeria
[2]*Institute of Food Security, Environmental Resources and Agricultural Research,*
Federal University of Agriculture, Abeokuta, Nigeria
[3]*Department of Animal Production and Health,*
Federal University of Agriculture, Abeokuta, Nigeria
[4]*Department of Animal Physiology,*
Federal University of Agriculture, Abeokuta, Nigeria
[5]*Abass Ranch, Opeji, Abeokuta, Ogun State, Nigeria*
***Corresponding author:** bemjimn@funaab.edu.ng, +2348035397059

Abstract

This study focused on comparing growth traits (body weights at birth, 3-month weaning and 6-month post-weaning) as well as growth curves of Kalahari Red (KR), a newly introduced goat breed in Nigeria and West African Dwarf (WAD) goat semi-intensively managed. Data on growth traits and weekly live weights were collected from 124 kids consisting of 61 KR and 63 WAD goats. The data were subjected to least squares analysis of variance to evaluate the effects of breed, sex, season, birth type and parity. The results showed that KR kids exceeded WAD kids in body weights at birth (2.30±0.06 kg vs 1.56±0.06 kg), 3-month weaning (8.88±0.57 kg vs 3.88±0.20 kg) and 6-month post-weaning (13.97±0.86 kg vs 5.05±0.37 kg). Corresponding pre-weaning average daily gain (ADG) estimates were 84.44±2.44 g and 31.73±1.16 g and post-weaning ADG were 61.88±1.81g and 24.84±1.21 g. Growth patterns of the two breeds were described using four different non-linear models: Brody, Gompertz, Logistic and Von Bertalanffy. Models were compared using parameter estimates (asymptotic weight 'A', integration constant 'B' and rate of maturity 'k'). Model with good fit was adjudged using coefficient of determination (R^2) and residual mean squares (RMS). The KR goats had higher parameter estimates than WAD goats. Von Bertalanffy model had the highest 'A' estimates (24.24±0.94 kg vs 11.99±0.54 kg for KR and WAD goats). Gompertz had highest 'B' and 'k' estimates (5.37±0.20 vs 3.38±0.09) and (0.19±0.01 vs 0.13±0.01) for KR and WAD goats. All four growth models generally had R^2 exceeding 99% and low RMS, hence giving good fit to the observed growth data. They can be used to implement feeding and management decisions that will optimize productivity. Information on superior growth performance of the Kalahari Red goat can be utilized to further investigate genetic improvement of the indigenous West African Dwarf population through crossbreeding.

Keywords: Growth traits; Curve parameters; Kalahari Red; West African Dwarf goat.

Une Etude comparative des modes de croissance des chèvres rouges du Kalahari et des chèvres naines d'Afrique de l'Ouest élevées dans le sud-ouest du Nigeria

[1]Omotosho, B. O., [1*]Bemji, M. N., [1]Bamisile, K., [1]Ozoje, M. O., [2]Oluwatosin, B. O.,[3]Sowande, O.S., [1]Wheto, M., [4]James, I. J.,[1]Lawal, A. M. et [5]Osinowo, O. A.

[1]*Department of Animal Breeding and Genetics,*
Federal University of Agriculture, Abeokuta, Nigeria

[2]*Institute of Food Security, Environmental Resources and Agricultural Research, Federal University of Agriculture, Abeokuta, Nigeria*
[3]*Department of Animal Production and Health, Federal University of Agriculture, Abeokuta, Nigeria*
[4]*Department of Animal Physiology, Federal University of Agriculture, Abeokuta, Nigeria*
[5]*Abass Ranch, Opeji, Abeokuta, Ogun State, Nigeria*
***Corresponding author:** bemjimn@funaab.edu.ng, +2348035397059

Résumé

Cette étude s'est concentrée sur la comparaison des traits de croissance (poids corporel à la naissance, sevrage à 3 mois et 6 mois après le sevrage) ainsi que les courbes de croissance du Kalahari Red (KR), une race de chèvre nouvellement introduite au Nigéria et West AfricanDwarf (WAD) chèvre gérée de manière semi-intensive. Des données sur les traits de croissance et le poids vif hebdomadaire ont été collectées auprès de 124 chevreaux comprenant 61 chèvres KR et 63 chèvres WAD. Les données ont été soumises à une analyse des moindres carrés de la variance pour évaluer les effets de la race, du sexe, de la saison, du type de naissance et de la parité. Les résultats ont montré que les enfants KR dépassaient les enfants WAD en poids corporel à la naissance (2,30 ± 0,06 kg vs 1,56 ± 0,06 kg), au sevrage de 3 mois (8,88 ± 0,57 kg vs 3,88 ± 0,20 kg) et 6 mois après le sevrage (13,97 ± 0,86 kg contre 5,05 ± 0,37 kg). Les estimations correspondantes du gain quotidien moyen (ADG) pré-sevrage étaient de 84,44 ± 2,44 g et 31,73 ± 1,16 g et l'ADG post-sevrage était de 61,88 ± 1,81 g et 24,84 ± 1,21 g. Les modèles de croissance des deux races ont été décrits à l'aide de quatre modèles non linéaires différents :Brody, Gompertz, Logistic et Von Bertalanffy. Les modèles ont été comparés à l'aide d'estimations de paramètres (poids asymptotique « A », constante d'intégration « B » et taux de maturité « k »). Le modèle avec un bon ajustement a été évalué en utilisant le coefficient de détermination (R2) et les carrés moyens résiduels (RMS). Les chèvres KR avaient des estimations de paramètres plus élevées que les chèvres WAD. Le modèle de Von Bertalanffy présentait les estimations « A » les plus élevées (24,24 ± 0,94 kg contre 11,99 ± 0,54 kg pour les chèvres KR et WAD). Gompertz avait les estimations « B » et « k » les plus élevées (5,37 ± 0,20 vs 3,38 ± 0,09) et (0,19 ± 0,01 vs 0,13 ± 0,01) pour les chèvres KR et WAD. Les quatre modèles de croissance avaient généralement un R2 supérieur à 99% et un RMS faible, ce qui correspondait bien aux données de croissance observées. Ils peuvent être utilisés pour mettre en œuvre des décisions d'alimentation et de gestion qui optimiseront la productivité. Les informations sur la performance de croissance supérieure de la chèvre rouge du Kalahari peuvent être utilisées pour étudier plus avant l'amélioration génétique de la population indigène de nains d'Afrique de l'Ouest par croisement.

Mots clés :traits de croissance ; Paramètres de courbe ; Kalahari Red ; Chèvre naine d'Afrique de l'Ouest.

Introduction

Genetic improvement in livestock species depends on the identification of breeds or individuals capable of transmitting desirable characteristics to their offspring (Mousa *et al*., 2013). The Kalahari Red goat is a native breed to South Africa which was developed mainly for meat production (Kotze *et al.,* 2004; Simela and Merkel, 2008). The breed is well adapted to the arid and semi-arid savannah with good foraging and excellent mothering abilities, hence regarded as "minimum care/maximum profit" breed (Ramsay *et al*., 2001). Limited published information revealed that age at first breeding is six months, average birth weight is 2.5 kg and kids grow fast with mature buck weighing 115 kg while does reach 75 kg (www.indigenousbreeds.co.za /indigenousbreeds/goat/kalahari). The WAD goats are found in large numbers in the southern parts of Nigeria. They are hardy, small, early maturing, prolific and are non-seasonal breeders weighing 1.55 kg at birth, 5.47 kg at weaning (Adenaike and Bemji, 2011), 9 kg at 6-month post-weaning (Hagan *et al*., 2014) and between 20-25kg at maturity **(Ikwuegbu *et al*., 1995)**. Interest in the Kalahari Red breed is widespread, since it has outstanding qualities of extreme hardiness, colour, size, fertility and fast growth rate (Kala, 2015). Given that the breed was newly imported into Nigeria with the aim of improving the carcass mass of the local goat populations, information on genetic and phenotypic characterization will further enhance efficient utilization of the populations as stipulated in literature (Bemji *et al*., 2014; Muritala *et al*., 2015). Although molecular characterization has been the subject of discussion in most publications (Kotze *et al.,* 2004; Pieters 2007; Bemji *et al*., 2014; Muritala *et al*., 2015), there is limited information on empirical research dealing with growth traits in the KR population in particular. This study therefore derived its relevance from the need to provide comparative baseline information on growth traits of both breeds managed under the same environment. Body weight and pre-weaning growth rate are often considered as early indicators of growth and economic benefit, these can affect body weight at puberty and first kidding (Portolano *et al.,* 2002; Hanford *et al.,* 2006). Growth curve elaborates gradual changes taking place in animal's body with the passage of time (Ozdemir and Dellal, 2009). The shape of the growth curve may change according to the genotype of the animals, environmental conditions and investigated characteristics (Efe, 1990). During an animal's lifetime, essential weight gain is reached before maturity stage and it is well known that animals achieve the target mature size in a well-defined sigmoid or S-shaped curve (Najari *et al*., 2007). Sigmoid curve has three phases: preparing, increasing and quietness. In first phase, growth starts at a specific point and increases gradually. In second phase, curve adopts a linear shape up to distortion point. In the last phase, the curve reaches asymptote (De Lange *et al*., 1998). Analysis of growth data are made possible by fitting of non-linear functions. The non-linear functions offer the opportunity to summarize the information needed to understand biological phenomenon of growth, an important component of livestock production system, into a small set of parameters that can be used to derive other relevant growth traits (Lopez *et al*., 2000; Kratochvilova *et al*., 2002; Gaddour *et al*., 2012). Commonly used examples of the functions include three parameters equations: Brody or monomolecular (Brody, 1945), Gompertz (Wadson, 1932), Von Bertalanffy (Von Bertalanffy, 1957), Logistic (Nelder, 1961) and four parameters Richards' equation (Richards, 1959). These non-linear models are more effective than linear model because the growth illustrates a sigmoid form and described relationship between lifetime weight and age. Parameters of these growth models are estimated for genetic improvement of growth in selection program. For these reasons, study of performance and growth pattern using non-linear models is essential to determine feeding and management decision, support systems for optimization of goat herd production. The aim of this study was therefore, to investigate and compare body weights at birth, 3-month weaning and 6-month post-weaning as well as growth patterns of the newly introduced KR goats and indigenous WAD goats.

Materials and methods

Location of the study

This research was conducted at the Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR) Farm, Federal University of Agriculture, Abeokuta (FUNAAB) located within latitude 7º 10' 30" and longitude 3º 25' 41" in the humid zone of southwest Nigeria. It receives a mean precipitation of 1,112.7mm with a seasonal distribution approximated at 110.9mm in the late dry season (January-March) 462.1mm in the early wet season (April-June), 376.6mm in the late wet season (July-September) and 163.1mm in the early dry season (October-December). Relative humidity averages 82 percent throughout the year. This location is 76m above sea level.

Management of animals and data collection

A total of 124 kids comprised 61 KR goats and 63 WAD goats utilized for this study. Fifty-four of the kids were from does kidding for the first time while 70 kids were from second parity does. The kids and their dams were raised on cross ventilated pens with slated floor. Nutrition was based on concentrate feed supplement of 15% crude protein which was fed to the animals at 200 to 700 g/head/day depending on breed and grazed on cultivated pasture. Water was offered *ad libitum*. Natural mating of does was carried out and non-return of does to oestrus was a confirmation that the does were pregnant. Following kidding, type of birth (single or twin) and sex of kid (male or female) were recorded and kid weighed within the first day of birth (birth weight), and subsequently weighed on weekly bases up to the 24^{th} week using Avery weighing scale calibrated in kilogram (kg). The kids were weaned from their dams at the age of 3 months. Pre-weaning (PRW) and post-weaning (PSW) average daily gains (ADG) were calculated according to Schoeman and Jordan (1999). PRW ADG (g) = (WWT-BWT)/90 days ×1000; PSW ADG (g) = (6MWT-WWT)/ 90 days × 1000. Two distinct seasons within which kidding occurred were considered, namely dry season (October to March) and wet season (April to September).

Statistical analysis

For body weight traits, data generated on birth weight, weaning weight, 6-month post-weaning weight, pre-weaning and post-weaning ADGs were subjected to least squares analysis of variance using the General Linear Model procedure of Statistical Analysis Software Program (SAS, 2003) to evaluate the effects of sex, season, birth type and parity. The effect of interactions between factors was not significant and hence dropped from the model. The following statistical model was used.

$$Y_{ijklmn} = \mu + P_j + S_k + T_l + S_m + \varepsilon_{ijklmn}$$

where: Y_{ijklmn} = trait of interest (kg), μ = population mean, P_j = effect of j^{th} parity (j = 1 or 2), S_k= effect of k^{th} sex (k = male or female), T_l= effect of the l^{th} type of birth (l= single or twin), S_m= effect of the m^{th} season of kidding (m = wet or dry) and ε_{ijklmn}= random residual error.

For fitting of growth curves, four non-linear regression models were fitted to the body weight-age data from week one to twenty-four for all the progenies of the two breeds using the NLIN procedures of SAS (2003). After sorting of outliers, the total individual curves were pooled. The curve parameters 'A' 'B' and '*k*' were also determined using the same package. The models include: Brody:

$Y_t = A(1 - Be^{-kt}) + \varepsilon$; Gompertz: $Y_t = A_e - Be^{-kt} + \varepsilon$; Logistic: $Y_t = A(1 - Be^{-kt})^{-1} + \varepsilon$ and Von Bertalanffy: $Y_t = A(1 - Be^{-kt})^3 + \varepsilon$;

where Y_t= observed live weight of the animal, A = asymptotic limit of weight when age approaches infinity, B = scalar vector (integration constant), k = *the* maturing rate (the larger the value of k, the earlier the animal matures), t = the time (birth to twenty four weeks of age), e = base of natural logarithm and ε = the random residual error. The evaluation criteria used to compare the accuracy of models were computing difficulty and goodness of fit. Computing difficulty is defined as the number of iterations needed to converge. The starting values of parameters are null for all models to allow the same convergence conditions. Goodness of fit is defined as the magnitude of the residual mean squares at convergence, which provides a measure of the estimation precision. The accuracy was evaluated by the non-linear coefficient of determination, R^2 and RMS. The best growth model had the highest R^2 and the lowest RMS .

Results

All the growth traits studied were significantly (P<0.05) affected by sex, season and type of birth for Kalahari Red and West African Dwarf goats. The results presented in Tables 1 and 2 revealed that KR kids exceeded WAD kids in body weights and ADG by 0.74 kg at birth, 5 kg at weaning, 8.92 kg at 6-month post-weaning, 52.71 g for pre-weaning ADG and 37.04 g for post-weaning ADG. The growth curves for both breeds studied for 24 weeks are summarized in Figure 1.

Male kids were heavier than female kids with corresponding values of 2.66±0.11 kg vs 2.00±0.07 kg for KR and 1.88±0.88 kg vs 1.23±0.08 kg for WAD at birth, 9.80±0.78 kg vs 8.25±0.79 for KR and 4.15±0.14 vs 3.43±0.34 kg for WAD at weaning, 15.57±1.18 kg vs 12.77±1.20 kg for KR and 5.75±0.51 kg vs 4.29±0.54 kg for WAD at 6-month post-weaning. Similar trend was observed for average daily gain with male kids showing superiority to their female counterparts with corresponding values 91.19±3.66 g vs 79.76±3.25g for KR and 30.06±2.54 g vs 28.36±4.52 g for WAD for PRW ADG. Kids born in the wet season were better (P<0.05) than dry season born kids in terms of all the five growth traits measured.

Single born kids were heavier (P<0.05) than twin-born kids at birth (2.59±0.13 kg vs 1.95±0.07 kg) for KR and (1.37±0.08 vs 1.69±0.07 kg) for WAD, weaning (11.70±0.43 kg vs 7.97±0.63 kg) for KR and (4.25±0.25 kg vs 3.56±0.30 kg) for WAD, post-weaning (18.21±0.81 kg vs 12.41±1.08 kg) for KR and (5.83±0.55 kg vs 4.16±0.05 kg) for WAD. Also, single kids had higher daily gain (P<0.05) than twin-born kids for pre-weaning ADG (111.11±4.64 g vs 75.75±2.76 g) for KR and (32.14±1.51 g vs 31.28±1.76 g) for WAD; and post-weaning ADG (88.67±3.57 g vs 52.85±1.96 g) for KR and (26.37±2.08 g vs 23.17±1.14 g) for WAD, while litter size did not affect birth weight significantly.

The growth patterns of KR (Figure 2) and WAD (Figure 3) were adequately represented by the four non-linear growth models (Brody, Gompertz, Logistic and Von Bertalanffy).

Table 3 showed that the model growth curve parameters: asymptotic body weight 'A', integration constant 'B' and rate of growth '*k*' differed between breeds with estimated values also differing among models. Von Bertalanffy model had the highest asymptotic weight 'A' for KR and WAD (24.24±0.94 kg vs 11.99±0.54 kg) while Gompertz had the least 'A' (17.36±0.20 kg vs 7.20±0.16 kg) for KR and WAD.

Table 1: Least squares means of body weight for KR and WAD goats as influenced by sex, season, birth type and parity at birth, weaning and 6-month

Source of variation	BWT (kg)				WWT (kg)				PWT (kg)			
	N	KR	N	WAD	N	KR	N	WAD	N	KR	N	WAD
Overall	61	2.30±0.06	63	1.56±0.06	61	8.88±0.57	63	3.88±0.20	61	13.97±0.86	63	5.05±0.37
Sex												
Male	36	2.66±0.11[a]	27	1.88±0.88[a]	36	9.80±0.78[a]	27	4.15±0.24[a]	36	15.57±1.18[a]	27	5.75±0.51[a]
Female	25	2.00±0.07[b]	36	1.23±0.08[b]	25	8.25±0.79[b]	36	3.43±0.34[b]	25	12.77±1.20[b]	36	4.29±0.54[b]
Season												
Late wet	35	2.54±0.07[a]	39	1.70±0.07[a]	35	9.60±0.69[a]	39	4.18±0.27[a]	35	15.08±1.10[a]	39	5.32±0.39[a]
Early dry	26	1.99±0.08[b]	24	1.27±0.10[b]	26	7.21±0.94[b]	24	3.51±0.29[b]	26	12.59±1.36[b]	24	4.07±0.59[b]
Type of birth												
Single	33	2.59±0.13[a]	25	1.37±0.08[a]	33	11.70±0.43[a]	25	4.25±0.25[a]	33	18.21±0.81[a]	25	5.83±0.55[a]
Twin	28	1.95±0.07[b]	38	1.69±0.07[b]	28	7.97±0.63[b]	38	3.56±0.30[b]	28	12.41±1.08[b]	38	4.16±0.50[b]
Parity												
1st Parity	25	2.26±0.10[a]	25	1.54±0.08[a]	25	8.43±1.02[a]	25	3.80±0.25[a]	25	13.71±1.55[a]	25	4.82±0.59[a]
2 Parity	36	2.33±0.08[a]	38	1.57±0.08[a]	36	9.02±0.66[a]	38	3.96±031[a]	36	14.17±0.99[a]	38	5.19±0.48[a]

[a,b]Means in the column within factor with different superscripts are significantly different ($P<0.05$).
BWT = birth weight.WWT = weaning weight.PWT = 6month post-weaning weight. N = number of observations. KR = Kalahari Red. WAD =West African dwarf

Table 2: Least squares means of pre-and post-weaning average daily gain of KR and WAD goats as influenced by sex, season, type of birth and parity

	PRWN ADG (g)				PSW ADG (g)			
Source of variation	N	KR	N	WAD	N	KR	N	WAD
Overall	61	84.44±2.44	63	31.73±1.16	61	61.88±1.81	63	24.84±1.21
Sex								
Male	36	91.19±3.66[a]	27	30.06±2.54[a]	36	73.18±3.05[a]	27	25.95±2.79[a]
Female	25	79.76±3.25[b]	36	28.36±4.52[b]	25	53.87±2.14[b]	36	24.19±1.02[a]
Season								
Late wet	35	88.74±3.32[a]	39	33.20±1.40[a]	35	65.14±2.44[a]	39	30.33±1.85[a]
Early dry	26	78.66±3.56[b]	24	29.49±2.00[b]	26	57.57±2.70[b]	24	16.59±1.70[b]
Type of birth								
Single	33	111.11±4.64[a]	25	32.14±1.51[a]	33	88.67±3.57[a]	25	26.37±2.08[a]
Twin	28	75.75±2.76[b]	38	31.28±1.78[b]	28	52.85±1.96[b]	38	23.17±1.14[b]
Parity								
1st Parity	25	82.24±3.99[a]	25	29.39±2.35[a]	25	59.13±2.06[a]	25	25.95±2.79[a]
2nd Parity	36	85.97±5.07[a]	38	33.10±4.22[a]	36	65.14±4.04[a]	38	24.19±1.02[a]

[a,b]Means in the column within factor with different superscripts are significantly different (P<0.05).
PRW ADG = pre-weaning average daily gain. PSW ADG = post-weaning average daily gain. N = number of observations. KR = Kalahari Red. WAD = West African dwarf.

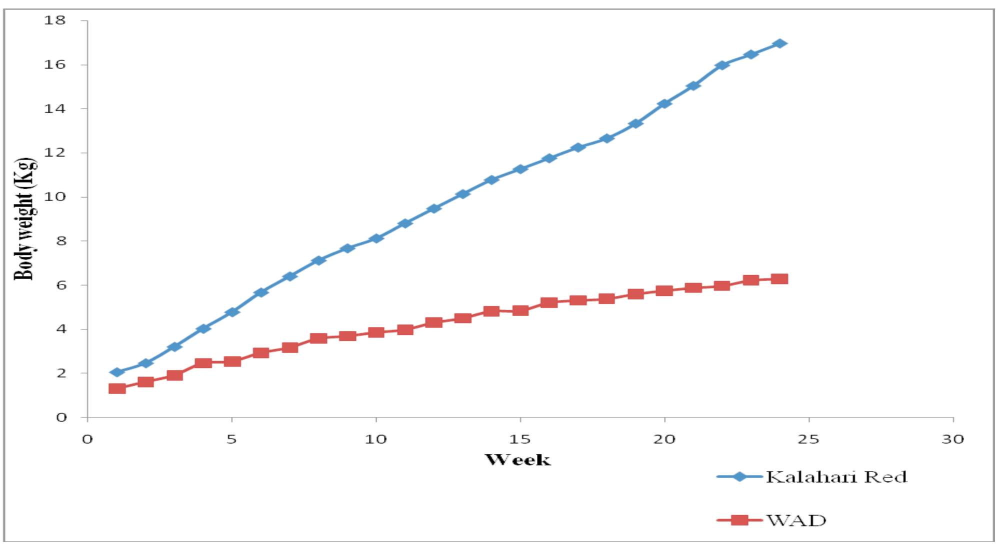

Figure 1: Weekly body weights of Kalahari Red and West African dwarf kids

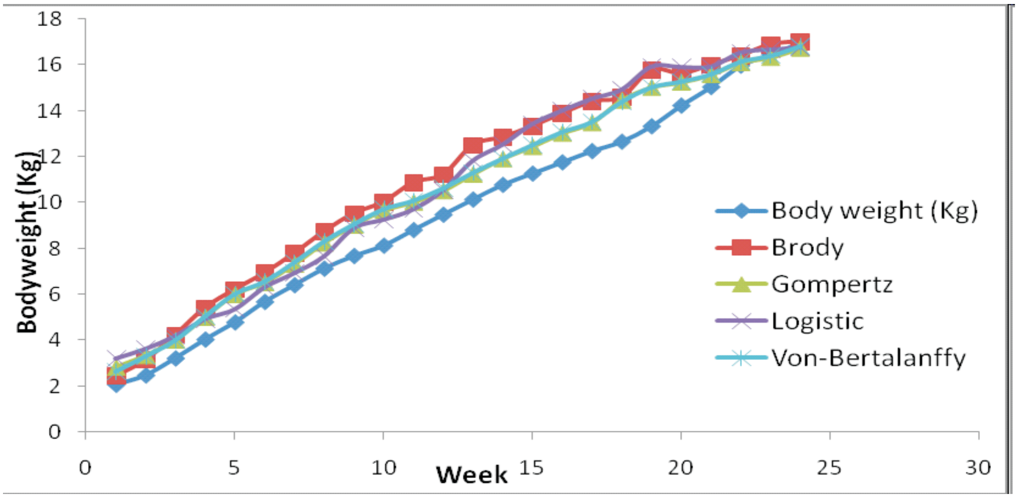

Figure 2: Growth curves of Kalahari Red kids

Male kids were heavier than female kids with corresponding values of 2.66±0.11 kg vs 2.00±0.07 kg for KR and 1.88±0.88 kg vs 1.23±0.08 kg for WAD at birth, 9.80±0.78 kg vs 8.25±0.79 for KR and 4.15±0.14 vs 3.43±0.34 kg for WAD at weaning, 15.57±1.18 kg vs 12.77±1.20 kg for KR and 5.75±0.51 kg vs 4.29±0.54 kg for WAD at 6-month post-weaning. Similar trend was observed for average daily gain with male kids showing superiority to their female counterparts with corresponding values 91.19±3.66 g vs 79.76±3.25g for KR and 30.06±2.54 g vs 28.36±4.52 g for WAD for PRW ADG. Kids born in the wet season were better (P<0.05) than dry season born kids in terms of all the five growth traits measured.

Single born kids were heavier (P<0.05) than twin-born kids at birth (2.59±0.13 kg vs 1.95±0.07 kg) for KR and (1.37±0.08 vs 1.69±0.07 kg) for WAD, weaning (11.70±0.43 kg vs 7.97±0.63 kg) for KR and (4.25±0.25 kg vs 3.56±0.30 kg) for WAD, post-weaning (18.21±0.81 kg vs 12.41±1.08 kg) for KR and (5.83±0.55 kg vs 4.16±0.05 kg) for WAD. Also, single kids had higher daily gain (P<0.05) than twin-born kids for pre-weaning ADG (111.11±4.64 g vs 75.75±2.76 g) for KR and (32.14±1.51 g vs 31.28±1.76 g) for WAD; and post-weaning ADG (88.67±3.57 g vs 52.85±1.96 g) for KR and (26.37±2.08 g vs 23.17±1.14 g) for WAD, while litter size did not affect birth weight significantly.

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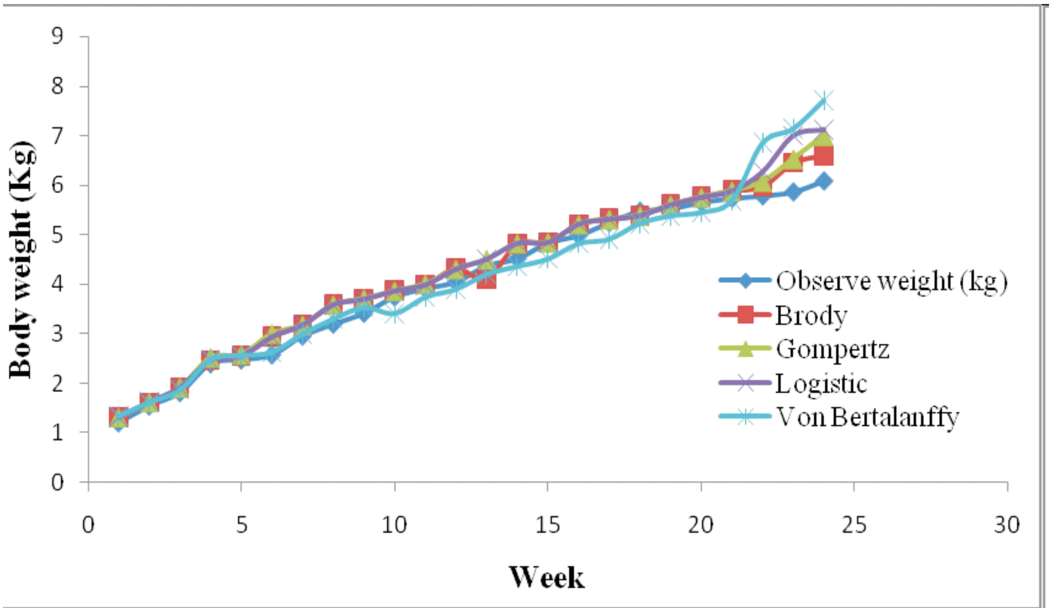

Figure 3: Growth curves of West African dwarf kids

Table 3: Parameter estimates and goodness of fit measure showing coefficient of determination, residual means square for Brody, Gompertz, Logistic and Von Bertalanffymodels

		Parameter estimate			Goodness of fit	
Models	**Breed**	**A**	**B**	***K***	**R^2**	**RMS**
Brody	KR	18.76±0.17	2.16±0.02	0.12±0.00	0.9998	0.0170
	WAD	8.12±0.20	1.67±0.01	0.08±0.00	0.9998	0.0032
Gompertz	KR	17.36±0.20	5.37±0.20	0.19±0.01	0.9996	0.0622
	WAD	7.20±0.16	3.38±0.09	0.13±0.01	0.9996	0.0090
Logistic	KR	19.70±0.21	0.54±0.00	0.10±0.01	0.9998	0.0177
	WAD	8.74±0.23	0.44±0.00	0.06±0.00	0.9998	0.0097
Von Bertalanffy	KR	24.24±0.94	0.95±0.01	0.04±0.00	0.9976	0.0544
	WAD	11.99±0.54	0.88±0.00	0.02±0.00	0.9992	0.0017

WAD =West African dwarf goat. KR =Kalahari Red. A = asymptotic weight. B = integration constant. K = rate of growth. R^2= co-efficient of determination. RMS = residual mean square.

Discussion

The results of this study clearly revealed that body weights differed based on the overall means for KR and WAD goats. The higher body weight observed in Kalahari Red breed is due to higher inherent ability to convert feed to muscle mass as reflected in the observed average pre-weaning and post-weaning daily gains. The KR goat is a new breed introduced in FUNAAB, Nigeria from South Africa. It has been classified as a large goat breed () with inherent potential for high birth weight and faster growth rate. As indicated by comparative growth curves for both breeds based on current datasets (Figure 1), KR goat breed maintained higher body weights at different stages of growth, also reflected in the mean body weights from birth to 6-month post-weaning. Unpublished studies at the same farm have shown that KR does were superior in milk production to WAD does; faster growth is therefore attributed to good milking ability of the dams which was available to the kids in sufficient quantity. The current estimates for body weights at birth corroborated reported figures for KR (www.indigenousbreeds.co.za/indigenousbreeds/goat/kalahari) and WAD (Bemji and Adenaike, 2011). The superiority of the males in terms of body weights and daily gain has been attributed to androgenic effect of male sex hormones. Other findings by Oderinwale (2014) have shown that males obtained relatively higher supply of nutrients during feeding than females and hence their superiority in body weights. This was similarly reported by other authors (Ikwuegbu *et al*., 1995; Amoah *et al*., 1996; Hagan *et al*., 2014) that male kids were generally heavier than female kids. Wet season in South West Nigeria is characterized by high rainfall that encourages lush vegetation with good quality feed which encourages milk production and hence the amount of milk available to the kids. Significant seasonal effects on body weights of kids have also been reported (Das *et al.,* 1996; Moore, 2000; Baiden, 2007). Significantly lower body weights of twin-born kids at weaning and 6-month post-weaning could be attributed to competition by litter mates for available milk from their dams compared to single-born kid. The current observation corroborated the findings of Oderinwale (2014) working with KR goat and Bushara *et al*. (2013) that birth weight was significantly influenced by type of birth. The effect of parity on body weights was insignificant. The does utilized for this study were of first and second parities. Their offspring could be similar in body weights given that both groups constitute young does. Table 3 showed that the model growth curve parameters: asymptotic body weight 'A', integration constant 'B' and rate of growth '*k*' differed between breeds with estimated values also differing among models. Highest asymptotic weight predicted by Von Bertalanffy model for KR goats implies that weight at later age will be higher than that of WAD goats. The integration constant 'B' had highest estimates from Gompertz model (5.37±0.20 and 3.38±0.09 for KR and WAD goats respectively). On the other hand, Logistic model had the least 'B' estimates (0.54±0.00 and 0.44±0.00 for KR and WAD goats respectively), with implication that Gompertz model predicted higher turning point of growth for KR goat than WAD goat. The rate of maturity '*k*' also differed among the four models. Gompertz model had the highest estimates for KR and WAD (0.19±0.01 vs 0.13±0.01) while Von Bertalanffy model had the least estimates (0.04±0.00 vs 0.02±0.00) for KR and WAD goats. Gompertz model predicted fastest maturity rate for KR goat compared to WAD goat. This was in agreement with Goonewardene *et al*. (2003) who reported that larger value for the rate of maturity indicates earlier maturity and smaller value indicates late maturity. The goodness of fit and computing difficulty measure based on R^2 and RMS (Table 3) indicated that all four non-linear models had good fit to the observed data. The KR and WAD goats had similar R^2 estimates exceeding 99% and low RMS estimates. These results closely agreed with high R^2 (0.9992) for Brody's model estimated using data from WAD goat (Ajao, 2012), 97.9 estimated using data from Kalahari female goats (Hifzan *et al*., 2015), 0.9979 estimated with data from Be*et al* goat (Waheed *et al.,* 2011), 0.991 estimated with data from Morkaraman and

Awassi lambs (Topal *et al.,* 2004) while Ozdemir and Dellal (2009) obtained 0.956 vs 0.957 for Gompertz and Logistic models. The growth curves (Figures 1-3) clearly represented what is expected of the first and second phases of a sigmoid curve as stipulated by Najari *et al*. (2007). In first phase, growth started from birth and increased gradually. In second phase, curves adopted a linear shape up the 24th week when the study lasted. The distortion point or asymptote (De Lange *et al*., 1998) was not very obvious since the animals were not monitored beyond 24 weeks and optimal age at maturity is likely to exceed this value.

Conclusion

It can be concluded from this study that KR exceeded WAD goat in terms of body weights at birth, weaning, 6-month post-weaning, pre-weaning and post-weaning average daily gains. Non-genetic factors (litter size, sex of kid and season of birth) significantly influenced body weights and average daily gain. All four growth models gave good fit to the observed growth data and can be used to implement feeding and management decisions that will optimize productivity. Information on superior growth performance of the KR goat can be utilized to further investigate genetic improvement of the indigenous WAD population through crossbreeding.

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