Research Journal of Animal Sciences 5 (1): 6-13, 2011
ISSN: 1993-5269

Growth Pattern of Purebred West African Dwarf Sheep and its Crosses with the West African Long Legged

[1, 5]A.B. Gbangboche, [2]T.I. Alkoiret, [3]S. Salifou, [4]F. Farnir, [4]P.L. Leroy and [3]F.A. Abiola
[1]Department of Animal Production, Faculty of Agronomics Sciences, University of Abomey Calavi, 01 P.O. Box 526 Cotonou, Republic of Benin
[2]Department of Animal Production, Faculty of Agronomy, University of Parakou, 01 P.O. Box 123 Parakou, Republic of Benin
[3]Department of Animal Health and Production, Polytechnic School of Abomey Calavi, University of Abomey Calavi, 01 P.O. Box 2009 Cotonou, Republic of Benin
[4]Department of Animal Production, Faculty of Veterinary Medicine, University of Liege, Bat 43, 20 Boulevard de Colonster, 4000 Liege, Belgium
[5]Laboratoiry of Biotechnology and Animal improvement, Institute of Biomedical Applied Sciences, Champ de Foire, 01 P.O. Box 918 Cotonou, Republic of Benin

Abstract: The weight patterns of the indigenous West African Dwarf (WAD) sheep and its crosses with the West African Long Legged (WALL) ram was analyzed using Gompertz (GP) and Von Bertalanffy (VB) models. Within both models, the VB model presents good accuracy of fit according to the higher determination coefficient, lowest mean squares errors, Bayesian information criterion and absolute mean residual deviation. Considering the models parameters (A, B and k), the correlations between A and k were negative. The values of A and B were respectively +15.90, +0.09 higher in F1 than WAD breeds. Otherwise, k is higher in WAD indicating the faster growth of this breed to reach maturity early than F1. For the live body weight (kg), the superiority of F1 over the WAD was as follow: +0.89 (BW), +1.68 (W3), +4.16 (W6), +6.36 (W9) and +9.32 (W12). When comparing the effects of sex, type of parturition and parity of ewe from birth up to 360 days of age, the trend of F1 was from +0.15 to +7.46 kg (single), + 0.57 to+9.98 kg (twin), +1.13 to +12.48 kg (male), +0.64 to +6.58 kg (female), +0.6 to +7.09 kg (parity2), +0.42 to +2.4 kg (parity3) and +0.13 to +7.33 kg (parity4) than WAD breed. This study may be helpful to improve the weight of WAD sheep through crossbreeding with WALL ram in controlled environment and early selection of ram for genetic improvement schemes.

Key words: Djallonke sheep, Sahelian sheep, growth curve, cross breeding, weight, environment

INTRODUCTION

In Benin as well as in African Sub-Saharan countries, the value of sheep as renewable resources for poor people is widely recognized but efforts to increase their productivity are insufficient compared to other livestock. As pointed out by Devendra (1981), the limited knowledge associated with inadequate understanding on sheep has hampered the development of technology to improve productivity. The indigenous sheep breeds of Benin Republic consist of the West African Dwarf (WAD) and accessory the West African Long-Legged (WALL) sheep. The WAD sheep (i.e., Djallonke sheep) is a hairy sheep breed found all over West and Central Africa South of 14° latitude and widely distributed throughout the savannah and humid zones (Carles, 1983). It is a compact breed with a small mature size and short horizontal lop ears. Coat colour varies from spotted black and white to solid black or white. Some have tan or brown coat colour and black bellies. Rams are horned and females usually polled. WAD sheep are able to limit parasite multiplication and remain productive in tsetse-infested areas where other breeds cannot survive without treatment (D'Ieteren, 1994). The details on the characteristics of WAD sheep were fully described (Epstein, 1971; Carles, 1983; Gatenby *et al*., 1997). The West African Long-Legged (WALL) sheep (i.e., Fulani, Peul, Bali-Bali, Maure, Tuareg, Guinea Long-legged and Sahelian sheep) is widespread from the Guinea savannah through the Soudan to Sahel (Epstein, 1971; Carles, 1983). The WALL sheep is hairier usually white, white and brown or white and black with lop ears.

Corresponding Author: A.B. Gbangboche, Department of Animal Production, Faculty of Agronomics Sciences, University of Abomey Calavi, 01 P.O. Box 526 Cotonou, Republic of Benin

The males display a long twisting pattern to the horns and the females are usually polled. WALL sheep were considered hardy and well adapted to the arid environment. Compared to the WAD sheep, the main difference is that the WALL sheep is taller, heavier and trypanosusceptible (Toure *et al*., 1981).

Over three decades, Adu and Ngere (1979) reported the limited meat production of WAD sheep that could alter gross income due to it biological characteristics (low growth rate, small body conformation and mature size). The need of WAD sheep breeders is to exploit new sheep breeds, to match genetic potential with divergent climates, feed resources and market preferences. The use of crossing WAD ewe with WALL rams for the meat purpose have been experimented providing impressive lessons learned (Taiwo *et al*., 1982; Kabuga and Akowuah, 1991; Osaer *et al*., 1994; Goossens *et al*., 1999). However, the cross breeding to improve growth traits is a complex activity that needs efficient organization and improved management, taken into account the capacity of breeder to manage the animals and to obtain the necessary external inputs. For this purpose, the Ecole Inter-Etats des Sciences et Medicine Veterinaires de Dakar (West Africa) and the Tropical Veterinary Institute of University of Liege (Belgium) have initiated during 1997, a research programme on F1 cross breeding involving WAD ewes with WALL rams in sub humid regions of Benin in order to boost meat production. The research challenge is to measure the growth pattern of target animals, to determine feeding and management plans and design breeding strategies to improve the whole growth process. Knowledge of factors affecting the shape of the growth curves of these animals and the relationship between the growths curves parameters are required to improve weight efficiency (Lambe *et al*., 2006). In developing countries, studies on growth pattern have been tested (Tsukahara *et al*., 2008; Malhado *et al*., 2009), using Brody (1945), Von Bertalanffy (1957), Richards (1959), Logistic, Nelder (1961) and Gompertz, Laird (1965) function for sheep growth function. The goodness of fit model involve various criteria such as the coefficient of determination (R^2), the Mean Squares Errors (MSE), the log-likelihood (lnL) values, the Akaike's Information Criteria (AIC), the least Average Prediction Error (APE) and the Absolute Mean residual Deviation (MAD) (Brown *et al*., 1976; Goonewardene *et al*., 1981; Beltran *et al*., 1992; Lambe *et al*., 2006). Given the lack of knowledge on the shape of growth in West African sheep breeds, the objective of this study was to analyze the growth patterns of two breeds i.e., the WAD and F1 (WAD x WALL) sheep using Gompertz (GP) and Von Bertalanffy (VB) growth models.

MATERIALS AND METHODS

Environment and animal management: The experience was carried at the Faculty of Agronomics Sciences station (University of Abomey Calavi) and at the Agriculture College farm of Adja-Ouere. The climate of the two sites was quite similar i.e., subhumid type with a mean annual rainfall of 1000-1200 mm within a period of about 250 days. The rain pattern divided the year into four seasons: Major rainy season (March to June), short dry season (July to August), short rainy season (September to October) and major dry season (November to February). There is no data on the trypanosomosis risk level of these sites. The management of the flocks was quite typical. Animals had been raised during the day (6-7 h) on natural and cultivated pasture of Andropogon, Hyparrhenia, Pennisetum, Setaria, Brachiaria, Panicum, Centrosema, leucaena and Stylosanthes throughout the year with supplementation (e.g., cottonseed cake, maize straw, wheat bran and cassava peels, groundnut haulms and brewery draff) for the nursing ewe and only in the dry season for the other animals. All lambs received an injection of Vitamins A, D_3 and E in the 1st 30 days after birth. Weaned lambs had no particular access to feed other than that offered to the ewes. All animals were penned at night. Salt licks and water were provided *ad libitum*. During the experiment phase, sick animals were treated and health care involved annual vaccination against Peste des Petits Ruminants, strategically deworming (Panacur® 10%, 5 mg kg^{-1} body weight) 4 times annually i.e., January-April-June and September. Monthly treatments against external parasites occur during the rainy season and every 2 months in dry season (pour-on acaricide, Bayticol® 1%). Additionnal strict health care measures were taken for F1 sheep to limit trypanosomosis stress involving systematic quarterly chemoprophylaxis (isometamidium chloride i.e., samorin® as curative drugs dose of 0.5 mg kg^{-1} bodyweight). The mature WALL rams (60-65 kg) were purchased from Gao in Mali (West Africa) and the WAD rams (35-40 kg) from the flock of the Faculty of Agronomics Sciences in Benin. From year 2004-2008, 7 WAD and 4 WALL rams were used as breeders displaying good reproductive performance. About 25 WAD ewes were assigned at random to each breed of rams for mating. To avoid dystocia the WALL rams did not mate the first parity ewes (Osuagwuh *et al*., 1980; Gama *et al*., 1991; Fahmy and Robert, 1997). Lambing occurred all year round and no strict breeding season was enforced. The lambs were left with the ewes on pastures up to weaning at 90 days and after were managed separately until slaughtering 360 days of age. Prior to experimentation, WALL rams were properly follow during 3 months acclimation period and both breeds were checked for trypanosomosis and helminthosis. Trypanosomosis was detected by microcoscopy and treated with diminazen aceturate (Veriben® at 3.5 mg kg^{-1} body weight) when the packed cell volume reached 17% or below. The number of strongle eggs per gram of faeces was determined and infested animals were treated with Panacur® 10%.

Performance records: The database consists of 3, 650 weight records from 730 animals, involving 547 WAD (2, 735 records) and 183 F1 (915 records) breeds. Each lamb has 5 records and was Weighted at Birth (BW) at 3 months (W3), 6 months (W6), 9 months (W9) and 12 months (W12) weight. BW was taken within 24 h of birth using a platform type dial balance (10 kg capacity and 0.05 kg accuracy). W3 and onwards were taken with a suspended spring balance (50 and 0.2 kg accuracy).

Growth models and statistical analyses: Gompertz (Laird, 1965) functions were fitted to model the relationship between weight and age, using the non linear model procedure (PROC NLIN) of SAS® 9.2 (SAS, 2009). The description of these models is:

$$\text{Gompertz (sigmoid)}, W_t = A \exp(-Be^{-Kt})$$

$$\text{Von Bertalanffy (sigmoid)}, W_t = A(1-Be^{-Kt})^3$$

Where:

- W_t = The observed live weight at age t
- A = The asymptotic or mature weight
- B = The constant of integration
- k = The maturing rate
- t = The age in day

The effect of WAD and F1, litter type (single and twin), sex (Male and female) and dam parity (1st-4th parity) on the growth curve parameters was tested for each model using the General Linear Model procedure (proc GLM) of SAS® 9.2 (SAS, 2009). The model selection criteria involve higher R^2, lower MSE and BIC (Brown *et al*., 1976; Topal *et al*., 2004; Lambe *et al*., 2006) and lower absolute mean residual deviation, MAD (Malhado *et al*., 2009).

The Degree of Maturity (DM) at time t as the value of the function W_1 relative to the asymptotic measure at maturity (A) was calculated (Fitzhugh and Taylor, 1971). The observed versus predicted weight from birth up to 360 days of age was performed, according to the fixed factors: breeds (WAD and F1), litter type (single and twin), sex (male and female) and dam parity (1st-4th parity).

RESULTS AND DISCUSSION

Growth curve parameters A, B and k: The parameter A was higher ($p<0.05$) in VB than GP model and within breeds in F1 than WAD breed indicating the possibility to improve body size through cross breeding of WAD ewe with WALL ram (Table 1-3). When fitting GP model in other sheep breeds, Malhado *et al*. (2009) reported A values between 28.48±10.55 and 32.52±7.64, comparable to the study. The finding of Topal *et al*. (2004) about A, 41.4±1.20 and 40.6±1.00 (GP model) and 42.5±1.20 and 41.7±1.10 (VB model) are within the range obtained with F1 breed of this study. According to the fixed factors, the parameter A was higher ($p<0.05$) for male than female, single than twin and increase significantly ($p<0.05$) with increasing parity number, except parity 2 for WAD (Table 2) and parity 3 for F1 breeds (Table 3). Similar effect of fixed factors was reported by Bathaei and Leroy (1996), McManus and Sarmento.

However, Malhado *et al*. (2009) not found significant effect of sex, type of parturition and breed on the parameter A.

The values of B (Table 1-3) were higher than those of Topal *et al*. (2004) varying between 2.06±0.05 and 2.08±0.04 (GP model) and 0.52±0.01and 0.52±0.01 (VB models), pointing out the importance of data structure and the breed on the parameter B. Within models and fixed factors, B is higher in GP than VB ($p<0.05$), F1 than WAD,

Table 1: Estimates f the parameters (A, B and k), the Mean Square Error (MSE), correlation between A and k, determination coefficient (R^2), the Bayesian Information Criterion (BIC) and the Mean Absolute Deviation (MAD) according to the Gompertz and Von Bertalanffy growth model for all genetic groups and WAD and F1 (WAD x WALL) genetic groups

		Genetic group	
Parameters/ Statistical analysis	General	WAD	F1 (WAD x WALL)
Records	3650	2735	915
Models parameters			
A	31.55±0.60‡	27.81±0.57‡[a]	43.70±1.36‡[b]
	34.61±0.90¥	30.06±0.80¥[a]	50.14±2.21¥[b]
B	2.64±0.05‡	2.62±0.06‡[a]	2.71±0.05‡[b]
	0.61±0.00¥	0.61±0.00¥[a]	0.62±0.00¥[b]
k	0.007±0.00‡	0.008±0.00‡[a]	0.006±0.00‡[b]
	0.005±0.00¥	0.006±0.00¥[a]	0.004±0.00¥[b]
Cor A and k	-0.92‡	-0.90‡	-0.94‡
	-0.95¥	-0.94¥	-0.97¥
Selection criteria			
MSE	26.45‡	22.75‡	14.42‡
	26.35¥	22.66¥	14.31¥
R^2	0.75‡	0.74‡	0.89‡
	0.75¥	0.74¥	0.89¥
BIC	8981.4‡	7303‡	1915.6‡
	8312.0¥	6985.0¥	1423.3¥
MAD	3.82‡	3.63‡	2.71‡
	3.80¥	3.61¥	2.69¥

Within a row (and within genetic group), value with different superscript letters differ significantly at $p<0.05$ ‡Gompertz model, ¥ Von Bertalanffy model

Table 2: Estimates of the parameters (A, B and k), the Mean Square Error (MSE), correlation between A and k, determination coefficient (R^2), the Bayesian Information Criterion (BIC) and the Mean Absolute Deviation (MAD), according to the Gompertz growth model for West African Dwarf (WAD) and F1 (WAD x WALL) genetic group

	Litter type		Sex		Parity			
Fixed factors	Single	Double	Female	Male	1	2	3	4
Records	1615	1120	1345	1390	665	490	570	510
	(695)	(220)	(450)	(465)	-	(185)	(370)	(360)
Model parameters								
A	32.43±0.69^{a}	21.24±0.56^{b}	26.58±0.83^{a}	29.01±0.76^{b}	24.65±1.44^{a}	25.12±0.46^{b}	31.76±0.47^{c}	37.45±0.62^{d}
	(45.00±1.30^{a})	(39.73±2.32^{b})	(37.52±1.05^{a})	(49.47±1.72^{b})	-	(40.39±1.66^{a})	(35.03±1.03^{b})	(57.38±3.08^{c})
B	2.40±0.05^{a}	3.46±0.22^{b}	2.66±0.10^{a}	2.59±0.08^{b}	2.84±0.11^{a}	3.03±0.12^{b}	2.42±0.05^{c}	2.30±0.04^{d}
	(2.66±0.05)^{a}	(2.92±0.09^{b})	(2.69±0.05^{a})	(2.73±0.06^{b})	-	(2.80±0.07^{a})	(2.53±0.09^{b})	(2.90±0.06^{c})
k	0.001±0.00^{a}	0.010±0.00^{b}	0.007±0.00^{a}	0.008±0.00^{b}	0.006±0.00^{a}	0.010±0.00^{b}	0.008±0.00^{c}	0.007±0.00^{d}
	(0.006±0.00^{a})	(0.006±0.00^{b})	(0.006±0.00^{a})	(0.006±0.00^{b})	-	(0.006±0.00^{a})	(0.007±0.00^{b})	(0.005±0.00^{c})
Cor A and k	-0.92	-0.87	-0.90	-0.90	-0.94	-0.86	-0.88	-0.91
	(-0.94)	(-0.95)	(-0.93)	(-0.94)	-	(-0.94)	(-0.90)	(-0.96)
Selection criteria								
MSE	14.73	16.79	22.36	21.74	10.55	5.64	4.86	4.57
	(11.37)	(5.95)	(4.89)	(10.68)	-	(3.31)	(10.02)	(11.13)
R^2	0.84	0.74	0.73	0.76	0.79	0.92	0.94	0.95
	(0.92)	(0.94)	(0.95)	(0.93)	-	(0.96)	(0.91)	(0.93)
BIC	4237.4	3231.1	3361.3	3948	645.8	1692	2006.3	1656.1
	(1601.1)	(421.4)	(893.5)	(1064.0)	-	(349.2)	(1178.3)	(918.5)
MAD	3.16	3.22	3.40	3.66	2.63	1.87	1.75	1.65
	(2.13)	(1.73)	(1.62)	(2.36)	-	(1.21)	(2.32)	(2.23)

The values for F1 (WAD x WALL) genetic group is within parentheses within a row (and within each factor), value with different superscript letters differ significantly at $p<0.05$

Table 3: Estimates of the parameters (A, B and k), the Mean Square Error (MSE), correlation between A and k, determination coefficient (R^2), the Bayesian Information Criterion (BIC) and the Mean Absolute Deviation (MAD), according to the Von Bertalanffy growth model for WAD and F1 (WAD x WALL) genetic groups

	Litter type		Sex		Parity			
Fixed factors	Single	Double	Female	Male	1	2	3	4
Records	1615	1120	1345	1390	665	490	570	510
	(695)	(220)	(450)	(465)	-	(185)	(370)	(360)
Model parameters								
A	35.06±0.95^{a}	22.52±0.79^{b}	28.84±1.17^{a}	31.25±1.06^{b}	28.30±2.31^{a}	26.71±0.63^{b}	33.53±0.60^{c}	39.98±0.82^{d}
	(51.19±2.07^{a})	(47.32±4.04^{b})	(42.55±1.64^{a})	(57.22±2.85^{b})	-	(47.15±2.16^{a})	(37.98±1.46^{b})	(71.19±5.87^{c})
B	0.58±0.00^{a}	0.75±0.03^{b}	0.62±0.01^{a}	0.60±0.01^{b}	0.65±0.01^{a}	0.67±0.02^{b}	0.58±0.01^{c}	0.56±0.006^{d}
	(0.61±0.00^{a})	(0.66±0.01^{b})	(0.62±0.00^{a})	(0.63±0.01^{b})	-	(0.64±0.01^{a})	(0.59±0.01^{b})	(0.65±0.00^{c})
k	0.005±0.00^{a}	0.007±0.00^{b}	0.006±0.00^{a}	0.006±0.00^{b}	0.004±0.00^{a}	0.007±0.00^{b}	0.006±0.00^{c}	0.005±0.00^{d}
	(0.004±0.00^{a})	(0.004±0.00^{b})	(0.005±0.00^{a})	(0.004±0.00^{b})	-	(0.004±0.00^{a})	(0.005±0.00^{b})	(0.003±0.00^{c})
Cor A and k	-0.95	-0.92	-0.94	-0.94	-0.97	-0.91	-0.92	-0.94
	(-0.96)	(-0.97)	(-0.96)	(-0.97)	-	(-0.97)	(-0.94)	(-0.98)
Selection criteria								
MSE	14.47	16.96	22.27	21.66	10.41	5.72	4.72	4.42
	(11.26)	(5.85)	(4.76)	(10.60)	-	(3.20)	(9.94)	(11.02)
R^2	0.84	0.73	0.73	0.77	0.79	0.92	0.95	0.96
	(0.92)	(0.94)	(0.95)	(0.93)	-	(0.97)	(0.91)	(0.93)
BIC	4154.4	3073.4	3177.1	3809.3	273.9	1624.8	1999.5	1653
	(1289.2)	(279.4)	(700.2)	(783.7)	-	(227.7)	(1128.2)	(731.8)
MAD	3.12	3.26	3.42	3.64	2.57	1.90	1.68	1.60
	(2.41)	(1.66)	(1.57)	(2.35)	-	(1.22)	(2.31)	(2.18)

The values for F1 (WAD x WALL) genetic group is within parentheses within a row (and within each factor), value with different superscript letters differ significantly at $p<0.05$

twin than single, lamb of parity 2 and 4 of both breeds and in female than male of WAD breed. Similar effect of breed on B as well as the type of parturition effect and the interaction between breed and sex was early reported in other sheep breeds (Malhado *et al*., 2009). The values of maturation rate k (Table 1-3) were quite higher than those found in Malhado *et al*. (2009) paper, varying between 0.0132 and 0.0171 and <0.012±0.001 (GP model) and 0.010±0.001 (VB models) reported by Topal *et al*. (2004). Within models and fixed factors, k is higher ($p<0.05$) in GP than VB, WAD than F1, male than female of WAD (GP model) while lower in VB model, increase consistency from parity 2-3 and comparable between single and twin of F1. The higher k value of WAD, imply that this breed show faster growth and could reach mature weight early and then could be mated and slaughtered earlier than F1 breed. Similar sex, litter type, parity and breed effects on k has been reported (Malhado *et al*., 2009) however, the higher k value of twin over single in WAD breed, constitutes a peculiar situation and need to be more investigated with other data set.

Correlations between parameters A and k: Negative correlations between A and k were found in both models, breed, sex, litter type and ewe parity (Table 1-3).These correlation were higher in VB than GP models in F1 than WAD breeds, single than twin of WAD sheep. The highest correlation of F1 over WAD lambs could be due the effect of crossbreeding mainly related to heterosis and complementarily. According to ewe parity, F1 lambs from parity 4 and 3 and those of WAD from Parity 1 and 2 present, respectively higher and lower correlation. In many studies on other sheep breeds, negative correlations were commonly found (Bathaei and Leroy, 1996; Tsukahara *et al*., 2008).

Selection criteria and goodness of fit: R^2 (>70%) within models and fixed factors (breeds, litter type, sex and ewe parity) were comparable (Table 1-3) while MSE, BIC and MAD lower in VB than GP. When fitting VB and GP models, Malhado *et al.* (2009), reported than in this study, highest R^2 values of 98%, lowest MSE (1.049 and 1.238) and MAD (0.68 and 0.63). The higher R^2 of this study, imply the good adjustment of data with both models. However, VB has the lowest MSE, BIC and MAD, indicating it accuracy to fit the studied growth (Table 1-3). According to many studies, the best function to describe the body growth in sheep remains controversial, depending of the data set, model fitted and fixed factors such as breed, season and year of birth, ewe parity and sex of lamb. That is why different functions have been consequently selected to fit growth curves: Logistic and Gompertz (Malhado *et al*., 2009), Richards and Gompertz (Lambe *et al*., 2006), Gompertz, Gompertz and Bertalanffy models (Topal *et al*., 2004).

Degree of Maturity (DM): The trends of DM point out the hypothesis that WAD present faster maturity rate than F1 breed (Table 4). Within models and fixed factors, DM was higher in GP than VB, single than twin, male than female and consistency increases from parity 2-4. Such information must be exploited in the choice of ewe for reproduction, sex and litter type of lambs to improve growth performance. Classically, females could be mated for the first time when they have about 60% of their final live body weight and in the case, the approximate age to reach this weight is 270 and 360 days, respectively for WAD and F1 breeds (Table 4). However, Devendra and Burns (1983) recommend collecting more live body weight data at first estrus as proportion of adult (mature) weight in various breed to prevent premature breeding and stunted growth.

Table 4: Estimates of maturity degrees (%) from Gompertz and Von Bertalanffy growth model, according to the litter type, sex and parity for birth day (day 1), 90, 180, 270 and 360 days weigh in WAD and F1 (WAD x WALL) genetic groups

	Age (days)				
Parameters	1	90	180	270	360
Model	7 (6)‡	28 (22)‡	54 (43)‡	74 (62)‡	86 (77)‡
	6 (5)¥	26 (19)¥	49 (19)¥	68 (37)¥	80 (67)¥
Litter type					
Single	9 (7)‡	28 (23)‡	52 (44)‡	71 (64)‡	84 (78)‡
	7 (6)¥	27 (21)¥	48 (39)¥	66 (56)¥	78 (69)¥
Double	3 (5)‡	24 (18)‡	56 (37)‡	79 (56)‡	91 (72)‡
	1 (4)¥	24 (16)¥	53 (31)¥	74 (47)¥	86 (60)¥
Sex					
Female	7 (7)‡	27 (23)‡	53 (44)‡	73 (64)‡	85 (78)‡
	5 (5)¥	26 (20)¥	49 (39)¥	67 (60)¥	79 (69)¥
Male	7 (6)‡	28 (21)‡	54 (42)‡	74 (61)‡	87 (76)‡
	6 (5)¥	27 (19)¥	50 (36)¥	69 (52)¥	81 (63)¥
Parity					
1	6‡	20‡	41‡	61‡	76‡
	4¥	18¥	36¥	53¥	66¥
2	5 (6)‡	29 (20)‡	60 (40)‡	81 (59)‡	92 (74)‡
	3 (5)¥	28 (18)¥	56 (34)¥	76 (50)¥	87 (64)¥
3	9 (8)‡	32 (29)‡	59 (54)‡	78 (74)‡	89 (86)‡
	7 (6)¥	31 (27)¥	56 (50)¥	73 (67)¥	85 (80)¥
4	10 (5)‡	31 (17)‡	55 (34)‡	74 (53)‡	85 (68)‡
	8 (4)¥	29 (14)¥	51 (28)¥	68 (42)¥	80 (55)¥

The maturity degree of F1 (WAD x WALL) genetic group is within parentheses; ‡, Gompertz model, ¥ Von Bertalanffy

Overall growth performance: GP and VB models over estimated BW and under estimated W3 in both breeds. However, due to its lowest MSE, MAD and BIC, VB was closer to the observed weight better than GP (Table 5). Those observed weights from birth up to 360 days consistently increase at +22.64 kg (WAD breed) and +31.37 kg (F1 breed). Between breeds, F1 lambs were +0.89 (BW), +1.68 (W3), +4.16 (W6), +6.36 (W9) and +9.62 (W12) heavier than WAD (Table 5). According to the type of birth, sex and ewe parity, the advantages of F1 over WAD range from BW to W12 as follow: +0.15 to +7.46 kg (single), +0.57 to+9.98 kg (twin), +1.13 to +12.48 kg (male), +0.64 to +6.58 kg (female), +0.6 to +7.09 kg (parity 2), +0.42 to +2.4 kg (parity 3) and +0.13 to +7.33 kg (parity 4) (Table 5).

Lambs of both breeds grew faster with increasing ewe parity, similarly to the reports of Gbangboche *et al.* (2006) and Bosso *et al.* (2007). The first parity ewes are still growing and the competition between fetal growth and

Table 5: Estimates of predicted live body weight from Gompertz and Von Bertalanffy growth model versus observed mean weight, according to the litter type, sex and parity in WAD and F1 (WAD x WALL) genetic groups

		Livebody weight			
Parameters	BW	W3	W6	W9	W12
Model	2.05 (2.56)‡	7.77 (4.44)‡	14.97 (17.01)‡	20.59 (23.07)‡	24.03 (35.15)‡
	1.78 (2.63)¥	7.99 (9.85)¥	14.95 (18.80)¥	20.42 (27.04)¥	24.15 (33.71)¥
	1.63 (2.52)ℜ	8.16 (9.84)ℜ	14.96 (19.12)ℜ	20.22 (26.58)ℜ	24.27 (33.89)ℜ
Litter type	**	**	**	**	**
Single					
	2.97 (3.18)‡	9.32 (10.35)‡	17.00 (20.00)‡	23.21 (28.76)‡	27.27 (35.15)‡
	2.65 (2.87)¥	9.52 (10.61)¥	17.01 (20.01)¥	23.07 (28.53)¥	27.28 (35.29)¥
	2.03 (2.81)ℜ	10.14 (10.52)ℜ	17.39 (20.45)ℜ	21.81 (28.01)ℜ	28.04 (35.50)ℜ
Double					
	0.69 (2.16)‡	5.24 (7.28)‡	12.01 (14.87)‡	16.90 (22.49)‡	19.37 (28.58)‡
	0.37 (1.87)¥	5.74 (7.47)¥	12.03 (14.94)¥	16.72 (22.32)¥	19.74 (28.66)¥
	1.04 (1.61)ℜ	5.29 (7.71)ℜ	11.46 (14.98)ℜ	17.92 (22.06)ℜ	18.81 (28.79)ℜ
Sex	**	**	**	**	**
Female					
	1.88 (2.58)‡	7.23 (8.54)‡	14.08 (16.64)‡	19.49 (24.01)‡	22.84 (29.36)‡
	1.62 (2.30)¥	7.43 (8.76)¥	14.05 (16.66)¥	19.33 (23.82)¥	22.96 (29.47)¥
	1.46 (2.10)ℜ	7.52 (8.77)ℜ	14.31 (17.18)ℜ	18.84 (23.09)ℜ	23.20 (29.78)ℜ
Male	2.21 (3.27)‡	8.29 (10.63)‡	15.84 (20.83)‡	21.66 (30.41)‡	25.19 (37.62)‡
	1.94 (2.95)¥	8.53 (10.91)¥	15.81 (20.86)¥	24.48 (30.16)¥	25.30 (37.76)¥
	1.79 (2.92)ℜ	8.78 (10.88)ℜ	15.59 (21.03)ℜ	21.54 (29.95)ℜ	25.35 (37.83)ℜ
Parity	**	**	**	**	**
1	1.45‡	5.02‡	10.75‡	15.02‡	18.70‡
	1.21¥	5.12¥	10.17¥	14.92¥	18.78¥
	0.95ℜ	4.78ℜ	11.70ℜ	13.14ℜ	19.47ℜ
2	1.24 (2.48)‡	7.30 (8.15)‡	15.21 (16.21)‡	20.48 (21.04)‡	23.12 (30.03)‡
	0.95 (2.18)¥	7.60 (8.35)¥	15.08 (16.26)¥	20.27 (23.82)¥	23.30 (30.13)¥
	1.38 (1.98)ℜ	7.10 (8.45)ℜ	15.51 (16.56)ℜ	20.18 (23.34)ℜ	23.24 (30.33)ℜ
3	2.82 (2.85)‡	10.31 (10.10)‡	18.86 (19.02)‡	24.95 (25.97)‡	28.40 (30.25)‡
	2.52 (2.54)¥	10.60 (10.37)¥	18.83 (18.96)¥	24.80 (25.75)¥	28.51 (30.41)¥
	2.12 (2.54)ℜ	11.46 (10.20)ℜ	17.60 (19.45)ℜ	25.19 (25.70)ℜ	28.23 (30.63)ℜ
4	3.20 (3.81)‡	9.92 (11.62)‡	19.84 (20.66)‡	27.68 (30.20)‡	32.12 (38.90)‡
	2.88 (3.49)¥	10.16 (11.90)¥	20.67 (29.95)¥	27.51 (29.95)¥	32.20 (39.01)¥
	2.77 (2.90)ℜ	10.19 (13.30)ℜ	18.73 (29.67)ℜ	28.92 (29.67)ℜ	31.79 (39.12)ℜ

The weight of F1 (WAD x WALL) genetic group is within parentheses** significance level ($p<0.01$) of fixed factors. ‡ = Gompertz model ; ¥ = Von Bertalanffy model; ℜ = Observed value

maternal growth could justify this situation (London and Weniger, 1995). Male lambs were quite heavier than female for all weights as in other reports (Yapi-Gnaore *et al.*, 1997; Gbangboche *et al.*, 2006) and might be partly due to hormonal effect such as androgen which is known to have growth and weight stimulating effects on male.

Single lambs were heavier than twin, similarly to other researchers (Gbangboche *et al.*, 2006; Bosso *et al.*, 2007) and could be due to the limited capacity of WAD ewes to provide more nourishment for the development of multiples fetuses and extra milk for lambs (Rajab *et al.*, 1992).

CONCLUSION

The fitting of GP and VB models to describe the weight age data of F1 and WAD breeds, provide biologically interpretable parameters (A, B and k). A was higher in VB while B and k higher in GP. Within breeds, A and B were higher in F1 than in WAD. Both models have shown negative correlations between A and k. The effects of litter type, sex of lamb and ewe parity were significant for all parameters of both models. According to the selection criteria, R^2 was similar between models but VB show the goodness of fit, through lowest MSE, BIC and MAD. However, both models overestimated BW, underestimated W3. The WAD lamb presented faster maturity rate (MAD) and could be recommended for mating at 90 days early for the first time than F1 breeds. From birth up to 360 days of age, F1 lambs were heavier than WAD and the significant effect of sex, litter type and parity ewe on maturing degree and body weight must be involve into any sustainable growth management program of these breeds. However, prior to perpetuate this experiment, further studies on the economic advantages of F1 will be helpful.

ACKNOWLEDGEMENTS

This study was made possible through support provided by the Ecole Inter-Etats des Sciences et

Medicine Veterinaires de Dakar. Special thanks to Mrs. M. Hilley and the authorities of the Faculty of Agronomics Sciences of the University of Abomey Calavi (Benin, West Africa).

REFERENCES

Adu, I.F. and L.O. Ngere, 1979. The indigenous sheep of Nigeria. World Rev. Anim. Prod., 15: 51-62.

Bathaei, S.S. and P.P. Leroy, 1996. Growth and mature weight of Mehraban Iranian fat-tailed sheep. Small Rumin. Res., 22: 155-162.

Beltran, J.J., W.T. Butts, T.A. Olson and M. Koger, 1992. Growth patterns of two lines of Angus cattle selected using predicted growth parameters. J. Anim. Sci., 70: 734-741.

Bosso, N.A., M.F. Cisse, E.H. van der Waaij, A. Fall and J.A.M. van Arendonk, 2007. Genetic and phenotypic parameters of body weight in West African Dwarf goat and Djallonke sheep. Small Rumin. Res., 67: 271-278.

Brody, S., 1945. Bioenergetics and Growth. Reinhold Publishing Co., UK., pp: 1023.

Brown, J.E., H.A. Fitzhugh and T.C. Cartwright, 1976. A comparison of nonlinear models for describing weight age relationships in cattle. J. Anim. Sci., 42: 810-818.

Carles, A.B., 1983. Sheep Production in the Tropics. Oxford University Press, New York, USA.

D'Ieteren, G.D.M., 1994. Trypanotolerant Livestock, a Sustainable Option for Increasing Livestock Production in Tsetse-Affected Areas. In: Toward Increased Use of Trypanotolerance: Current Status of Research and Future Direction, Rowlands, G.J. and A.J. Teale (Eds.). ILRAD/ILCA, Nairobi, Kenya, pp: 3-11.

Devendra, C. and M. Burns, 1983. Goat Production in the Tropics. Commonwealth Agricultural Bureaux, London, UK., pp: 64-73.

Devendra, C., 1981. The potential of sheep and goats in less developed countries. J. Anim. Sci., 51: 461-473.

Epstein, H., 1971. The Origin of Domestic Animals of Africa. Vol. 2, Africana Publishing Corporation, New York.

Fahmy, M.H. and S. Robert, 1997. Ewe and lamb behavior at parturition in prolific and non-prolific sheep. Can. J. Anim. Sci., 77: 9-15.

Fitzhugh, Jr. H.A. and C.S. Taylor, 1971. Genetics analysis of degree of maturity. J. Anim. Sci., 33: 717-725.

Gama, L.T., G.E. Dickerson, L.D. Young and K.A. Leymaster, 1991. Effects of breeds, heterosis, age of dam, litter size and birth weight on lamb mortality. J. Anim. Sci., 69: 2727-2743.

Gatenby, R.M., G.E. Bradford, M. Doloksaribu, E. Romjali, A.D. Pitono and H. Sakul, 1997. Comparison of sumatra sheep and three hair sheep crossbreeds. I. Growth, mortality and wool cover of F1 lambs. Small Rumin. Res., 25: 1-7.

Gbangboche, A.B., M. Adamou-Ndiaye, A.K.I. Youssao, F. Farnir, J. Detilleux, F.A. Abiola and P.L. Leroy, 2006. Non-genetic factors affecting the reproduction performance, lamb growth and productivity indices of Djallonke sheep. Small Rumin. Res., 64: 133-142.

Goonewardene, L.A., R.T. Berg and R.T. Hardin, 1981. A growth study of beef cattle. Can. J. Anim. Sci., 61: 1041-1048.

Goossens, B., S. Osaer, M. Ndao, J. Van Winghem and S. Geerts, 1999. The susceptibility of Djallonke and Djallonke-Sahelian crossbred sheep to *Typanosoma congolense* and helminth infection under different diet level. Vet. Parasitol., 85: 25-41.

Kabuga, J.D. and F. Akowuah, 1991. Reproductive performance of Djallonke x Sahelian crossbred ewes in Ghana. Small Rumin. Res., 5: 245-254.

Laird, A.K., 1965. Dynamics of relative growth. Growth, 29: 249-263.

Lambe, N.R., E.A. Navajas, G. Simm and L. Bunger, 2006. A genetic investigation of various growth models to describe growth of lambs of two contrasting breeds. J. Anim. Sci., 84: 2642-2654.

London, J.C. and J.H. Weniger, 1995. Investigation into traditionally managed Djallonke-sheep production in humid and sub humid zones of Asante, Ghana. III. Relationship between birth weight, preweaning growth and postweanning growth of lambs. J. Anim. Breed. Genet., 112: 431-453.

Malhado, C.H.M., P.L.S. Carneiro, P.R.A.M. Affonso, A.A.O. Souza and J.L.R. Sarmento, 2009. Growth curves in Dorper sheep crossed with the local Brazilian breeds, Morada Nova, Rabo Largo and Santa Ines. Small Rumin. Res., 84: 16-21.

Nelder, J.A., 1961. The fitting of a generalization of the logistic curve. Biometrics. J. Biomet. Soc., 17: 89-110.

Osaer, S., B. Goosens, D.J. Clifford, S. Kora and M.A. Cassama, 1994. Comparison of the susceptibility of Djallonke sheep and West African Dwarf goats to experimental infection with two differents strains of *Trypanosoma congolense*. Vet. Parasitol., 51: 191-204.

Osuagwuh, A.I., B.B. Taiwo and L.O. Ngere, 1980. Crossbreeding in tropical sheep: Incidence of distocia and parturition losses. Trop. Anim. Health Prod., 12: 85-89.

Rajab, M.H., T.C. Cartwright, P.F. Dahm and E.A.P. Figueireda, 1992. Performance of three tropical hair sheep breeds. J. Anim. Sci., 70: 3351-3359.

Richards, F.J., 1959. A flexible growth functions for empirical use. J. Exp. Bot., 10: 290-300.

SAS, 2009. SAS/STAT User's Guide. Version 9.2. SAS Institute Inc., Cary, NC., USA.

Taiwo, B.B.A., L.O. Ngere and I.O.A. Adeleye, 1982. Comparative growth performance of Nigerian dwarf sheep and its crosses with Permer, Uda and Yankassa. Word Rev. Anim. Prod., 18: 57-63.

Topal, M., M. Ozdemir, V. Aksakal, N. Yildiz and U. Dogru, 2004. Determination of the best nonlinear function in order to estimate growth in Morkaraman and Awassi lambs. Small Rumin. Res., 55: 229-232.

Toure, S.M., M. Seye, M. Mbengue and T. Dieye, 1981. Trypanotolerance studies of comparative pathology on Dwarf Djallonke sheep and Sahelian Fulani sheep. ISRA/LNERV., Dakar.

Tsukahara, Y., Y. Chomei, K. Oishi, A.K. Kahi, J.M. Panandam, T.K. Mukherjee and H. Hirooka, 2008. Analysis of growth patterns in purebred Kambing Katjang goat and its crosses with the German Fawn. Small Rumin. Res., 80: 8-15.

Von Bertalanffy, L., 1957. Quantitative laws inmetabolism and growth. Q. Rev. Biol., 32: 217-230.

Yapi-Gnaore, C.V., A. Oya, J.E.O. Rege and B. Dagnogo, 1997. Analysis of an open nucleus breeding programme for Djallonke sheep in the Ivoiry Coast. 1. Examination of non-genetics factors. Anim. Sci., 64: 291-300.