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Modeling and comparison of the maturing rates of Damara, Dorper and Swakara sheep at Neudamm Farm

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Abstract

Although sheep play an important role in the Namibian livestock industry, there is a paucity of information on their production performance. The objective of the study was to compare the mature weights, and maturing rates for Damara, Dorper and Swakara sheep reared at Neudamm Farm. Four hundred and eight (408) sheep (84 Swakara, 296 Damara and 28 Dorper) were weighed monthly for 6 months. The Brody, Van Bertalanffy, Gompertz and logistic growth models were fitted to the data to determine the mature size and maturing rate. Based on the R^2 and the BIC, the Brody growth function gave the best fit. The estimated mature weights for Damara, Dorper and Swakara sheep were 46.8±1.1 kg, 53.9±1.0 kg and 48.8±1.1 kg, respectively, with the corresponding maturing rates of 0.0037±0.0001, 0.0025±0.0003 and 0.0021±0.0001 kg/day. Although the Damara sheep have a smaller size compared to Dorper sheep, they mature faster, making them a better breed for mutton production. The Dorper had the largest mature sizes, although their rate of maturation was lower than the Damara sheep.

Keywords: Sheep, growth models, maturing rates, breeds, sex.

1. Introduction

Growth, described as changes in volume, size or shape of an organism over time (Thornley & Johnson, 1990; Ulutas et al., 2010) is an economically important biological attribute in livestock production and breeding. Growth curves, mathematical representations of the functional relationship between age and live weight of an animal for all or part of the animal's life span (Echeverri et al., 2013), are one of the ways of scientific description of growth with passage of time (Ozdemir & Dellal, 2009; Lupi et al., 2015). Fitting growth curves to estimate and predict the growth functions of livestock is crucial for assessing growth characteristics for breeding and commercial/economic purposes. The characteristics obtained from growth functions are hereditary and are usually used for selection purposes (Daskiran et al., 2010). Growth curve parameters change with factors affecting weight, especially the genetic potential of the breed (Alexandre et al., 1997) and many growth models use weight as a proxy for growth. Since the growth parameters are hereditary and differ with the genetic potential of the animal, the growth characteristics for Damara, Dorper and Swakara sheep maybe different and hence need to be modelled differently. For mutton production purposes, it is economically viable to farm with sheep that have larger mature sizes and require less time to attain their mature sizes.

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Many linear and nonlinear mathematical models are designed to describe the growth rate of live matter. However, the growth pattern of animals is linear during the early stages of their life span but turns to a sigmoidal shape as the animal grows (Ozdemir & Dellal, 2009). As such, linear models cannot perfectly describe the growth patterns, making non-linear models the best option to establish the mathematical behaviour for biological body development and rate of maturity for sheep. Non-linear growth curves such as the Brody model, the Gompertz, the Von Bertalanffy and the logistic model assume that growth rate declines linearly with the weight of an animal on a logarithmic scale and the animal and its metabolic rate obeys an allometric relationship. The Brody model has no point of inflexion, while the logistic has a point of inflexion at 0.5 of the mature weight (Majid et al., 1996), with the Gompertz having an inflexion at 0.368 of the mature weight, Van Belartanffy at 0.296 of the mature weights and the Richards has a point of inflexion determined by the model parameters.

Non-linear models have been extensively used and compared in modelling the growth of animals and other living matter. Keskin et al. (2009) compared the fitness of the Quadratic, Cubic, Gompertz and Logistic models in explaining the growth curves of Konya Merino sheep and found the Cubic model to have the best fit. The Quadratic and Gompertz models showed the best fit in Konya Merino ewe lambs. Gaddour et al. (2012) tested the fit of five non-linear growth models in estimation and prediction of growth patterns for kids of indigenous Alpine and Damascus goats and their crosses and found that the growth curves differed with kids' genotype. The iterative procedure identified the Gompertz model to be the best used in adjusting the kids' growth evolution. Lupi et al. (2015) analysed the Brody, the Verhulst, Gompertz and the Logistic for Segurena sheep and found the Von Belatanffy to be the most appropriate in explaining the biological and commercial growth while the Brody was not suitable in explaining the commercial growth curve. Majid *et al*. (1996) fitted the Brody, Von Bertalanffy, Gompertz, Logistic and Richards models to cattle growth data and found that the Brody, the Von Bertalanffy, the Logistic and the Richards fitted the data well while the Gompertz had a poor fit.

The weight difference between males and female sheep can influence the shape of the growth curve as has been noted by several authors (e.g. McManus et al., 2003; Lupi et al., 2015), used non-linear models to characterise the biological and commercial growth patterns of Segurena sheep, and their results showed a strong impact of sexual dimorphism on growth, with female sheep maturing earlier than males. A study by Majid et al. (1996) concluded that Brahman males mature faster than females, and the reverse was true for the Kedah-Kelantan Breed where females matured earlier.

Very few studies have modelled the growth rate of Damara, Dorper and Swakara sheep in Namibia with farmers mainly using the weaning weights as a selection criterion. It is vital to have standard growth curves for each breed of sheep because each breed has a different growth rate. Modelling the growth rate and the maturing rate is essential for the recommendation in production and breeding. However, the selection of the best model to describe the sheep is controversial, and the above literature suggests that the selection of the model of best fit is empirical. The objectives of this research were, therefore, to fit four nonlinear models to growth data on Damara, Dorper and Swakara sheep at Neudamm farm and to compare the growth parameters using the best fitting models.

1. Materials and Methods

2.1 Source of data

The research was conducted at the University of Namibia's Neudamm Farm, which is approximately 30 km east of Windhoek. The area receives an annual rainfall of about 350 to 400 mm (Mendelsohn et al., 2002) and the primary perennial grasses on the farm are *Anthephora pubescens* and *Schmidtia pappophoroides*. The weight-age data was collected from all the 408 sheep consisting of 84 Swakara, 296 Damara and 28 Dorper sheep kept on the extensive rangeland. The live body weights of the sheep were measured monthly for a period of six months from March to September 2016. The respective ages at weighing for the animals were determined by subtracting the birth date from the weighing date.

2.2 Non-linear models used for data analysis

The growth curves were estimated using the R version 3.2.5 (R Core Team, 2018) packages *easynls* (Arnhold, 2017) and growth rates (Petzoldt, 2016) and the PROCNLIN procedure (SAS, 2003). The R^2 and the Bayesian Information Criterion (BIC) were employed to assess the goodness of fit of four models in explaining the relationship between live weight and passage of time (age) for the Neudamm sheep breeds. The non-linear functions fitted to the data are presented in Table 1.

Table 1: Non-linear models used for modelling the growth curves of the Neudamm sheep breeds

Model	Mathematical representation
Brody function:	$W = A\,(1 - be^{-kt})$
Von Bertalanffy function:	$W = A\,(1 - be^{-kt})^3$
Logistic function:	$W = A\,(1 - be^{-kt})^{-1}$
Gompertz function:	$W = A\,be^{-kt}$

The parameters for the functions in Table 1 are interpreted biologically as: W is live weight at time t. A is the asymptotic value as the function tends to infinity and is interpreted as average mature weight regardless of fluctuations due to genetic and environmental factors. b is a scaling parameter which allows for estimation of the inflexion age, marking the beginning of the auto-deceleration stage until the animal attains maturity and k, commonly referred to as the maturing index, is a function of the ratio of growth rate to mature weight. Large k values indicate early-maturing individuals, while small k values indicate late-maturing individuals.

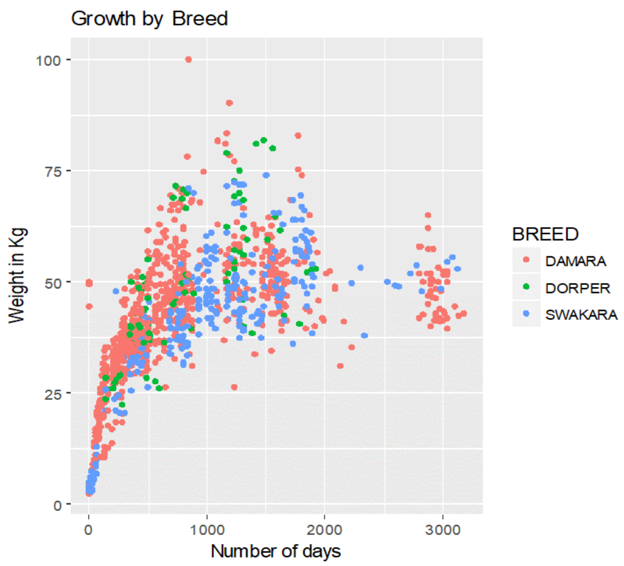

Figure 1a. Growth patterns for Neudamm sheep breeds.

Figure 1b. Growth patterns for Neudamm sheep by sex.

2. Results

3.1 Scatter plots for growth patterns for Neudamm sheep

Fig. 1a shows the plot of weight against age in days for the Neudamm sheep by breed and Fig. 1b disaggregates the growth patterns by sex. Fig. 1a suggests different growth patterns for different breeds with the Swakara having the lowest weights across all age groups while Fig. 1b shows that males were weighing more than females across all age groups. As a result, further analysis was performed to compare variations in growth by sex and breed.

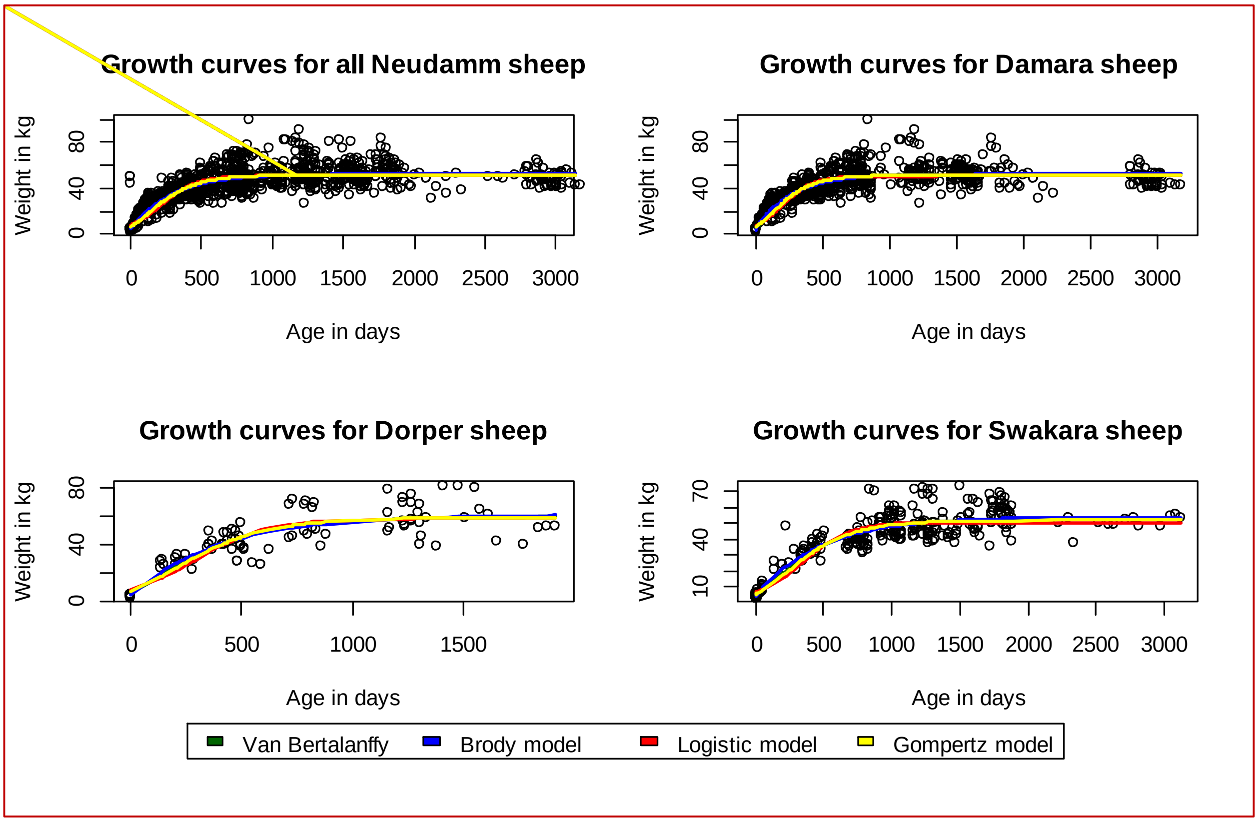

Figure 2. Comparison of growth models for Neudamm sheep breeds.

3.2 Growth curves for the non-linear growth models

Fig. 2 shows the growth curves for the four non-linear growth models fitted to the age weight data for the Neudamm breeds of sheep. Table 2 presents the parameter estimates for the different growth functions fitted to Neudamm sheep breeds.

The Brody model has the best model fit (highest R-squared, lowest BIC) statistics for all breeds. However, the highest maturity rates were recorded for the Logistic model. The results from the Brody model show that Damara sheep have the highest maturity rate of 0.0037 kg/day followed by Dorper sheep with 0.0025 kg/day and lastly the Swakara sheep with a maturity rate of 0.0021 kg/day. As a result, further analyses were done using the Brody model as it explains the growth parameters best across all the three breeds.

3.3 Parameter correlations coefficients

Table 3 shows the correlation coefficients for the estimated model parameters for the Brody model. Although the absolute values are not very high, the correlation coefficients between birth weight and mature size are positive for all three breeds, an indication that sheep with high birth weight would attain a higher mature size. However, the negative correlation coefficients between mature size and rate to maturity implies that sheep with high mature weight take long to attain their mature size while those with lower mature sizes mature earlier.

Table 2: Parameter estimates for the fitted models for Damara, Dorper and Swakara sheep

Model	Breed	Birth weight	Mature weight	B	Maturing rate	R^2	BIC
Brody	Damara	3.67(0.01)	46.8(1.09)	0.922(0.008)	0.0037(0.00013)	0.97	-293.82
	Dorper	4.12(0.03)	53.9(1.01)	0.924(0.030)	0.0025(0.0003)	0.95	2.26
	Swakara	3.67(0.01)	48.8(1.14)	0.925(0.012)	0.0021(0.00014)	0.98	-188.17
Von Bertalanffy	Damara	3.67(0.04)	45.9(1.01)	0.569(0.001)	0.0052(0.00017)	0.96	-214.94
	Dorper	4.15(0.02)	52.8(1.03)	0.571(0.004)	0.0036(0.00040)	0.95	9
	Swakara	3.74(0.03)	48.23(1.03)	0.574(0.020)	0.0031(0.00017)	0.97	-161.88
Gompertz	Damara	3.64(0.05)	46.6(0.42)	2.550(0.068)	0.0060(0.0002)	0.96	-179.17
	Dorper	4.12(0.02)	53.9(1.76)	2.571(0.246)	0.0042(0.00047)	0.95	12.26
	Swakara	3.68(0.07)	48.8(0.65)	2.585(0.121)	0.0037(0.00021)	0.97	-149.31
Logistic	Damara	3.67(0.05)	44.8(0.41)	11.207(0.375)	0.0087(0.00031)	0.96	-88.87
	Dorper	4.14(0.02)	50.9(1.57)	11.295(1.234)	0.0060(0.0007)	0.95	20.96
	Swakara	3.76(0.07)	47.5(0.64)	11.633(0.836)	0.0057(0.00035)	0.97	-115.66

Values are the means and standard errors (in parentheses).

Table 3: Parameter correlations

Breed	Correlation A and *b*	Correlation Birth weight and A
Damara	-0.4684	0.0386
Dorper	-0.5780	0.2014
Swakara	-0.6254	0.1837

3.4 Comparison of Brody growth parameter estimates for Damara, Dorper and Swakara sheep

Fig. 3 shows the Brody model fitted to all three breeds of sheep. Swakara sheep have the lowest weight at all stages of growth. However, the Damara have higher weights until about 500 days after birth where the Dorper out-weigh the Damara as the Damara attain their mature size while the Dorper are still growing, implying that the Damara have the highest maturity rates. The asymptotic age is highest for the Dorper, followed by the Damara and lowest for the Swakara, that are not only smaller but also seem to take the longest time to attain their mature size.

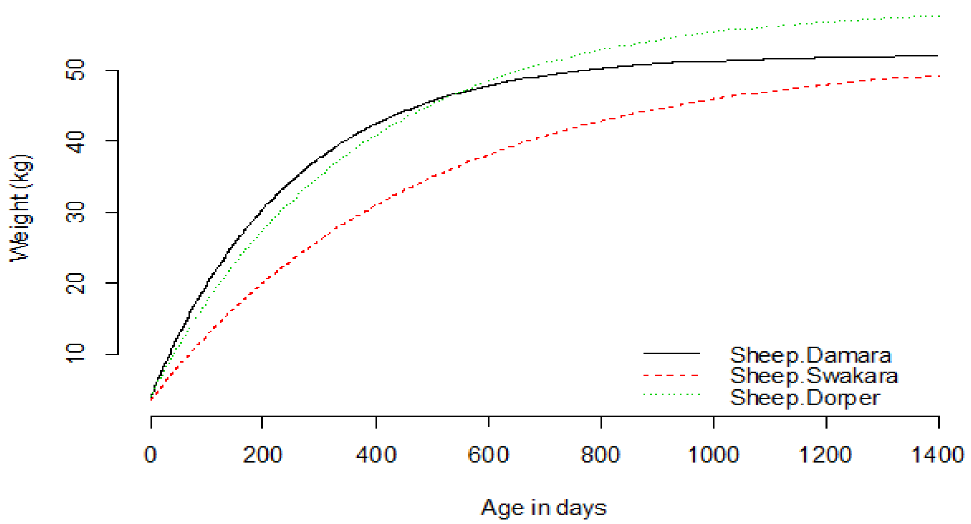

Figure 3. Comparison of Brody growth curves for Damara, Dorper and Swakara sheep.

3.5 Comparison of growth parameters by sex of sheep

Table 5 shows that the model fit parameters improved when growth parameters for male and female sheep for each breed were estimated separately. The Brody model is still superior to other models in all breeds. The Dorper males and females have higher mature weights compared to their Damara and Swakara counterparts while the Damara have the lowest. However, the Damara have the highest maturity rates. Females have higher rates of maturity across all breeds. The Dorper males have the highest mature size and lowest maturing rates.

Table 5: Growth models for male and female sheep for each breed

Model	Breed	Sex	Birth weight	Mature weight	B	Maturing rate	R^2	BIC
Brody	Damara	Female	3.56(0.45)	46.0(0.4)	0.923(0.089)	0.0034(0.00012)	0.97	-280.8
		Male	3.85(0.77)	49.9(2.4)	0.923(0.011)	0.0023(0.00018)	0.96	-34.6
	Dorper	Female	4.23(1.65)	50.9(1.5)	0.917(0.030)	0.0030(0.00033)	0.97	-30.6
		Male	4.04(2.84)	67.3(1.2)	0.940(0.028)	0.0012(0.00028)	0.94	24.0
	Swakara	Female	3.60(0.63)	46.7(0.7)	0.923(0.012)	0.0025(0.00017)	0.98	-208.5
		Male	3.98(1.40)	59.7(2.9)	0.933(0.020)	0.0015(0.00019)	0.96	-16.7
Von Bertalanffy	Damara	Female	3.56(0.44)	45.2(0.4)	0.571(0.013)	0.0047(0.00016)	0.97	-220.1
		Male	3.88(0.75)	48.4(1.7)	0.569(0.017)	0.0038(0.00025)	0.96	-6.7
	Dorper	Female	4.26(1.60)	50.4(1.3)	0.561(0.044)	0.0044(0.00046)	0.97	-25.9
		Male	4.11(2.60)	64.3(6.4)	0.600(0.055)	0.0022(0.00056)	0.94	28.2
	Swakara	Female	3.63(0.62)	46.3(0.6)	0.572(0.021)	0.0037(0.00022)	0.98	-188.5
		Male	4.05(1.20)	58.4(1.9)	0.589(0.037)	0.0024(0.00023)	0.97	-7.8
Gompertz	Damara	Female	3.59(0.43)	44.9(0.4)	2.528(0.074)	0.0055(0.00019)	0.96	-193.8
		Male	3.90(0.75)	47.9(1.5)	2.509(0.093)	0.0047(0.00030)	0.96	6.1
	Dorper	Female	4.28(1.58)	49.9(1.3)	2.457(0.245)	0.0051(0.00056)	0.97	-23.5
		Male	4.15(2.60)	62.8(5.5)	2.718(0.033)	0.0028(0.00045)	0.94	30.1
	Swakara	Female	3.64(0.62)	46.1(0.6)	2.537(0.129)	0.0044(0.00026)	0.98	-178.9
		Male	4.08(1.20)	57.4(1.7)	2.645(0.232)	0.0029(0.00025)	0.97	-3.6
Logistic	Damara	Female	3.60(0.44)	44.3(0.4)	11.283(0.425)	0.0080(0.00030)	0.96	-130.7
		Male	3.94(0.76)	46.1(1.2)	10.688(0.511)	0.0073(0.00045)	0.95	38.9
	Dorper	Female	4.32(1.54)	49.4(1.3)	10.444(1.316)	0.0076(0.00093)	0.96	-16.4
		Male	3.97(2.44)	52.9(4.3)	12.332(2.051)	0.0045(0.00069)	0.93	-35.2
	Swakara	Female	3.65(0.64)	45.4(0.5)	11.435(1.020)	0.0070(0.00045)	0.98	-154.9
		Male	4.14(1.13)	56.3(1.6)	12.580(1.656)	0.0043(0.00038)	0.97	7.1

Values are the means and standard errors (in parentheses).

3. Discussion

The study applied non-linear models to estimate growth parameters for the Neudamm Farm sheep. The goodness of fit statistics show that the fitted models are comparable to the results of Ozdemir and Dellal (2009) who observed R^2 values of 0.957 and 0.956 for logistic and Gompertz growth models, respectively. The results are superior to the findings of Tsukahara et al. (2008) who obtained R^2 of 0.937 in the Brody model and Mc Manus et al. (2003) who reported lower R^2 values (0.84) when estimating the growth curves of Bergamasca sheep using the Logistic model. As a result, the models are adequate in describing the growth patterns of the Neudamm sheep.

The most suitable function to describe the growth patterns is the Brody model, as indicated by the highest R^2 and lowest BIC values. These findings are in line with the results of Waheed et al. (2011), whose study with Beetal goats indicated the Brody and the Gompertz explained the data efficiently. The Gompertz and Quadratic models showed the best fit to the Konya Merino lamps by depicting higher R^2 values and lower mean squared prediction error (MSPE) and no auto-correlation ahead of the Cubic and Logistic models (Keskin et al., 2009). However, the results contradict Lupi et al. (2015) who reported that the Brody model failed to estimate the commercial growth curve in their study with Segurena sheep. Mahaldo et al. (2009) observed the Von Bertalanffy, the Gompertz and the logistic models fitted their data well in terms of R^2 while the Brody recorded high residual mean square (RMS). On the other hand, Mc Manus et al. (2003) concluded that the Logistic model was more appropriate in explaining the growth curves of Bergamasca sheep. Although the Gompertz model fell below standard in Majid et al. (1996) study with three genotypes of beef cattle, in this study, it was equally competitive as it recorded goodness of fit statistics that do not differ much from the other models. Topal et al. (2004) compared the Brody, the Gompertz and the logistic in the estimation of Awassi and Morkaraman lambs and the Gompertz fitted the Awassi best, while the Von Bertalanffy gave the best fit for the Markaraman sheep.

All the results show that the Brody model gave the highest mature size parameters for all breeds while the logistic model had the lowest. The study findings concur with Majid et al. (1996) whose study showed that the parameter for the Brody to be higher than one for the Von Bertalanffy, the Gompertz and the logistic and the Richards' values being higher than the rest. Just like in their study, the logistic model recorded the highest rates to maturity. This is probably because the logistic estimates of mature size are the lowest and hence take less time to attain. Ozdemir and Dellal (2001), Tsukahara et al. (2008) and Malhado et al. (2009) argue that the Brody model overestimates the mature weight parameter and underestimates the growth rate at the initial stages and overestimates if from about 50 to 150 days of age.

The results of the study show that the growth parameters varied by breed with the Damara sheep attaining their mature weight faster than the other breeds. This is probably because they have the smallest mature weight when compared to the other two breeds, and they quickly attain mature size. The results concur with the negative correlation between mature size(A) and rate to maturity (k) for all models and all breeds, which imply that sheep with lower mature weights attain maturity faster when compared to those with higher mature sizes. However, the Swakara have the lowest rate of maturity that is inferior to the Dorper maturing rate even though the Swakara sheep are smaller in mature weight. The results of the study agree with Efe (1990) and Akbas et al. (1999), who argue that growth parameters vary according to genotype.

The study findings indicate that the mature sizes for male and female sheep are different for all the breeds studied with the rate to maturity for females higher for all three breeds, leading to the conclusion that there is sexual dimorphism for growth. The findings concur with the findings of Lupi et al. (2015) where there was sexual dimorphism for growth, with female sheep maturing earlier than males. However, these findings contradict Mahaldo et al. (2009) as their research with crosses of Dorper and Brazillian local breeds and Mc Manus et al. (2003) who reported that males reach the asymptotic weight faster than females. Contrary to these findings, a study conducted by Waheed et al. (2011) with Beetal goats and Mahaldo (2008) study with Santa Ines crossed with Texel lamps concluded that sex did not affect any of the parameters in the model. On the other hand, in another study with three genotypes of beef cattle, Majid et al. (1996) reported that Brahman males matured earlier than females, whereas the in the Kedah-Kelantan breed females tended to be earlier maturing than males.

4. **Conclusions**

All the four non-linear models (Brody, Von Bertalanffy, Gompertz and Logistic) fitted the sheep growth data well and can be used for estimation of the growth parameters for Neudamm sheep, although the Brody model had the best fit. According to the results, Damara sheep mature faster than the Dorper and Swakara and hence are more economical to farm with for mutton production, especially given the high uncertainty of the weather patterns at Neudamm. However, the Dorper have larger mature sizes although their rate of maturation is lower and may perhaps be better be used in terminal crossing.

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