Original Research Article

COMPARISON OF NON-LINEAR GROWTH CURVE MODELS IN NON DESCRIPT CALIFORNIA AND NEW ZEALAND RABBITS REARED IN THE TROPICAL CONDITIONS OF NIGERIA

Abstract

Nonlinear functions of body weight at different age intervals were used to estimate the growth pattern in New Zealand White and California rabbits. Gompertz and Logistic functions of 3 and 4 parameters were fitted to Age-weight data matrix. Age-weight records of New Zealand White and California rabbits from birth were monitored to 56 days to estimate the average growth curve for each breed. The weight difference between breeds was consistently in favor of California rabbits as compared to New Zealand White. It was concluded that the gompertz and logistic models were both parsimonious and adequate in describing the growth patterns of New Zealand White and California rabbits in the tropical conditions of Nigeria.

Introduction

The medium rabbits in the tropical countries serve as a good source of cheap animal protein due to quest for protein sufficiency among the teeming populace of Sub Saharan African (Akinsola, 2012). Rabbits possess unique biological characteristics such as high biological value amino acids, meat low in calories and fat, prolificacy, short gestation length, initial capital outlay, great genetic flexibility, highly unsaturated lipids (60% of the total fatty acids), valuable animal model for biomedical research, low sodium and cholesterol levels [1]. Weight changes data are used by farmers to monitor on the spot assessment of health status of rabbit for forecasting growth trait within trajectory of time. Growth is a complex trait of interest in domestic animals and is as expressed as the increase in size, number, or mass with time. Growth could be expressed as the increase in size number or weight changes. The use of maximum-likelihood solving estimates in reducing the model noise using discrete and continuous data in model fitting have been reported by several studies. The use of gompertz and logistic models were used to analyse the growth of rabbit [2], lamb [3], pig [4] and cattle [5, 6]. Several researches had modeled rabbit growth curve using logarithmic model [7], stochastic model [8] and general linear mixed model [9].

Some selected mathematical functions commonly used in describing the growth phase of rabbits include the Gompertz, Logistic, Brody, von Bertalanffy and Richards growth models [9]. The growth functions can be grouped into three main categories: those with a diminishing returns behavior (Brody model), those with sigmoidal shape and a fixed inflection point (Gompertz, Logistic and von Bertalanffy models) and those with a flexible inflection point (Richards model). The Logistic, Gompertz and von Bertalanffy models exhibit inflection points at about 50, 37 and 30% of the mature weight (asymptote), respectively.

Therefore, the objective of this study was to define the most appropriate nonlinear model to estimate California and New Zealand rabbit breeds bodyweight changes over time trajectory in Northern Guinea Savannah Zone of Nigeria.

MATERIALS AND METHODS

The forty animals (n=20 California and n=20 New Zealand White) used in this experiment originated from the Dagwom experimental rabbit farm at National Veterinary Research Institute, Vom, Jos, Plateau State. The rabbits were kept in individual cages and were fed with conventional formulated growers feed and grasses such as *Calopogonium mucunoides and*

Panicum maximum ad libitum. Fresh drinking water was also provided always to the rabbits. Other daily routine management practices were carried out regularly. Bodyweight of rabbits were taken by digital weighing scale (Mettler Toledo, Top Pan Sensitive Balance, J. Liang Int. Ltd. U.K.) on weekly basis.

Statistical procedures

Bodyweights at different ages were fitted to 3-parameters and 4-parameters models. The three parameter functions sought to find a way to fit a response that are bound between zero and the estimated asymptote. The four parameter functions are bounded between two estimated asymptotes. Age and Inflection point were computed as describe in the non linear algorithm of JMP 13 statistical software. The following growth curve models were used to determine the parameters belonging to the growth curves (Table 1).

Table 1: Functional form of growth curve models

Models	Functions

Logistic 3P[1]	$$BW = a \cdot Exp\left(-Exp\left(-b \cdot (Age - c)\right)\right)$$
Gompertz 3P[2]	$$BW = \frac{c}{\left(1 + Exp\left(-a \cdot (Age - b)\right)\right)}$$
Logistic 4P[3]	$$BW = a + (b - a) \cdot Exp\left(-Exp\left(-c \cdot (Age - d)\right)\right)$$
Gompertz 4P[4]	$$BW = \frac{(d - c)}{\left(1 + Exp\left(-a \cdot (Age - b)\right)\right)}$$

P=parameter; a=growth rate; b=inflexion point; c=lower asymptote; d=upper asymptote; BW=Bodyweight; [1][4]; [2][10]; [3][11]; [4][12].

The model performance was compared based on the coefficient of determination (R^2), root means square error (RMSE), Akaike information criterion (AIC) and Bayesian information criterion (BIC). **RMSE** and R^2 of models were considered for the calculated goodness of fit parameters for the comparison among the different models between breeds of rabbits. Coefficient of determination (R^2) = 1-(SSE/SST) where SSE is the sum of square of errors, and SST is the total sum of squares. Akaike's information criteria (AIC) = n*ln (SSE/n) + 2k, where n; the number of observations, SSE; sum of square of errors, k; the number of parameters.

Schwarz Bayesian information criterion (BIC) = n*ln(SSE/n) + k*ln(n), where n; the number of observations, SSE; sum of square of errors, k; the number of parameters [13] . The growth data was fitted using the prediction profiler interface of JMP 13.2 software. Estimated mean parameters obtained from different models were used to plot general growth curves of the non descript rabbits.

RESULT

Table 2 shows the selection criteria of differently parameterized mathematical models in non descript New Zealand White and California Rabbits. All the models were parsimonious with reduced model noise in reconstructing the growth curve between the breeds. Logistic 4P showed the highest coefficient of determination of R^2=0.989 and 0.992 in New Zealand and California Rabbits. Gompertz 3P and Gompertz 4P had similar prediction efficiencies in the New Zealand White (R^2=0.988) while Gompertz and Logistic 4P showed similar values in California Rabbits (R^2=0.992). The best Bayesian information criterion and Akaike information criterion was recorded in Gompertz 3P (0.56 and 111.04) for New Zealand White and California rabbits (98.20 and 107.41). Gompertz 3P had most reduced best model noise in New Zealand White while Logistic 4P recorded the least noise in California Rabbit.

Table 2: Selection Criteria (weight in grams) for differently parameterized mathematical models in Non descript New Zealand and California White Rabbits

Model/Breed	AIC	BIC	SSE	MSE	RMSE	R^2
New Zealand White						
Gompertz 3P	111.04	101.82	16272.44	2712.07	52.07	0.988
Logistic 3P	111.57	102.36	17271.94	2878.65	53.65	0.987
Logistic 4P	121.96	102.95	14446.30	2889.26	53.75	0.989
Gompertz 4P	122.56	103.55	15434.23	3086.84	55.55	0.988
California						
Gompertz 3P	107.41	98.20	10880.82	1813.46	42.58	0.990
Logistic 3P	108.58	99.37	12387.85	2064.64	45.43	0.989
Logistic 4P	117.62	98.61	8916.57	1783.31	42.22	0.992
Gompertz 4P	117.95	98.94	9247.95	1849.59	43.00	0.992

P=parameters; AIC=Akaike Information Criterion, BIC= Bayesian Information Criterion, SSE-Sum of square error, MSE-Mean of square error, RMSE-Root mean square error, R^2=Coefficient of Determination

The growth curves parameter estimate in Non descript New Zealand White and California Rabbits are presented in Table 3 and Figures 1 and 2. The optimal age for maturity was at 28 days with bodyweight ranging from 1006.94 – 3522.14 g in New Zealand White and 2544.88 – 3639.49 g in California rabbits. The Gompertz 3P and 4P showed the best age at inflection point in New Zealand White (13.40 days) and California rabbits (28.84 days). The California rabbits showed early maturing/growth rate (0.04 – 0.06) than New Zealand White (0.01 – 0.06).

Table 3: Growth curves parameter estimate in Non descript New Zealand and California White Rabbits

Models/Breed	Growth rate	Inflection point	Optimal age (weeks)	First derivative	Second derivative	Optimal weight (grams)
New Zealand						
Gompertz 3P	0.01	13.40	28	18.10	0.68	1795.17
Logistic 3P	0.06	41.38	28	17.78	0.76	2776.18
Logistic 4P	0.03	33.01	28	17.70	0.56	1006.94
Gompertz 4P	0.04	25.25	28	17.96	0.59	3522.14
California						
Gompertz 3P	0.06	39.86	28	16.55	0.85	3629.49
Logistic 3P	0.06	31.30	28	16.09	0.87	2980.89
Logistic 4P	0.04	30.88	28	16.00	0.82	2650.22
Gompertz 4P	0.04	28.84	28	15.89	0.80	2544.88

P=Parameter

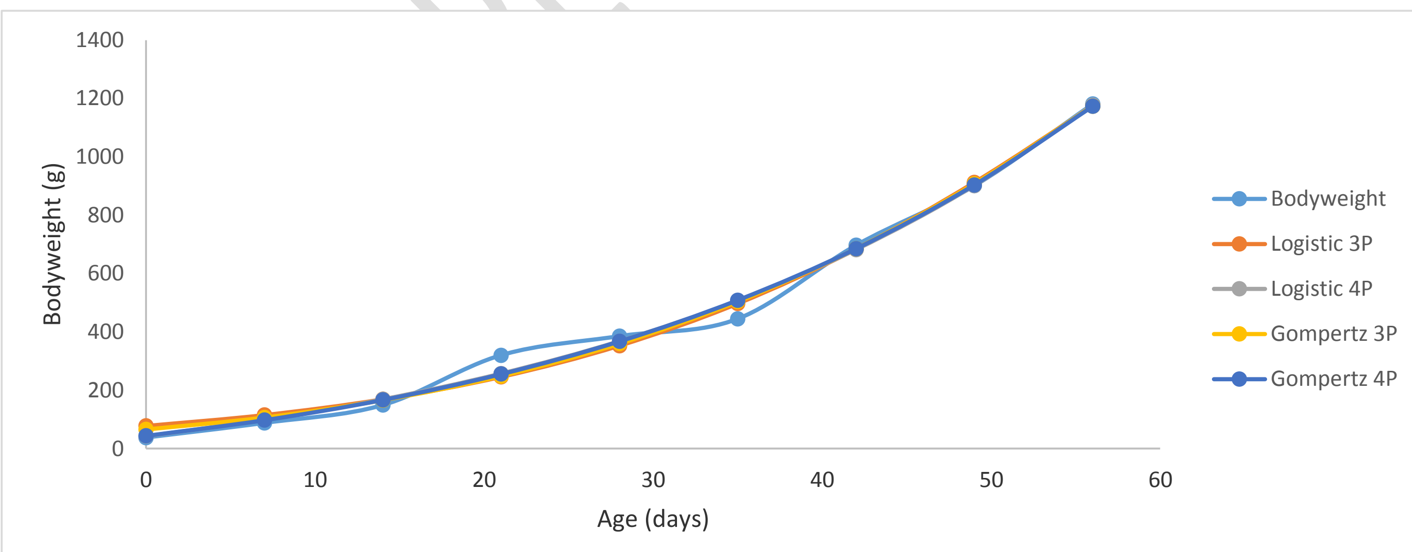

Figure 1: Curve fitting for body weight changes in relations with age in New Zealand White Rabbit

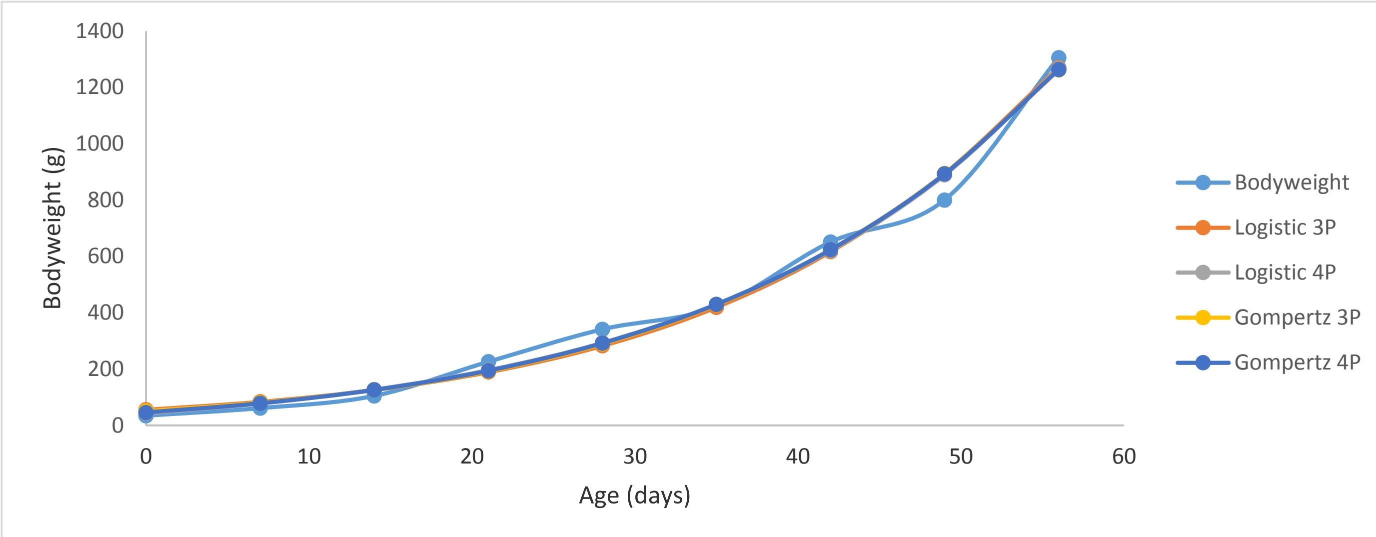

Figure 2: Curve fitting for body weight changes in relations with age in California Rabbit

DISCUSSION

Genetic gain are directly related to economics of production which have attracted the attention of geneticist, livestock scientists and private rabbit enterprises. The utilization of these parameters in growth models using age-weight gain matrix data could influence economic returns positively. The higher coefficients of determination recorded for both breeds were comparable with observations of several researches about the growth of rabbits and these were analysed with Logarithmic model [7] Stochastic model [8] and General Linear Mixed Model [9]. The higher maturity values observed in California rabbits research about the growth of rabbits were analyzed agrees with the report of [14] who showed that large values of *k* indicated early maturing individuals, whereas small *k* values indicated late maturing individuals. Point of inflection was correspondent to two parameters, namely age at point inflection (*ti*) and weight at point of inflection (*yi*). The rabbit breed with higher *growth rate* value showed higher point of inflection. Differences in growth patterns were expressed in terms of differences in mature weight and maturing rate in both New Zealand White and California rabbits. The optimal weight in New Zealand White rabbit showed larger fluctuations as compared to California rabbits. The California rabbit was heavier and also matured earlier than the New Zealand White rabbits. Comparisons of asymptotic body weight obtained with different functions showed that the Gompertz 4P in New Zealand White and Gompertz 3P model in California rabbit provided better weight estimates. [1] reported variations in prediction model estimates in different genotypes of rabbit. The Logistic and Gompertz models is more accurate in predicting the body weight of these animals and has better overall fit. The prediction of adult BW using nonlinear functions can be accurate when growth curve parameters and their covariance components are estimated jointly [6]. The estimation of potential final weight in different species is a function of an algorithm fitting and the accuracy of judging is possible only when precise final weight is available [3].

Conclusion

The Gompertz and Logistic models were both parsimonious and adequate for describing the growth patterns of New Zealand White and California rabbits. The California rabbit were heavier and mature than New Zealand White rabbit during the growth phase. In comparison, the time taken to reach maturity was longer for New Zealand White rabbit as compared to California rabbits.

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