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NON-LINEAR GROWTH MODELS FOR PIGS

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The knowledge of growth curves in pigs is important for determining the biological and economical efficiencies of pigs. Appropriate models fitted to the data may be used to protect future pork production and may also determine appropriate time of maturity of pigs. This information may be useful for planning of future meat production in India.

Non-linear models have been studied on production of agricultural products by Jain *et al.*, (1992) Prajneshu and Das (1998), Jha (1995), Sharma and Jha (1997). Lal *et al.*, (2003) studied non-linear models poultry meat production. The animal growth data are generally non-linear in nature. From the available literature, it seems that no attempt has been made to study growth of pigs using non-linear models. An attempt has been made in this paper to fit non-linear growth models viz. Exponential, Logistic and Gompertz on the data pertaining to body weights of pigs.

Materials and Methods

The data pertain to two research stations of All India Coordinated Research Project (AICRP) on pigs viz. Jabalpur and Tirupati for male and female pigs separately. The collected data were body weights (kg.) of crossbred (Largewhite-Yorkshire x Desi) pigs in both the research stations. The weekly data were recorded up to pre-weaning i.e. birth to eight weeks of age and four weekly data till maturity during the years 1987 - 1990 in Jabalpur and 1986 - 1989 in Tirupathi. The data of 48 males and 57 females for a period of 36 weeks in Jabalpur and 49 males and 38 females for period of 32 weeks in Tirupati were studied. The data for 1998 - 89 of both Jabalpur and Tirupati research stations were upto 20 weeks only, hence could not be used for the study.

The data on body weights of the pigs were plotted first for both male and female separately and the shape of the curve was examined. On the basis of the shape and curves, three models viz, Exponential Model, Logistic model and Gompertz model were fitted on the data for obtaining the appropriate model. A brief description of these models is given here for better understanding.

Exponential Model : This model can be represented by

$$E(y_t) = \alpha e^{-\beta t}$$

where y_t denotes the body weight at time t, α (>0) is the value of y_t at the time t = 0 and β is the exponential rate of growth over time and E(.) represents the expected value.

Logistic model : y_t denotes the response variable under study (body weight)

Table 1 : Estimates and measures of fitted models for male and female pigs at Jabalpur and Tirupati research stations.

Research Station	Year	Sex	Model	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\gamma}$	MAE	RMSE	MAPE
Jabalpur	1987 - 88	Male	Exponential	4.61	-0.06	–	2.60	3.71	26.55
			Gompertz	27.62	2.54	0.10	1.30	2.18	18.42
			Logistic	7.67	0.17	24.74	1.67	2.61	21.56
		Female	Exponential	4.58	-0.06	–	2.59	3.64	24.02
			Gompertz	29.33	2.63	0.09	1.38	2.51	19.87
			Logistic	8.29	0.16	25.91	1.77	3.00	23.28
	1989 - 90	Male	Exponential	4.26	-0.08	–	2.90	5.60	27.86
			Gompertz	135.1	3.85	0.04	0.79	0.97	2.24
			Logistic	17.41	0.12	61.14	1.24	1.73	6.83
		Female	Exponential	3.96	-0.08	–	2.86	6.17	27.04
			Gompertz	638.3	5.33	0.023	1.21	1.77	5.86
			Logistic	29.00	0.11	102.8	1.07	1.30	2.74
Tirupati	1986 - 87	Male	Exponential	5.97	-0.07	–	4.58	6.15	39.26
			Gompertz	48.85	3.51	0.11	0.60	0.81	3.45
			Logistic	16.28	0.21	42.44	0.87	1.26	8.35
		Female	Exponential	6.61	-0.07	–	4.50	5.81	35.57
			Gompertz	46.47	3.40	0.11	0.62	0.92	6.46
			Logistic	14.79	0.21	41.05	0.97	1.52	10.87
	1987 - 88	Male	Exponential	6.28	-0.78	–	3.32	4.32	18.68
			Gompertz	95.93	3.36	0.06	1.62	2.13	8.94
			Logistic	14.43	0.14	66.79	2.10	2.75	11.94
		Female	Exponential	5.67	-0.07	–	2.97	3.92	20.64
			Gompertz	78.27	3.27	0.62	1.25	1.65	7.85
			Logistic	13.60	0.14	55.87	1.72	2.19	10.81

Table 2 : Shapiro-Wilk's and Run-test for testing normality and randomness of residuals

Research Station	Year	Sex (Male/ Female)	Shapiro-Wilk's test		Run-test		
			Statistics-W	Pr<W	Total cases	No.of runs	Pr < Z
Jabalpur	1987 - 88	Male	0.9834	0.9848	16	5	0.076
		Female	0.9738	0.8958	16	5	0.076
	1989 - 90	Male	0.9491	0.4754	16	5	0.070
		Female	0.9536	0.5494	16	6	0.267
Tirupati	1986 - 87	Male	0.9037	0.1085	15	6	0.290
		Female	0.9764	0.9386	15	6	0.478
	1987 - 88	Male	0.9751	0.9252	15	6	0.341
		Female	0.9410	0.3954	15	6	0.290

at time t, α (>0) denotes intrinsic growth rate and γ, the ceiling value. Then this model is represented by

$$E(Y_t) = \frac{\gamma}{1 + \beta \exp(-\alpha t)}$$

where $\beta = \frac{\gamma - Y_0}{Y_0}$ and Y_0 is the value of Y_t at $t = 0$

Gompertz model : This model is represented by

$$E(Y_t) = \gamma \exp[-\beta \exp(-\alpha t)]$$

where symbols have same meaning as in logistic model. Both the Logistic and Gompertz models are of sigmoid shape. The difference between the two is that Logistic is symmetric while Gompertz model is not symmetric about the point of inflection.

Criteria for Model Selection : There are situations in which the use of model is not particularly well founded and several competing models may appear to fit the data equally well in practice. Hence, there is a need to know the criteria that will help us to test the goodness of fit *vis-a-vis* comparison among different competing models. The three most prominent criteria of fitting the models are used here. These criteria are Mean Absolute Error (MAE), Root Mean Squared Error (RMSE) and Mean Absolute Percentage Error (MAPE). The description and properties of these criteria are available in Sarkar (2004).

The data on body weights for Jabalpur and Tirupati research stations for male and female pigs for different years were first plotted and the shape of the curve was observed. On the basis of the sketch of the curves, three non-linear models viz. Exponential, Logistic and Gompetz were attempted for the best fit on body weight data of pigs for male and female separately. The selection of model was made on the basis of minimum value of MAPE, RMSE and MAE and also on the valid estimates of parameters. To work out percentage prediction error the curve was fitted upto 28 weeks of age and error was computed for 32 and 36 weeks of age.

Further the best fitted models were tested for independence and normality of the residuals. For randomness of residuals run test (Siegel, *et al.*, 1956) and for testing the normality of the residuals Shapiro - Wilks test statistics W (Shaprio and Wilk, 1965) were applied.

Results and Discussion

Jabalpur Research Station : For the body weight of male pigs for the year 1987-88, the value of MAE was 1.30 for Gompertz model that was smaller than the other two models. The other two measures viz. MAPE and RMSE were also least for Gompertz model. Thus Gompertz model was observed to be bets fit for male pigs at Jabalpur research station. For female pigs also MAPE, MAE and RMSE measures were minimum for Gompertz model than the exponential and Logistic models. Thus Gompertz model was found to be fit for both male and female for the year 1987-88 (Table 1).

The results of fitted models for Jabalpur research station for 1989-90 (Table 1) indicated that the values of MAPE, MAE and RMSE were minimum for Gompertz model for male pigs. But the estimate of ceiling value (the maximum weight that a pig can attain) was 135.1 kg that was not in the range, a pig could attain it. The next best fitted model was Logistic model. The estimates obtained from this model were valid. Thus Logistic model was the best fit in this case. Further, for female pigs, MAPE, MAE and RMSE measures were minimum for Logistic model and moreover the estimate of ceiling value for Gompertz model was absurd. Thus Logistic model would be better in this case also.

Tirupati Research Station : For Tirupati research station also three models namely Exponential, Gompertz and Logistic were attempted for the year 1986 - 87 and 1987 - 88. For both male and female, Gompertz model was found to be having the least value for the three measures of selection viz. MAPE, MAE and RMSE in both the years. The estimates of the parameters were in the valid range for this model in all the case. Thus Gompertz was observed to be the best fitted for male and female pigs.

The best-fitted models were tested for independence and normally of the residuals and are presented in Table-2. W-statistics of the Shapiro-Wilk's test revealed that the residual were distributed normally in all the situations and also residuals were distributed independently as the two tailed probability is more than 0.05 in all the cases in run-test.

Summary

The growth of crossbred (i.e. cross of Largewhite - Yorkshine X Desi) pigs, maintained at Jabalpur and Tirupati research stations of AICRP on pigs during 1986-1990 was studied for suitable statistical non-linear models, viz. Exponential, Gompertz and Logistic models. These models had been examined to obtain the best fitted model using the criteria of mean absolute error (MAE), root mean squared error (RMSE), and mean absolute percentage error (MAPE). The best fitted models were tested for independence by using run-test for normally using Shapiro - Wilk test on the residuals and errors were found to be normally and independently distributed. In most of the cases, it was observed that Gompertz model was the best fitted model and shape of the curve of body weight also indicated the suitability of Gompertz model. In general that Gompertz model was the most suitable model for understanding the growth behaviour of pigs maintained in India.

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