Indian Journal of Animal Sciences 71 (5): 476-479, May 2001

Growth of Holstein cows in high altitude of Turkey

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Received: 25 April 2000; Accepted: 23 November 2000

Key words: Growth curve, Holstein cows

The growth pattern of Holstein cows in high altitude of Turkey was estimated using several models, and these models were compared for fitting to age-weight data of Holstein because fitting accuracy of a model can be changed by traits and species.

Data were collected from an experimental dairy cattle farm in Erzurum region located in the North-eastern of Anatolia in Turkey. During the experimental period minimal and maximal monthly temperatures were −17°C and 19.1°C, respectively. Over the years total annual rainfall ranged between 319-426 mm and average humidity 63.5 to 70.7%.

A commercial concentrate feed of 16 % CP with medium quality roughage as grass alfalfa, sainfoin and grazing in low quality pasture was fed according to age and weight of animal. Calves were forced to consume colostrum after calving. Before weaning (until 2 months of age) calves were fed with milk and calf starter. From weaning to 6 months of age, feeding was based on calf starter feed and good quality roughage. Animal was fed with grower feed after 6 months of age. During the spring and summer they consumed roughage from grazing pasture while concentrate feed was still offered during this period. If pasture is not sufficient, supplementary roughage was also offered.

All cows are housed in barn except during summer. Live weights of 69 Holstein cows from 1990 to 1997 were collected every 3 month from birth to 18 months of age, then every 6 month. Number of age-weight points was not consistent among animals.

Simple linear, quadratic, cubic models as linear in parameters and Brody, Bertalanffy, Logistic, Gompertz and Richards models as non-linear in parameters were used to describe the growth pattern of Holstein heifers. Number of parameters and fitting simplicity of the models were different and they are described in Table 1.

The models were individually applied to each animal to describe the growth curves of cows and to see the variations of growth curve parameters among individuals. In the study this analysis was called as individual.

Since number of age-weight points was not fixed for each animal, the models were also fit to data set including age-weight data of all individual simultaneously. This analysis was called as simultaneous.

Growth curve parameters were also estimated using only the mean of weights at each age point to see the general tendency of growth and compare the result of this analysis with the results of previous analyses described above. This analysis was called as mean-weight.

Growth curve parameters and coefficient of determination of the models were used to select the best fitting model.

Brody, Bertalanffy, Logistic, Gompetz and Richards

Table 1. Models used to describe the growth curve of Holstein heifers

Model type	Name of model	Equation	Number of parameters
	Simple linear	$Y_t = A + B*t$	2
Linear	Quadratic	$Y_t = A + B*t + C*t^2$	3
in parameters	Cubic	$Y_t = A + B*t + C*t^2 + D*t^3$	4
	Brody	$Y_t = A-B*\exp(-K*t)$	3
Non-linear	Bertalanffy	$Y_t = A(1-B*\exp(-K*t))^3$	3
in parameters	Logistic	$Y_t = A(1+B*\exp(-K*t))^{-1}$	3
	Gompertz	$Y_t = A\exp(-B*\exp(-K*t))$	3
	Richards	$Y_t = A(1-B*\exp(-K*t))^M$	4

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Table 2. Estimates from simultaneous analyses of age-weight data by using several models

Models	Equation	R^2	df	MSE	F	P
Simple linear	$Y_t = 143 + 5.7*t$	0.73	684	5449	1825	.0000
Quadratic	$Y_t = 58 + 14.1*t - 0.118* t^2$	0.91	683	1795	3467	.0000
Cubic	$Y_t = 30+19.1*t-0.287*t2+0.0014* t^3$	0.93	682	1463	2888	.0000
Brody	$Y_t = 478 -458*exp (-0.05*t)$	0.93	683	1492	15944	.0000
Bertalanffy	$Y_t = 454 (1-0.561*exp (-0.08*t))^3$	0.93	683	1413	16849	.0000
Logistic	$Y_t = 437 (1+5.89*exp (-0.14*t))^{-1}$	0.92	683	1561	15234	.0000
Gompertz	$Y_t = 448 exp(-2.26* exp (-0.094*t)$	0.93	683	1433	16607	.0000
Richards	$Y_t = 456 (1-0.65*exp (-0.076*t))^{2.4}$	0.93	682	1414	12628	.0000

R^2 adjusted coefficient of determination, df degree of freedom of residual, MSE mean square error, F and P are F value and significance level of models, respectively.

models (Brown *et al.* 1976, Fitzhugh 1976, Morrow *et al.* 1978, Oliveria 1994) were fitted by Levenberg-Marquardt method from generalized least-squares analyses. In this method iteration algorithm was used for the solution with convergence criterion of 1.0E-0.8. Results from literature and previous analyses of the data were used for initial values of the parameters to decrease the number of iterations required to reach the solutions. If analyse is not convergenced or if solutions are biologically impossible several starting values were used. If degree of freedom for error term is less then 2, results of analyses of those individuals were excluded from overall consideration.

Although Moore (1985) stated that linear model was generally sufficient to explain the growth curve of mammalian, quadratic, Cubic, Brody, Bertalanffy, Logistic, Gompertz and Richards models gave better fit to the data ($R^2_a = 0.91$) than the linear models (Table 2).

Observed and estimated growth curves by using Cubic and Bertalanffy models from simultaneous analyse (Table 2) are presented in Fig. 1. Cubic model is simple and gave the best fitting among linear models in the parameters and Bertalanffy that is non-linear model and had the lowest MSE.

Monthly weights from birth to 50 months of age were estimated by using the models. Body weights are lighter than the value of Holstein in the other countries (Heinrichs and Hargrove 1987, Heinrichs and Losinger 1998).

Differences between actual and estimated weights were given in Fig. 2. Observed birth weights were in good agreement with estimated ones from Richards, Bertalanffy and cubic models. Birth weights were underestimated by Brody model and overestimated by all other models. These results were also seen in Fig. 2. Simple linear model overestimated the weights in the first 10 months while negative deviations were observed after 10 months of age. The deviations of estimated weights by using the other models from observed were quite similar with increase in age of cows (Fig. 2).

Table 3. Mean (± standard deviation) of estimates from individual analyses of age-weight data (n=69) using several models

Models	R^2	A	B	C or K	D
Simple linear	0.87 (0.010)	110 (5.6)	8.5 (.40)	-	-
Quadratic	0.97 (0.003)	31.5 (6.04)	17.4 (.65)	-0.179 (.018)	-
Cubic	0.98 (0.003)	25.9 (9.25)	18.2 (1.13)	-0.229 (.050)	0.001 (0.001)
Brody	0.95 (0.005)	483 (8.9)	496 (11.7)	0.053 (.002)	-
Bertalanffy	0.96 (0.005)	448 (7.3)	.59 (.01)	0.09 (.002)	-
Logistic	0.96 (0.004)	427 (7.9)	.12 (.004)	3.21 (.05)	-
Gompertz	0.96 (0.004)	433 (7.1)	.103 (.003)	2.40 (.043)	-
Richards	0.96 (0.005)	456 (10.7)	.399 (.06)	0.086 (.005)	-

R^2 adjusted coefficient of determination, A, B, C or K and D are parameters of model.

The results of these analyses ie. simultaneous, individual and mean-weight (Tables 2, 3 and 4) depicted that the R^2 was close to each other in simultaneous and mean-weight analyses, but higher in the analyses using individual estimates. Moving simultaneous to individual analyses, increases in R^2 were 19 %, 7 % and 5 % for simple linear, quadratic and cubic models, respectively, while it was 2-4 % for Brody, Bertalanffy, Logistic, Gompertz and Richards.

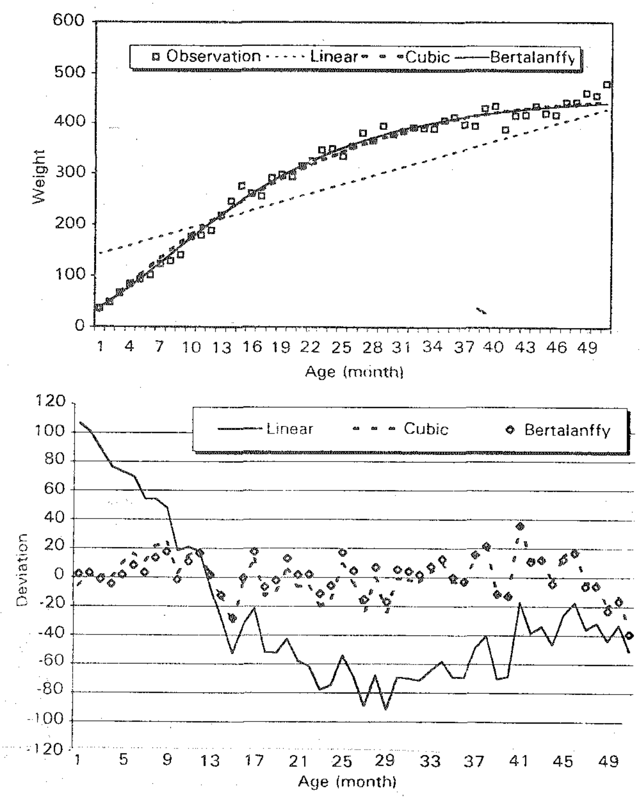
In terms of fitting performance, only two models from linear model group (linear and cubic) and one model from non-linear group (Bertalanffy) were chosen to represent the models. Cubic and Bertalanffy models gave the best fit for all types of analyses. Using individual type of analysis, weights after about 30 months of ages were overestimated slightly by cubic model.

A is asymptotic weight at time t = 8 for non-linear models

Table 4. Estimates from mean-weight analyses of mean age-weight data using several models

Models	Equation	R^2	df	MSE	F	P
Simple linear	$Y_t = 219 + 3.6*t$	.66	78	4143	156	.0000
Quadratic	$Y_t = 83 + 12.2*t - 0.095*t^2$	.92	77	961	466	.0000
Cubic	$Y_t = 34+18.1*t-.252*t2+.0011*t^3$	.94	76	700	436	.0000
Brody	$Y_t = 468 - 472*exp(-.06*t)$	.94	77	694	5899	.0000
Bertalanffy	$Y_t = 459\ (1-.56*exp(-.08*t))^3$	.95	77	650	6310	.0000
Logistic	$Y_t = 452\ (1+4.77*exp(-.12*t))^{-1}$	.94	77	749	5464	.0000
Gompertz	$Y_t = 456\ exp(-2.18*exp(-.087*t))$	.95	77	665	6157	.0000
Richards	$Y_t = 460\ (1-.73*exp(-.073*t))^{2.1}$	.95	76	656	4682	.0000

R^2 adjusted coefficient of determination, df degree of freedom of residual, MSE mean square error, F and P are F value and significance level of models, respectively.



Figs 1-2. **1.** Observed and estimated growth curves from simple linear, cubic and Bertalanffy models. **2.** Difference between observed and estimated weights using different models.

in the parameters while this parameter is related to initial weight for linear models in the parameters. Parameter A compared with its expectation was overestimated by simple linear and quadratic models but not by cubic model (Table 2). Parameter A estimates were almost similar from individual and simultaneous analysis for non-linear models (Tables 2 and 3).

Consequently, non-linear models in the parameters gave the best fitting accuracy to dairy cattle data with the biological meaning of parameters. On the other hand cubic model can also be used for the purposes because of its simplicity and equal accuracy for fitting compared with non-linear model in the parameters.

The growth pattern of Holstein cows in high altitude of Turkey was estimated by using simple linear, quadratic, cubic, Brody, Bertalanffy, logistic, Gompertz and Richards models. All models except simple linear model gave better fit to the data. Non-linear models in the parameters gave the best fitting accuracy to dairy cattle data with the biological meaning of parameters. Cubic model can also be used for the purposes because of its simplicity and equal accuracy compared with non-linear model in the parameters.

SUMMARY

Growth patterns of Holstein cows in high altitude of Turkey were estimated by simple linear, quadratic, cubic models as linear in parameters and Brody, Bertalanffy, Logistic, Gompertz and Richards models as non-linear in parameters, and fitting accurracy of the models to age-weight data of Holstein were compared. Quadratic, Cubic, Brody, Bertalanffy, Logistic, Gompertz and Richards gave better fit to the data than the linear models. There were slight differences among these better fitting models in sum of squares explained by model. Non-linear models in the parameters gave the best fitting accuracy to dairy cattle data with the biological meaning of parameters. Cubic model can also be used for the purpose because of its simplicity and equal accuracy for fitting compared with non-linear model in the parameters.

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