Application of different growth models to "Nero di Parma" pigs

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ABSTRACT - The growth curves of 280 "Nero di Parma" pigs from birth to maturity were calculated by applying nine different models (regressions from 1st to 4th degree and nonlinear regressions following the Brody, Logistic, Janoschek, Bertalannfy and Gompertz models) to 1109 individual records of body weight (BW) from two different data sets. The goodness of fit of experimental data was calculated by means of Residual Variance, Akaike Information Criterion, Residual Standard Deviation and R^2. The best fit was obtained by Gompertz equation, as follows: BW(kg)= 240.2±2.4 * esp (-exp (-0.0069±0.0001*(age(d)–213.5±3.1))). Regardless to the model, all correlations between actual and estimated BW were highly significant (P<0.001): the highest correlation (0.980) was obtained by the application of the Gompertz equation. In conclusion the growth of "Nero di Parma" pigs can be well described by applying the Gompertz model to field data.

Key words: Pigs, Nero di Parma, Growth curves, Non linear models.

Introduction - The swine genetic type "Nero di Parma" has been obtained after a preservation programme of a local black breed in Parma province, suitable both for indoor and outdoor rearing systems. Actually, 841 females and 45 males are registered by Italian Swine Breeders Association and they are reared in 38 herds spread in Northern Italy. Because of its origin and the different rearing conditions used for this genetic type, it could be difficult to attribute to "Nero di Parma" the same growth parameters that have been recently calculated for local (Pugliese *et al.*, 2003; Lemus-Flores *et al.*, 2005) or more selected pigs (Van Lunen and Cole, 1998; Ferguson and Kyriazis, 2003). Moreover there is little information about this genetic type (Sabbioni *et al.*, 2006, 2007), and it does not take into account the weight gain. The aim of the research was to choose the best growth model for "Nero di Parma" pig, in order to obtain useful parameters for the management of this genetic type.

Material and methods - The research was carried out on two different datasets: the first one contained 420 weight records from 210 pigs of the genetic type "Nero di Parma", reared in five intensive herds and submitted to genetic controls for weight gain. The pigs were weighted at first during the weaning period and then between 75 and 100 d of age. The pigs were raised initially in farrowing cages until 28 d, then in boxes on slatted floors, and they were fed on commercial feeds offered *ad libitum*. The second database contained 689 weight records of 70 "Nero di Parma" pigs from birth to maturity during years 2003-2008; the pigs were raised at 16 indoor or outdoor herds and fed on commercial feeds offered *ad libitum*; in the outdoor system the diet was integrated after weaning with pasture in the brushwood. The pigs were weighted at approximately 60 d intervals until 1 year of age, then at approximately 120 d intervals until 2 years of age; 59 of them were further weighted during the 3rd or 4th year of age. The final dataset then contained 1109 individual records from 280 female, male and castrated male pigs; each pig was weighted

from 2 to 10 times (mean = 4). By means of the application of linear and multiple regression and nonlinear regression analysis (SAS, 2003), 9 growth models were tested (regressions from 1st to 4th degree and Brody, Logistic, Janoschek, Bertalannfy and Gompertz growth models). The parameters of the models were estimated and the goodness of fit indicators (Residual Variance, RV; Residual Standard Deviation, RSD; Akaike Information Criterion, AIC; R^2) were calculated (Wellock *et al.*, 2004). The correlation coefficients between actual and estimated BW were then calculated for each tested model.

Results and conclusions - The estimated parameters of the 9 proposed equations are presented in Table 1. Regressions from 1st to 4th degree showed a negative intercept; the estimate of birth weight was always lower than 0 kg (table 2), like so with the Brody model. Growth models from 6 to 9 gave positive estimates of birth weight (1.2-6 kg), but only equation 8 gave a correct estimate (1.2 kg). The predicted values at the age of two years ranged between 241.7 and 258.6 kg and between 216.6 and 240.6 kg, respectively, by applying the regressions from 1st to 4th degree or the nonlinear growth models. The lowest value was estimated by equation 6 and the highest by equation 3.

The indicators of the goodness of fit of the proposed models are presented in Table 3. Equation 9 (Gompertz growth model) best fitted the experimental data, showing the lowest values for RV, AIC and RSD. Equations from 7 to 9 showed also the highest R^2. These results agree with the studies of Wellock *et al.* (2004). Both linear and quadratic regression failed to fit the experimental data. In fact they are particularly useful to describe the growth during limited periods (Keskin and Birol, 2006). According to the results (Table 3), the Gompertz equation was the best fitting model for "Nero di Parma" pig. Some combinations of Gompertz parameters were then calculated with the aim to improve the description of the growth. In fact, the *A* parameter indicates the mature BW, *b* is the rate of growth and *c* is the age of maximum growth. When t= *c*, consequently BW= *A*/e, where e = base of natural logarithms (2.7182818…) (Wellock *et al.*, 2004). In that moment the average daily gain (ADG_{max}) is calculated as *b***A*/e. On the basis of the experimental data, "Nero di Parma" pigs

Table 1. Regression equations and growth models of body weight (BW, kg) for "Nero di Parma" pigs (t =age, d) and parameters estimates (SE within brackets).

Model	Equation for BW	A	b	c	d	e
1: 1st degree regression	$A+bt$	-0.91 (0.62)	0.332 (0.004)	-	-	-
2: 2nd degree regression	$A+bt+ct^2$	-8.31 (0.51)	0.494 (0.006)	-2.0E-4 (6.3E-6)	-	-
3: 3rd degree regression	$A+bt+ct^2+dt^3$	-6.36 (0.61)	0.437 (0.012)	-4.0E-5 (2.9E-5)	-8.4E-8 (1.5E-8)	-
4: 4th degree regression	$A+bt+ct^2+dt^3+et^4$	-1.24 (0.62)	0.249 (0.015)	9.0E-4 (6.0E-5)	-1.4E-6 (7.8E-8)	5.4E-10 (3.0E-11)
5: Brody	$A(1-b\exp(-ct))^1$	397.1 (14.0)	1.023 (0.002)	1.3E-3 (6.5E-5)	-	-
6: Logistic	$A/(1+\exp(b-ct))$	216.8 (1.7)	3.553 (0.039)	0.0145 (2.7E-4)	-	-
7: Janoschek	$A-(A-b)\exp(-ct^d)$	237.5 (2.8)	3.768 (0.451)	2.2E-5 (4.0E-6)	1.848 (0.034)	-
8: Bertalannfy	$A(1-b\exp(-ct))^3$	259.7 (3.1)	0.834 (0.007)	4.8E-3 (1.0E-4)	-	-
9: Gompertz	$A\exp(-\exp(-b(t-c)))$	240.2 (2.4)	0.0069 (0.0001)	213.5 (3.1)	-	-

Table 2. Estimated BW (kg) at d 0 and d 730 of age.

Model	1	2	3	4	5	6	7	8	9
BW at d 0	-0.9	-8.3	-6.4	-1.2	-9.1	6.0	3.8	1.2	3.1
BW at d 730	241.7	245.5	258.6	255.7	238.7	216.6	234.3	240.6	233.5

at the age of 213.5 d reach a BW of 88.7 kg and they show their maximum ADG (0.609 kg/d).

Correlations between actual weights and estimated weights by means of the nine proposed models are reported in table 4. Though they all are highly significant (P<0.001) the highest value was registered by equation 9 (Gompertz).

Table 3. Goodness of fit indicators of growth models for "Nero di Parma" pigs.

Model	RV	AIC	RSD	R^2
1: 1st degree regression	326.4	6423.0	18.1	0.874
2: 2nd degree regression	171.9	5713.9	13.1	0.934
3: 3rd degree regression	167.5	5687.2	12.9	0.936
4: 4th degree regression	131.2	5418.3	11.5	0.950
5: Brody	189.8	5823.8	13.8	0.941
6: Logistic	119.6	5311.6	10.9	0.963
7: Janoschek	105.3	5172.4	10.3	0.968
8: Bertalannfy	105.1	5168.3	10.3	0.968
9: Gompertz	102.4	5139.4	10.1	0.968

Table 4. Correlation coefficients between actual and estimated BW.

BW estimated by equation	Actual BW
1: 1st degree regression	0.935
2: 2nd degree regression	0.966
3: 3rd degree regression	0.967
4: 4th degree regression	0.974
5: Brody	0.963
6: Logistic	0.977
7: Janoschek	0.979
8: Bertalannfy	0.979
9: Gompertz	0.980

All coefficients are significant (P<0.001)

In conclusion, all the models adjusted well to the data, but the regressions from 1st to 4th degree partially failed to estimate the weight, above all at the beginning of the growth curve. The Gompertz model was more indicated to describe the growth of the "Nero di Parma" pigs and could be used in improvement programs. Further analyses must be carried out with the aim to investigate about the effect of environmental and genetic factors on the parameters of growth curves in "Nero di Parma" pigs.

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