Effect of sex and season of birth on Gompertz growth curve parameters in "Nero di Parma" pigs

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ABSTRACT

The growth curves of "Nero di Parma" pigs were studied by applying the Gompertz equation to 1069 body weight (BW) records from 285 pigs (156 females, 129 castrated males) born in 11 outdoor and 5 indoor herds; pigs were fed commercial complete feeds offered *ad libitum* and, on a limited basis in the outdoor system, diets were integrated with pasture. The parameters of the Gompertz equation were compared with reference to sex and season of birth.

Mature BW for castrated males (229.0 kg) was 3.5% greater than that for females (221.3 kg) (P<0.05), but growth rate was 7.6% lower ($7.38*10^{-3}$ *vs* $7.99*10^{-3}$, respectively) (P<0.05) and age at maturity (205.7 *vs* 189.6 d, respectively) was 16.1 d greater (P<0.05). Summer and winter born pigs showed a lower mature BW (P<0.05) than those born in other seasons. Summer born pigs grew slower than those born in spring (9.57%), winter (9.58%) and autumn (21.47%) (P<0.05). Earlier maturing pigs were those born in autumn, followed by those born in winter, spring and summer, respectively. Regardless of sex and season of birth, pigs showed their maximum ADG (ADG_{max}) of 635 g/d at 82.6 kg BW. Castrated males have a lower ADG_{max} than females (622 *vs* 650 g/d) at a heavier weight (84.2 *vs* 81.4 kg). Autumn born pigs showed the highest ADG_{max} (695 g/d), reached at 84.9 kg BW.

The growth performance of "Nero di Parma" pigs is greater than those reported for Italian domestic pig breeds. The significant effect of the studied environmental factors on the growth curve in this genetic type will make it possible to choose the best rearing conditions in relation to its usual weight at slaughter (>180 kg).

Key words: Pig, Nero di Parma, Growth, Gompertz model.

RIASSUNTO

EFFETTO DEL SESSO E DELLA STAGIONE DI NASCITA SUI PARAMETRI DELL'EQUAZIONE DI GOMPERTZ NEL SUINO "NERO DI PARMA"

Il tipo genetico suino "Nero di Parma", ottenuto a seguito di un lungo programma di conservazione di una razza locale in provincia di Parma ed inserito in un Registro Riproduttori Ibridi, è rappresentato attualmente da 841 femmine e 45 maschi, allevati in allevamenti intensivi e all'aperto nell'Italia settentrionale. Gli animali sono tipicamente macellati nella stagione invernale a pesi molto elevati (>180 kg) ed utilizzati essenzialmente per la produzione di prodotti di salumeria a lunga stagionatura. Le curve di crescita del suino "Nero di Parma" sono state studiate applicando l'equazione di Gompertz a 1069 pesate individuali di 285 suini (156 femmine e 129 maschi castrati), presenti in 16 aziende e allevati all'aperto (sistema semi-intensivo) ed al chiuso; gli animali sono stati alimentati con mangimi completi del commercio somministrati ad libitum (negli allevamenti all'aperto era anche previsto il pascolo nel sottobosco). I parametri dell'equazione di Gompertz sono stati confrontati in relazione al sesso ed alla stagione di nascita.

Nei maschi castrati, rispetto alle femmine, il peso alla maturità è risultato superiore del 3,5% (rispettivamente kg 229 e 221,3) (P<0,05), la velocità di crescita è risultata più bassa del 7,6% (rispettivamente 7,38*10⁻³ e 7,99*10⁻³) (P<0,05) e l'età alla maturità superiore di 16,1 d (rispettivamente 205,7 e 189,6 d) (P<0,05). I suini nati in estate ed inverno hanno mostrato un peso alla maturità più basso (P<0,05) di quelli nati in autunno e primavera. Quelli nati in estate sono cresciuti più lentamente di quelli nati in primavera (9,57%), in inverno (9,58%) e in autunno (21,47%). I suini più precoci sono risultati quelli nati in autunno, seguiti, rispettivamente, da quelli nati in inverno, primavera ed estate. Indipendentemente dal sesso e dalla stagione di nascita i suini hanno manifestato il loro massimo accrescimento giornaliero (ADG$_{max}$) di 635 g/d a 82,6 kg di peso; i maschi castrati hanno mostrato un ADG$_{max}$ minore rispetto alle femmine (622 vs 650 g/d), ma ad un peso superiore (84,2 vs 81,4 kg). I suini nati in autunno hanno mostrato l'ADG$_{max}$ più alto (695 g/d), raggiunto ad un peso vivo di 84,9 kg.

Le performance registrate per il suino "Nero di Parma" sono risultate superiori a quelle dei suini appartenenti alle razze autoctone italiane, desunte dalla bibliografia. L'effetto significativo dei fattori ambientali studiati sulla curva di crescita permette di scegliere le migliori condizioni di allevamento in relazione al peso alla macellazione richiesto.

Parole chiave: *Suino, Nero di Parma, Accrescimento, Modello di Gompertz.*

Introduction

"Nero di Parma" is a hybrid breeding pig obtained after a preservation programme of a local black coated pig breed in Parma, Northern Italy. More precisely, the local breed, named Nera Parmigiana, saw its number reduced during the past century because it was heavily crossed with "white coated" pig breeds, especially in the plains area of the province, as in the mountain territory the substitution of the breed with more productive pigs occurred more slowly. More recently, the reduction became dramatic and the breed was considered as extinct with only the crossbred population remaining in province of Parma. During 1990s, thanks to the contribution of several local institutions, a programme was planned with the aim to develop and enhance the breeding of this population in the area of origin. This programme took into account the selection of boars and sows within the crossbred population spread in the mountain area of the province of Parma, directly derived from and genetically connected to the extinct local breed. The obtained founder black coated population was then collected and raised in some herds under the supervision of the local Breeders' Association and the University of Parma.

The founder population was studied by

Sabbioni *et al.* (2006) with the aim to assess the genetic variability and the structure. The mean inbreeding coefficient of the founder population resulted very high (27.4%), due to a low absolute number of founders (f_t=22), as well as a low effective number of founders (f_e=3.16). The study showed the need to plan a management policy in order to markedly reduce the high inbreeding by correctly managing the matings.

During 2006 the "Nero di Parma" genetic type was approved by the Ministry of Agriculture (D.M. no. 20196, 24/1/2006). Currently, 841 females and 45 males are registered by the local Breeders Association as hybrid breeding pigs approved by ANAS (National Swine Breeders Association); they are reared in 38 herds, both intensive and extensive, spread across Northern Italy.

The interest in the genetic type originated from the higher prices of meat from "Nero di Parma" pigs with respect to conventional pig meat, especially in the area of origin. In fact, the slaughter weight is preferably more than 180 kg; in this case, carcasses are used for the production of dry cured, long aged cold cuts of local interest and slaughtering is concentrated in the cold season to allow good ripening. Lighter pigs (100-120 kg) are slaughtered for the production of pork meat, and in this case the slaughtering time is indifferent.

In spite of the high rate of inbreeding, the reproductive efficiency (Sabbioni *et al.*, 2007) resulted in line with local breeds in Italy (Franci and Pugliese, 2007), and it was strongly affected by rearing conditions during the suckling period (3.95 piglets weaned in outdoor system *vs* 6.57 in indoor system).

Until now, optimal rearing conditions have yet to be defined and few studies have been published about the growth performance of "Nero di Parma" pigs (Beretti *et al.*, 2009; Sabbioni *et al.*, 2009). Moreover, be-cause of the origin and of the different rearing conditions of the genetic type, it could be difficult to attribute to "Nero di Parma" pigs the same growth parameters that have been calculated in recent years for local (Campodoni *et al.*, 2003; Pugliese *et al.*, 2003; Lemus-Flores *et al.*, 2005) or more selected pigs (Van Lunen and Cole, 1998; Ferguson and Kyriazis, 2003).

The comparison of different growth models for "Nero di Parma" pigs (regressions from 1st to 4th degree and nonlinear equations following the Brody, Logistic, Janoschek, von Bertalannfy and Gompertz models) showed that the Gompertz equation best fits the experimental data and it could be considered in the growth analysis of "Nero di Parma" pigs (Sabbioni *et al.*, 2009). Another report (Wellock *et al.*, 2004) also indicates that the Gompertz model loads in pigs to a much more acceptable prediction of live weight than do other models.

The aim of the present research was to study the effect of some factors, such as sex and season of birth, on the growth of "Nero di Parma" pigs, as assessed by the application of the Gompertz equation.

Material and methods

The research was carried out on the individual body weight (BW) records of 285 "Nero di Parma" pigs from 101 sows mated by 25 boars. Two different datasets were used: the first one contained 430 weight records from 215 pigs (122 females and 93 castrated males), reared in five intensive herds and submitted to genetic controls for weight gain, in order of their enrolment to ANAS (National Swine Breeders Association). The pigs were first weighed during the suckling period (mean age ±SD=16±10 d) and then between 75 and 110 d of age (mean age ±SD=98±7 d). They were initially raised in farrowing cages until 28 d, then in boxes

on slatted floors, and they were fed on commercial complete feeds offered *ad libitum*. The second database contained 639 weight records of 70 pigs (34 females and 36 castrated males) from birth to the age of two years, during years 2003-2009. The pigs were raised at 5 indoor and 11 outdoor herds and fed on commercial complete feeds offered *ad libitum*; in the outdoor system the diets were integrated after weaning with pasture in the brushwood. The pigs were weighed at birth and at approximately 60 d intervals until 1 year of age, then at approximately 120 d intervals until 2 years of age. Both in the first and in the second dataset, males were castrated within d 10 of birth.

The two datasets were pooled in order to obtain a final dataset containing 1069 individual records from 156 females (545 records from 1.25 to 257 kg BW, from 1 to 725 d of age) and 129 castrated males (524 records from 1.30 to 266 kg BW, from 1 to 767 d of age); each pig was weighed 2 to 10 times (mean value=4).

The individual data were submitted to nonlinear regression analysis (SAS, 2003) following the Gompertz model:

$$BW = A \exp(-\exp(-b\,(t-c)))$$

where BW is the body weight (kg) at day t, A is the mature BW (kg), b is the rate of growth and c is the age (d) of maximum growth (Emmans, 1989). Some combinations of Gompertz parameters were then calculated with the aim to better describe the growth (Emmans, 1989; Wellock *et al.*, 2004). In fact, when t=c, so BW=A/e, where e=base of natural logarithms (2.7182818…). In that moment the extent of daily gain (ADG_{max}) can be calculated as $b*A$/e.

The parameters of the Gompertz equation were calculated for the pooled dataset and then separately for females and castrated males and for pigs born in different seasons (spring, from March to May; summer, from June to August; autumn, from September to November and winter, from December to February). Residuals were normally distributed (W statistic=0.634; P<0.001). The effects of the rearing conditions were not taken into account because of the unbalanced number of observations in the different herds and above all because indoor born pigs were often subsequently moved to outdoor farms during the fattening period.

Comparisons of the growth parameters between sexes and among seasons of birth were done by means of the Student t-test using pooled estimates of standard error to determine significant differences (Ferguson and Kyriazis, 2003).

Results and discussion

Table 1 reports the parameters of the Gompertz equation for BW estimation calculated from the complete dataset and separately for females and castrated males and for pigs born in different seasons.

The mean mature BW of "Nero di Parma" pigs was 224.6 kg, a value lower than those reported by Solanes and Stern (2001) for Large White sows (ranging between 258 and 285 kg), but higher than those reported by Franci and Pugliese (2007) for Italian autochthonous breeds (reaching a maximum of 200 kg in the Casertana breed). This agrees with the recent history of "Nero di Parma" pigs, which, as above reported, were obtained at the end of the '90s within a crossbred population derived from "white coated" pigs and the Nera Parmigiana breed. Koivula *et al.* (2008) report a common mature weight in Finnish Yorkshire boars, gilts and barrows of 201.3 kg. In this case, the low value could be due to the low final weight (approximately 100 kg) used in the study, a value that resulted too close to the inflexion point and that could have affected the parameters estimate.

Table 1.   Parameters of the Gompertz equation (± SE) for BW estimation in "Nero di Parma" pigs as affected by sex and season of birth.

		Animals	A	b	c	Residual SE	R^2	P
Pooled	no.	285	224.6 ± 2.1	0.007681 ± 0.000161	196.9 ± 2.8	9.65	0.963	< 0.001
Sex:								
Females	"	156	221.3^a ± 2.5	0.007988^b ± 0.000214	189.6^a ± 3.4	8.95	0.963	< 0.001
Castrated males	"	129	229.0^b ± 3.6	0.007378^a ± 0.000239	205.7^b ± 4.8	10.30	0.964	< 0.001
Season of birth:								
Spring	"	97	230.7^c ± 2.5	0.007108^b ± 0.000215	208.1^b ± 4.4	5.45	0.982	< 0.001
Summer	"	61	225.2^b ± 8.4	0.006428^a ± 0.000403	229.6^c ± 11.3	11.12	0.944	< 0.001
Autumn	"	86	230.8^c ± 3.2	0.008185^c ± 0.000237	182.4^a ± 3.8	9.70	0.976	< 0.001
Winter	"	41	215.2^a ± 6.0	0.007109^b ± 0.000463	207.2^b ± 9.6	9.23	0.962	< 0.001

^{a,b,c}: different (P<0.05) within each parameter.

Equation parameters for castrated males showed a mature BW 3.5% greater than that for females (P<0.05), but a 7.6% lower growth rate (P<0.05) and an age at maturity significantly (P<0.05) greater (+ 16.1 d).

Ford and Klindt (1989) reported that sex differences in the growth of pigs are less apparent than those observed in other species and in any case differences are not apparent until after 45 kg BW. Whittemore *et al.* (1988) suggested that mature BW, estimated by means of the Gompertz model, of Large White x Landrace pigs ranges between 200 (for females slaughtered at 182.3 kg BW and 330 d of age) and 250 kg (for boars slaughtered at 205.2 kg BW and 332 d of age) as castrated males are intermediate (225 kg of mature BW for pigs slaughtered between 198.9 and 213.7 kg at the age of approximately 330 d). Di Lella *et al.* (1979) reported a significant effect of sex on growth of crosses between Casertana and Large White breeds: castrated males reached the slaughtering weight of about 90 kg in a lower time than females (84 d *vs* 102).

Also the season of birth significantly

(P<0.05) affected the parameters of the Gompertz equation. In particular, summer and winter born pigs have shown lower mature weights than those born in autumn and spring. The difference between autumn and spring born pigs was not significant (P>0.05). Summer born pigs grew slowly than those born in spring (9.57%), winter (9.58%) and autumn (21.47%). Earlier maturing pigs, *i.e.* those with the earliest age of maximum growth, were those born in autumn, followed by those born in winter, spring and summer, respectively.

The parameters of the Gompertz model reported in Table 1 were used to calculate ADG_{max} of "Nero di Parma" pigs (Table 2). The pooled data set showed a maximum ADG of 635 g/d at 82.6 kg BW; castrated males have a lower ADG_{max} than females (622 *vs* 650 g/d) at a heavier weight (84.2 *vs* 81.4 kg). Autumn born pigs showed the highest ADG_{max} (695 g/d), reached at 84.9 kg BW.

These effects are probably more related to the rearing conditions of pigs than to their feeding conditions because the nutri-

Table 2.   Weight of maximum growth and ADG_{max} for "Nero di Parma" pigs as affected by sex and season of birth.

	Weight of maximum growth (kg)	ADG_{max} (g/d)
Pooled	82.6	635
Sex:		
Females	81.4	650
Castrated males	84.2	622
Season of birth:		
Spring	84.9	603
Summer	82.8	533
Autumn	84.9	695
Winter	79.2	563

Table 3.   Liveweight (kg) at selected ages (d) and percentage of weight at maturity (parameter A of the Gompertz equation) in "Nero di Parma" pigs.

Age (d)	Pooled		Sex				Season of birth							
			Females		Castrated males		Spring		Summer		Autumn		Winter	
	kg	% of A	kg	% of A	kg	% of A	kg	% of A	kg	% of A	kg	% of A	kg	% of A
90	23.14	10.31	24.12	10.90	21.88	9.56	22.80	9.88	19.37	8.60	27.44	11.89	21.57	10.03
180	71.94	32.04	75.16	33.96	68.38	29.86	68.06	29.50	56.91	25.26	83.28	36.08	63.98	29.73
270	126.97	56.54	130.76	59.08	122.92	53.67	121.18	52.53	104.14	46.23	141.70	61.38	113.50	52.74
360	168.77	75.15	171.27	77.38	166.25	72.59	164.27	71.21	146.14	64.88	182.74	79.17	153.57	71.36
450	194.63	86.67	195.34	88.25	194.20	84.80	192.87	83.60	176.73	78.46	206.41	89.42	180.12	83.70
540	209.04	93.08	208.26	94.09	210.38	91.86	209.90	90.99	196.60	87.28	218.80	94.79	195.92	91.04
720	220.57	98.22	218.16	98.56	223.93	97.78	224.71	97.41	215.81	95.81	228.02	98.78	209.65	97.42

tive level was in all cases *ad libitum*. On the contrary, the pooled data set was comprehensive of different rearing conditions, *i.e.* intensive and outdoor or semi-intensive rearing systems. In this last one the climate conditions of the extreme hot and cold seasons, such as summer and winter, probably strongly affected the growth of animals and the attainment of a complete body development, respectively. A significant effect of season of birth on post natal growth in pigs was reported by Woltmann *et al.* (1992), but they showed higher off-test weights in autumn born than in spring born pigs fed *ad libitum*.

Starting from the parameters of the Gompertz equations reported in Table 1, the BW at selected ages (90-720 d) and the corresponding percentage of weight at maturity (Table 3) were calculated.

"Nero di Parma" pigs are usually slaughtered at least at 18 months of age, at the attainment of a live weight not less than 180 kg. Compared to *in vivo* performance by Italian domestic pig breeds (Franci and Pugliese, 2007), "Nero di Parma" showed differences for the mean weight achieved at the same age with Nero Siciliano (90.4%) and Calabrese (56.0%), as differences with Casertana (1.4-13.0%), Mora Romagnola (6.6%) and Cinta Senese (9.3%) were lower.

Conclusions

The significant effect of the studied environmental factors on the growth curves of "Nero di Parma" pigs are of high practical interest because they allow pig breeders to take advantage of some environmental conditions to select the best age to mate gilts for the first time or for the attainment of the slaughter weight in females and castrated males. Moreover, because the farrowing season of sows affects not only the litter survival, but also the subsequent pig growth, parities could be usefully concentrated in spring for the attainment of the particularly high weight at slaughter during the cold season of the following year. Instead pigs born in other seasons could be directed to the production of pork meat.

Further research must be carried out to assess the effect of other environmental conditions on the growth, with particular reference to rearing system and feeding level and on the development of different body tissues, with the aim to optimize the slaughtering age.

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