A MATHEMATICAL MODEL FOR THE LACTATION CURVE OF THE RABBIT DOES

CASADO C., PIQUER O., CERVERA C., PASCUAL J. J.

Unidad de Alimentación Animal, Departamento de Ciencia Animal.
Universidad Politécnica de Valencia, 46041 Valencia, Spain.
jupascu@dca.upv.es

ABSTRACT

The aim of this study was to compare four models considering their fitting to average lactation curve, their ability to predict individual curves and the biological interpretation of their equation coefficients. A total of 550 lactations from 134 rabbit does (from 1st to 5th lactation) were used. Four models were evaluated: quadratic function [QF; $L = a + b\cdot D + c\cdot D^2$], modified beta function [BF; $L = k \cdot (D/30)^a \cdot (1- (D/30))^b$], modified polynomial function [PF; $L = a + b\cdot D - ½\cdot D^{c}$] and gauss function [GF; $L = k \cdot e^{[-½\cdot((D - m)/s)^2]}$]. In the models described, *L* denotes daily milk yield (g), *D* denotes the lactation day and *a*, *b*, *c*, *k*, *m* and *s* are the equation coefficients. All the models presented a good fitting to the average lactation curve (R^2>0.97). QF, BF and PF showed better fitting values (RSME < 5.9 g/day) than GF (RSME = 8.3 g/day). Although the prediction of peak parameters was acceptable with the different models, all of them tended to underestimate both milk yield and day of maximum production. Respect to the ability to predict individual lactation curves, the proportion of "poor" fits was only around 15% and similar for all the models. The best values corresponded to BF (85% of the curves fit with R^2>0.60) and worst-ones were obtained for GF (42% of the curves with R^2>0.80). Changes on the height and persistence of the curve result in changes on "b" and "c" coefficients of the QF and PF, being badly interpreted. In addition, these models give low information about the changes at the beginning of the lactation. In the case of BF, while changes in "a" coefficient seem to be related with changes in the milk yield of does at the beginning of the lactation, changes in "b" coefficient summarise the variations observed at the end of the lactation. In conclusion, all the evaluated models showed a good fitting to the mean and individual rabbit lactation curves. However, due to the greater independence and biological interpretation of the modified beta function coefficients, this function seems to a better model to analyse possible changes in the lactation curve shape of rabbit does.

Key words: lactation curves, rabbit doe, model fitting.

INTRODUCTION

In dairy species the study of models to predict the lactation curves is most frequent. In those animals lactation curves have a wide variety of applications, such as extension of incomplete records for use in genetic evaluations, formulation of rations, economic evaluation of different management schemes, etc. (GROENEWALD, 1995). Although rabbit is not dairy specie, the knowledge of milk yield and the lactation curve shape is very important to evaluate the performance of reproductive rabbit does, especially in nutrition works (FERNÁNDEZ-CARMONA *et al.*, 2001; XICCATO *et al.*, 1995; MCNITT and LUKEFAHR, 1990; MOHAMED and SZENDRÖ, 1992).

Nutrition works usually report milk production data, but did not give information about the lactation curve shape. Only few authors studied the lactation curve from the point of view of modelling (LEBAS, 1968; MCNITT and LUKEFAHR, 1990; SABATER *et al.*, 1993). Main of them proposed a quadratic equation ($y = a + bx + cx^2$) to predict the daily milk yield, which had a good fitting but with a poor biological interpretation. On the other hand, important changes have been produced in the lactation curve shape during the last years, as consequence of an earlier weaning (from 42 to 28 days) and the larger litter size in the farms.

Therefore, the aim of this study was to compare four models considering their fitting to average lactation curve, their ability to predict individual curves and the biological interpretation of their equation coefficients.

MATERIAL AND METHODS

Lactation records

A total of 550 lactations from 134 New Zealand X Californian rabbit does (from 1st to 5th lactation) were used. In order to obtain greater variability, does came from two different genetic lines with different selection degree: H1 (n=67) and H2 (n=67), does were fed with two diets with different energy content: M (n=68) and E (n=66) and data came form does were at different physiological state: currently pregnant (n=193) or non-pregnant (n=357). Litter size was standardized at birth (10 pups) and maintained during the whole experimental period.

Mathematical models

Four models were evaluated: quadratic function, modified beta function, modified polynomial function and gamma function. In the models described, L denotes daily milk yield (g), D denotes the lactation day from parturition to 28th day (usual weaning) and a, b, c, k, m and s are the equation parameters.

The first model proposed to describe the lactation curve of rabbit does was a *quadratic function* (QF):

$$L = a + b \cdot D + c \cdot D^2$$

where:

- a is the milk yield at $D = 0$ (intercept);
- b, c regulate the tendency of the curve;
- $D_{max} = -b/2c$

The second model proposed was a *modified beta function* (BF). As the definition interval of the beta function is 0-1, and the rabbit doe lactation period usually arrives to 28-30 days, the model was modified dividing *D* by 30:

$$L = k \cdot (D/30)^{a} \cdot (1- (D/30))^{b}$$

where:

- *k* regulates height of the curve;
- *a, b* regulate the tendency of the curve;
- $D_{max} = 30a/(a+b)$

The third model was a *modified polynomial function* (PF) obtained as a combination of the two previous models:

$$L = a + b \cdot D - ½ \cdot D^{c}$$

where, the equation parameters (*a*, *b* and *c*) have a similar interpretation than QF parameters, being in this case $D_{max} = b - (c/2)$.

Finally, the last model proposed was the *gauss function* (GF):

$$L = k \cdot e^{[-½ \cdot ((D - m)/s)^2]}$$

where:

- *k* regulates the height of the curve
- *s* regulates the tendency of the curve
- $D_{max} = m$

Statistical Analysis

The analysis of the data was carried out with the statistical package of SAS (STATISTICAL ANALYSIS SYSTEM INSTITUTE, 1990). The coefficients of the equations were estimated for the average and individual lactation curves by a nonlinear regression procedure (PROC NLIN), evaluating their accuracy in function of the root mean standard error (RMSE) and determination coefficient (R^2) values. Initial values for the coefficients were obtained from a previous tentative (DE LA PUERTA, 2003).

RESULTS AND DISCUSSION

Prediction of average lactation curves

Table 1 shows the equation parameters obtained for the average lactation curve fitting with the 4 evaluated models and the predicted lactation peak parameters.

All the models presented a good fitting to the average lactation curve ($R^2 > 0.97$). QF, BF and PF showed better fitting values (RSME < 5.9 g/day) than GF (RSME = 8.3

g/day), and consequently any of them could be used to estimate the daily milk yield of rabbit does. Similar results were just obtained by DE LA PUERTA (2003), where quadratic and polynomial models (R^2 = 0.97) presented a better fit than gamma function (R^2 = 0.88).

Table 1: Estimated parameters for average lactation curve with R^2, RSME and the peak of lactation.

			Parameters mean (s.e.)						Peak of lactation	
Eq.	**a**	**b**	**c**	**k**	**m**	**s**	**R^2**	**RSME**	**(g/day)**	**day**
									269.75*	18*
QF	82.305 (3.546)	22.164 (0.564)	-0.673 (0.019)				0.985	5.813	263.91	17.65
BF	0.489 (0.014)	0.371 (0.014)		470.156 (10.746)			0.986	5.648	261.22	17.06
PF	84.564 (3.335)	21.073 (0.440)	2.073 (0.007)				0.985	5.804	266.61	16.71
GF				268.661 (2.540)	16.654 (0.170)	12.326 (0.268)	0.970	8.300	268.66	16.65

* Mean real values.

On the other hand, although the prediction of peak parameters was acceptable with the different models, all of them tended to underestimate both milk yield and day of maximum production. This could be related to the asymmetry of the rabbit doe lactation curve when weaning occurs at 28^{th} day of lactation.

Prediction of individual lactation curves

Although rabbit does belongs to the same breed and have the same environmental conditions, there were great differences in the milk yield and lactation curve shape as consequence of the type of diet, parity order, genetic level and individual variability. Therefore, besides of a good fitting to the average lactation curve, an adequate model must present an adequate "goodness", defined as their accuracy to predict the maximum number of individual curves (OLORI *et al.*. 1999).

The "goodness" of the 4 models to predict individual lactation curves (Table 2) was evaluated based on the criterion of OLORI *et al.* (1999): "Good" for R^2>0.80; "Fair" for 0.80>R^2>0.60 and "Poor" for R^2<0.60.

The proportion of "poor" fits was only around 15% and similar for all the models. However, the proportion of "good" fits varied between the models tested from 42 to 46%. As also happen for the average lactation curve, the best values corresponded to BF (85% of the curves fit with R^2>0.60) and worst-ones were obtained for GF (42% of the curves with R^2>0.80).

Table 2: "Goodness" of models to fit individual lactation curves.

	$R^2 > 0.80$		$0.80 > R^2 > 0.60$		$R^2 < 0.60$	
Eq.	**No.**	**%**	**No.**	**%**	**No.**	**%**
QF	240	43.64	227	41.27	83	15.09
BF	255	46.36	212	38.55	83	15.09
PF	243	44.26	224	40.80	82	14.94
GF	231	42.0	237	43.09	82	14.91

Interpretation of the equation coefficients

Figures 1, 2 and 3 show the changes of the lactation curves shape when one of the three parameter changes for QF, PF and BF, respectively.

As mentioned above, the coefficient "a" of QF and PF give information about the milk yield at day "0", and consequently is related to the initial point of the curve. Fixing the other parameters (Figure 1 and Figure 2), changes in both "b" or "c" coefficients of these functions seems to be related to differences in the height of the curve and to the persistence of the milk yield (second half of lactation). Therefore, changes on the height and persistence of the curve usually affect both parameters, being badly interpreted. On the other hand, these functions give us low information about the changes at the beginning of the lactation.

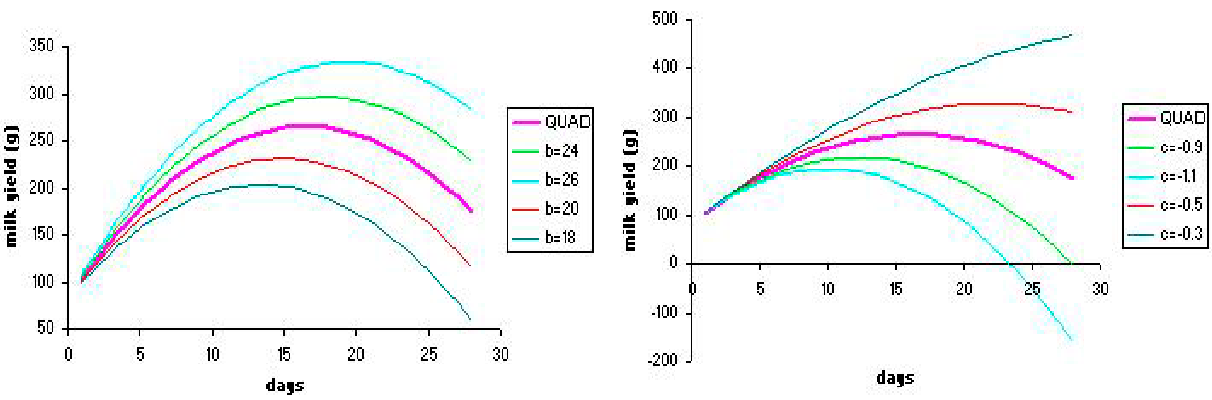

Figure 1: Changes in "b" and "c" coefficients of the quadratic function for the lactation curve of rabbit doe.

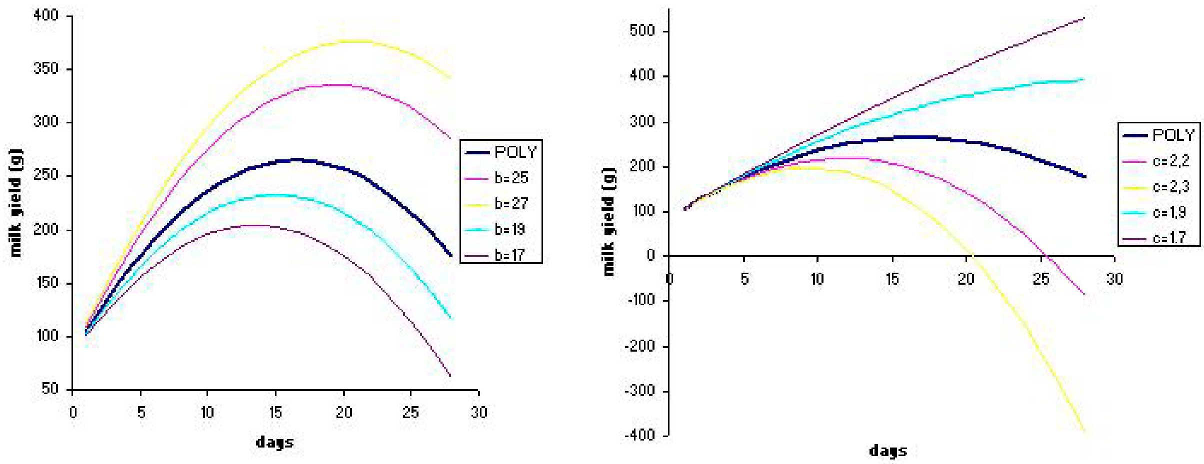

Figure 2: Changes in "b" and "c" coefficients of the modified polynomial function for the lactation curve of rabbit doe.

In the case of BF, the "k" coefficient regulates the height of the curve, although changes on "a" or "b" for "k" constant could also change slightly the height (Figure 3). However, while changes in "a" coefficient seem to be related with changes in the milk yield of does at the beginning of the lactation, changes in "b" coefficient summarise the variations observed at the end of the lactation. Therefore, the changes in height and shape of the rabbit lactation curve could be better interpreted from the variations observed in the BF, due to the higher independence of its coefficients.

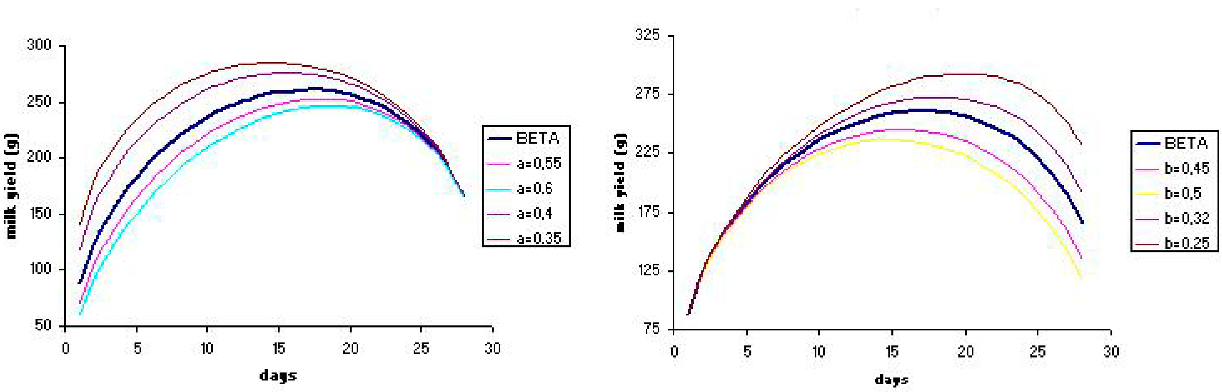

Figure 3: Changes in "a" and "b" coeffcients of the modified beta function for the lactation curve of rabbit doe.

In conclusion, all the evaluated models showed a good fitting to the mean and individual rabbit lactation curves. However, due to the greater independence and biological interpretation of the modified beta function coefficients, this function seems to a better model to analyse possible changes in the lactation curve shape of rabbit does. More information about the ability of these coefficients to reveal differences on rabbit doe performance would be useful in the future.

ACKNOWLEDGEMENTS

The present work was supported by a grant from the Spanish Minister of Science and Technology (project AGL2000-0595-C03-03).

REFERENCES

DE LA PUERTA R. 2003. The lactation curve of reproductive primiparous rabbit does. 790101-173-050. MSci. *Thesis. Wageningen University and Research Centre.*

FERNÁNDEZ-CARMONA, J., QUEVEDO, F., CERVERA, C., PASCUAL, J.J., 2001. Utilización de piensos energéticos en conejas primíparas I. Parámetros productivos. *XXVI Symposium de Cunicultura de ASESCU, Aveiro (Portugal).* 125-135.

GROENEWALD P.C.N., FERREIRA A.V., VAN DER MERME H.J., SLIPPERS S.C. 1995. A mathematical model for describing and predicting the lactation curve of Merino ewes. *Anim. Sci.,* **61**: 95-101.

LEBAS. F. 1968. Measure quantitative de la production laitère chez la lapine. *Ann. Zoot.* **17**: 169-182.

MCNITT J.I., LUKEFAHR S.D. 1990. Effects of breed. parity. day of lactation and number of kits on milk production of rabbits. *J. Anim. Sci*., **68**: 1505-1512.

MOHAMED M.M.A., SZENDRÖ ZS. 1992. Studies on nursing and milk production of does and milk intake and suckling behaviour of their kits. *J. Appl. Rabbit Res.,* **15**: 708-716.

OLORI V.E., BROTHERSTONE S., HILL, W.G., MCGUIRK B.J. 1999. Fit of standard models of the lactation curve to weekly records of milk production of cows in a single herd. *Livest. Prod. Sci.,* **58**: 55-63.

SABATER C., TOLOSA C., CERVERA C. 1993. Factores de variación de la curva de lactación de la coneja. *Arch. Zoot.,* **42**: 105-114.

STATISTICAL ANALYSIS SYSTEMS INSTITUTE. 1990. User's guide statistics. *Statistical Analysis System Institute Inc., Cary, NC.*

XICCATO G., PARIGI-BINI R., DALLE ZOTTE A., CARAZZOLO A., COSSU M.E. 1995. Effect of dietary energy level, addition of fat and physiological state on performance and energy balance of lactating and pregnant rabbit does. *Anim. Sci.,* **61**: 387-398.