JOURNAL OF ANIMAL SCIENCE
The Premier Journal and Leading Source of New Knowledge and Perspective in Animal Science

# Lactation curves in captive Iberian red deer (Cervus elaphus hispanicus)

A. Garcia, T. Landete-Castillejos, A. Molina, B. Albinana, C. Fernandez, J. Garde and L. Gallego

*J Anim Sci* 1999. 77:3150-3155.

# Lactation Curves in Captive Iberian Red Deer (*Cervus elaphus hispanicus*)[1]

A. García*, T. Landete-Castillejos†,[2], A. Molina*, B. Albiñana*, C. Fernández‡, J. Garde*, and L. Gallego*

*Departamento de Ciencia y Tecnología Agroforestal, ETSIA and †Sección de Recursos Cinegéticos, IDR, Universidad de Castilla-La Mancha, 02071 Albacete, Spain and ‡ETSIA Orihuela, Universidad Miguel Hernández, 03312 Orihuela, Spain

**ABSTRACT:** This study examines milk production and the effect of milk production and sex of calf on body weights and gains of red deer calves and hinds of the Iberian subspecies (*Cervus elaphus hispanicus*). Milk production was assessed in 14 hinds by weighing calves before and after suckling and by adjusting these values to the Gamma function. Gamma estimates of total milk production up to d 105 were similar to the amounts computed directly from double weighing. Hinds showed two types of lactation curve: 1) the standard mammal lactation curve, with an asymmetrical peak at wk 2 to 4 (Type I) and 2) decreasing curves with no peak (Type II). Although there was great interindividual variability, hinds with Type I curves showed a trend to produce more milk than those with Type II. The type of curve did not seem to affect weight variables of the calf or those of the dam. Calves that gained more weight consumed greater amounts of milk ($P < .05$). Males were heavier than females at birth ($P < .05$), but males did not differ from females in their weight at 105 d, milk consumption, and gain. Gender did not affect hind weight, but dams of male calves showed a trend to be lighter ($P = .063$) at d 105 than dams of female calves. Our results suggest that suckling differences found in other studies between male and female calves may not involve differences in milk production, although other rearing costs seem to affect hind weight losses. They also suggest that the curve type may not depend only, as reported, on the nutrition plane.

Key Words: Red Deer, *Cervus elaphus*, Milk Production, Lactation Curve, Parental Investment

 J. Anim. Sci. 1999. 77:3150–3155

## Introduction

Lactation in red deer, *Cervus elaphus*, lasts approximately 4 mo if a hind becomes pregnant again, but it can extend to the next rut, approximately 12 mo, if she does not (Clutton-Brock et al., 1982a,b). Calves suckle four to six times daily for a few seconds per bout (Arman et al., 1974; Clutton-Brock et al., 1982a). Iberian deer are one of the smallest subspecies of red deer (Jiménez, 1992), and their size may affect milk production.

Deer have two types of lactation curves. Type I is the typical mammal curve with a peak during wk 2 to 4 (Arman et al., 1974; Loudon et al., 1983; Robbins et al., 1987). Type II is a decreasing curve (Arman et al., 1974; Sadleir, 1980) that is attributed to a poorer diet (Loudon et al., 1983, 1984).

Lactation studies often focus on suckling behavior as a positive estimate of milk transferred (Clutton-Brock et al., 1982a; Gauthier and Barrette, 1985; Cameron, 1998), although this assumption may not be correct (Cameron, 1998; Cameron et al., 1999). The most common alternative method for estimating milk production in deer, milking, requires the use of anesthetics and oxytocin, but both may alter milk production and composition (Robbins et al., 1987). Deuterium oxide is also useful, although it requires conditions rarely met in deer, involves stressful procedures, and overestimates milk intake (Holleman et al., 1975; Cameron et al., 1999). The double weighing procedure, however, is easy to conduct, but it may underestimate milk transfer (Brown et al., 1982; Butte et al., 1984) and may be more variable than milking (Beal et al., 1990).

Our objective was to use the double weighing procedure and its derived Gamma function to estimate daily milk production in Iberian deer and to examine the effect of calf sex and type of lactation curve on milk

[1]The authors wish to thank the game management company Lagunes S.L. for their cooperation in the research reported on this paper. We would also like to thank Francis Gilbert from the School of Biology, Nottingham University, for kindly providing a statistical program developed by him to conduct the nonparametric tests, Fulgencio Cebrián for his help in data collection, and three anonymous referees for their comments. This research has been partly funded by CICYT project no AGF96-1091.

[2]To whom correspondence should be addressed (fax: +34-67-599238; E-mail: landete@cita-ab.uclm.es).

Received December 9, 1998.

Accepted May 20, 1999.

production and weight gains. The experiments comply with animal welfare legislation and guidelines (ASAB, 1991).

## Materials and Methods

Wild-caught 3-yr-old adult hinds (n = 14) were studied. All hinds had reared a calf the previous year. Mating occurred in near free-ranging conditions during the breeding season (September and October) in a game state. Five months before giving birth, hinds were transferred to the university deer enclosures for the remainder of the experimental period. The enclosures occupied a triangle of 100 m on each side.

Calving took place naturally during the months of May and June 1996. All 14 hinds had one calf each (nine males and five females). Calves were groomed by the dam until dry, weighed to the nearest 10 g, and identified. Dams were weighed weekly to the nearest 100 g before being fed.

Both during gestation and throughout lactation, hinds were fed diets based on suggestions by Brelurut et al. (1990), using barley straw and hay from barley, alfalfa, oat, and sweet beetroot (16% protein). Deer had ad libitum access to feed. Fifteen days after birth, calves had free access to a creep feeder that contained an 18% CP concentrate diet.

Daily milk production in hinds was calculated by weighing calves before and after suckling (double weighing). Once a week from wk 1 to 15, calves were isolated from their dams for 6 h (from 0800 to 1400). They were then weighed and allowed to suckle their dams for 10 to 15 min before being weighed again. Suckling occurred very quickly and took only 1 to 2 min. Only a few suckling bouts were observed during the rest of the suckling period. In a pilot experiment, the filling state of the udders was standardized by isolating calves overnight then allowing them to suckle before the 6-h isolation period was started. However, overnight isolation stressed the calves, often preventing them from suckling during the double weighing tests. This technique was terminated to limit animal stress.

Daily milk production was obtained by multiplying the one daily observation by 4. To avoid social disruption, all calves were weaned on the same day, although for statistical comparisons analysis was conducted on the first 105 d of lactation (15 wk).

The following algebraic model developed by Wood (1967) for cattle was used to obtain lactation curves: $y_t = a\, t^b\, e^{-ct}$, where $y_t$ is the average daily yield in the $t^{th}$ day and a, b, and c are constants.

We chose this model rather than that of Jenkins and Ferrell (1984) because the Gamma function can produce curves of Types I and II, whereas the latter can only produce curves of Type I irrespective of the data (our unpublished data).

*Statistical Analysis.* Milk production and lactation curves were computed fitting the logarithmic transformed data to the regression line derived from the logarithm of the equation given above. The parameters a, b, and c thus estimated were used both to obtain the lactation curves and the estimated daily production. Curves of Type I differed from those of Type II in that b was positive. This criterion was used to classify curves and, thus, to use pooled data from every class of hinds to compute an averaged curve of each type following the previous procedure. Comparisons between weight of the calves at birth (**WCB**), at 105 d (**$WC_{105}$**), the weights of the hinds at these times (**WHB**, **$WH_{105}$**), conversion index (**$CI_{105}$**) and milk production up to d 105 with respect to the type of curve (I or II, see below) or the sex of the calf were conducted using specific or general tests of one-way nonparametric ANOVA depending on whether we formulated a priori predictions (Meddis, 1984). The sex ratio and the association of lactation curve type and sex of the calf were conducted by means of chi-square tests. Spearmann correlation tests were conducted to assess relationships among variables.

## Results

Milk production in most hinds fitted significantly to the Gamma function (Table 1). Lactation curves of Type I had a positive b, and Type II lactation curves had a negative b. Total milk produced as estimated by double weighing correlated with the estimates obtained from the corresponding Gamma function ($r_s = .938$, $P < .001$, Table 2).

Curves differed greatly between hinds (Figure 1); thus, the averaged curve for each type maintained the shape typical of the class but had a poor fit (Table 1 and Figure 1). Total milk production over the 105-d period was greater for Type I than for Type II (119 vs 106 kg). This pattern was also observed in Gamma estimates for each hind and double weighing, although results failed to achieve statistical significance ($P > .10$, Table 2). The greater amount of milk produced by hinds with Type I curves did not seem to be caused by the greater energetic needs of their offspring: calves whose dams showed Type I curves were not heavier at birth ($P > .10$) or at d 105 ($P > .10$) than those of dams showing Type II curves (Table 3). The greater amount of milk produced by hinds with Type I lactation curves was not the result of the weight of the hind or sex of the calf ($P > .10$). Calves whose dams showed Type I curves were not born earlier than calves whose dams showed Type II curves (16.7 ± 4.5 vs 13.6 ± 3.0 d, $P > .10$), and there was no correlation between date of birth and calf weight at birth or d 105 ($P > .10$). Date of birth also did not correlate with milk produced by the hind ($P > .10$). The gains per kilogram of milk ingested did not differ between groups ($P > .10$).

The gender of the calf did not have an effect on most variables (Table 3). Males were heavier than females at birth ($P = .026$) but not at d 105 ($P > .10$). There was no difference ($P > .10$) in weight of the dams gestating males and those gestating females (91.6 ± 2.0 vs 88.3

Table 1. Parameters characterizing the Gamma function corresponding to estimated lactation curves of Iberian red deer

| Curve and hind | a[a] | b[b] | c | $R^2$ | *P* |
|---|---|---|---|---|---|
| Type I | | | | | |
| 2 | 2.02 | .03 | .026 | .44 | .03 |
| 3 | 2.14 | .06 | −.084 | .76 | .00 |
| 5 | 1.07 | .36 | −.095 | .98 | .54 |
| 9 | .90 | .09 | −.052 | .27 | .16 |
| 11 | 1.92 | .04 | −.072 | .25 | .18 |
| 12 | 1.36 | .27 | −.051 | .04 | .79 |
| 14 | 1.09 | .20 | −.087 | .43 | .04 |
| Type II | | | | | |
| 1 | 1.60 | −.03 | −.054 | .75 | .00 |
| 4 | 2.23 | −.20 | −.094 | .54 | .01 |
| 6 | 1.80 | −.99 | .112 | .33 | .04 |
| 7 | 1.76 | −.15 | −.044 | .39 | .05 |
| 8 | 1.52 | −.50 | .085 | .11 | .51 |
| 10 | 2.06 | −.02 | −.095 | .52 | .01 |
| 13 | 2.39 | −.64 | .060 | .50 | .02 |
| Type I | 1.42 | .14 | −.066 | .15 | 0 |
| Type II | 1.89 | −.35 | −.007 | .29 | 0 |

[a]This parameter corresponds to milk produced in the 1st wk. The model is Production (week) = $a \cdot week^{b} \cdot e^{(-c \cdot week)}$.

[b]This parameter characterizes the type of curve; positive values correspond to Type I curves and negative ones to Type II curves.

± 6.5 kg). Although males weighed more than females at birth, gender of calf did not affect hind weight at birth (*P* > .10). However, dams of male calves showed a trend to be lighter at d 105 (*P* = .063) than those that bore females. Males also showed a nonsignificant trend (*P* = .091) to be more efficient at growing (greater gains per kilogram of milk consumed) than females, although sex did not affect milk consumption (*P* > .10).

Heavier hinds did not have heavier calves (*P* > .10), and greater growth of the calves did not affect hind weight (*P* > .10). However, heavier calves at birth were also heavier at d 105 ($r_s$ = .803, *P* = .002). There was also a positive correlation between the weight of the hinds at birth and that at d 105 ($r_s$ = .849, *P* = .001). There was no correlation between weight of the dam at d 105 and the amount of milk produced (*P* > .10). There was no correlation (*P* > .10) between the amount of milk consumed up to d 105 and either weight gained by the calf or weight change of the dam during lactation when data from all curves were considered. However, both relationships became significant when only significant curves (Table 1) were used to compute milk production ($r_s$ = .65, *P* = .033 and $r_s$ = .617, *P* = .041).

Table 2. Measured and estimated milk production in Iberian hinds by pre- and postsuckling weighing of their calves, and by adjusting values to the Gamma function

| Curve type and hind | Double weighing, kg | Gamma estimates, kg |
|---|---|---|
| Type I | | |
| 2 | 185 | 179 |
| 3 | 137 | 143 |
| 5 | 121 | 107 |
| 9 | 77 | 77 |
| 11 | 138 | 130 |
| 12 | 168 | 158 |
| 14 | 88 | 85 |
| Mean | 131 ± 15 | 126 ± 14 |
| Averaged Type I curve | — | 119 |
| Type II | | |
| 1 | 108 | 112 |
| 4 | 102 | 97 |
| 6 | 84 | 83 |
| 7 | 110 | 109 |
| 8 | 135 | 131 |
| 10 | 114 | 115 |
| 13 | 133 | 133 |
| Mean | 112 ± 7 | 111 ± 7 |
| Averaged Type II curve | — | 106 |
| Overall mean | 121.4 ± 8.2 | 118.5 ± 7.8 |

## Discussion

Lactation curves showed a significant fit to the Gamma function in most hinds. The low correlation coefficients in some cases and the lack of statistical significance may be due to using a single weekly observation rather than the daily milking measures by Wood (1967). Also, milk estimates by double weighing may have less accuracy than amounts obtained by milking (Brown et al., 1982; Beal et al., 1990).

Despite using a different method (fitting data to a Gamma curve instead of using interindividual means of milk production), our results also show two types of curves similar to those of Loudon et al. (1983, 1984) and Arman et al. (1974). However, when computing the

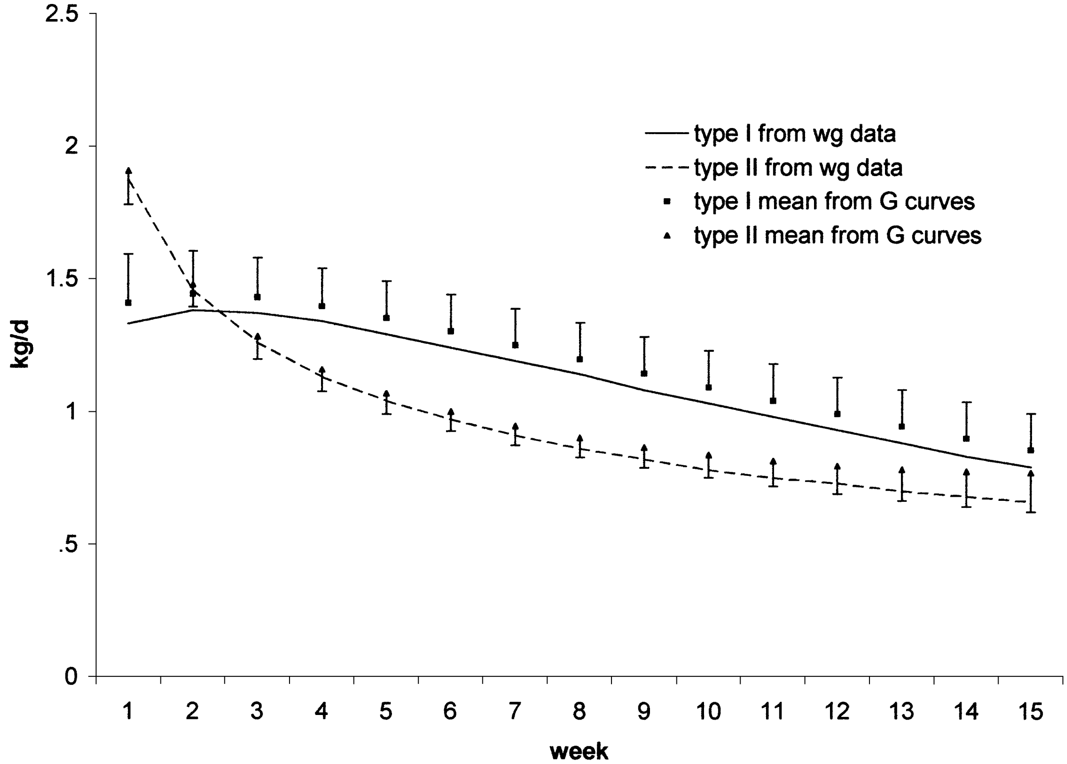


Figure 1. Lactation curves in Iberian deer. Gamma (G) curves from weight data have been estimated from pooled double weighing data. Mean curves have been obtained by averaging gamma curves for each hind. Type I curve is similar to the theoretical lactation curve in mammals. Curve Type II has been described in deer feeding on poor-quality pastures.

averaged Type I and II curves, the great interindividual variability resulted in a poor predictive value of the model and a similar production of milk for both.

Mean daily production by Gamma estimates (1.13 ± .07 kg/d) and by double weighing (1.16 ± .08 kg/d) were within the range of 1.2 to 2.85 kg reported by Krzywinski et al. (1980). Arman et al. (1974) found a maximum milk production ranging from 1.53 kg/d to 2.0 kg/d in Type I and from 1.2 to 2.5 kg/d in Type II curves under similar feed conditions, whereas Loudon et al. (1983, 1984) found initial milk production values of 1.85 ± .1 kg/d and a peak of 2.20 ± .12 kg/d in Type I curves obtained from individuals on good pastures and 1.4 to 1.6 kg/d in Type II curves found in individuals on poor pastures.

In the present experiment, total milk production for 105 d measured by double weighing was 121.4 ± 8.2 kg and that estimated by Gamma function was 118.5 ± 7.8 kg. Arman et al. (1974) found values of milk production in Scottish red deer of 136.2 kg in a lactation period of 150 d. In contrast, Loudon and Kay (1984) obtained 171 kg for 100 d in the same subspecies, and Robbins et al. (1987) reported a milk production of 240 kg for the American subspecies of red deer, the wapiti. The find-

Table 3. Weights of calves and their dams by type of lactation curve and sex of calf for Iberian red deer

| Item | n | WCB, kg[a] | $WC_{105}$, kg[b] | $CI_{105}$[c] | WHB, kg[d] | $WH_{105}$, kg[e] |
|---|---|---|---|---|---|---|
| Type I | 7 | 6.4 ± .6 | 29.8 ± 2.2 | .191 ± .021 | 85.2 ± 2.0 | 84.7 ± 2.5 |
| Type II | 7 | 6.5 ± .3 | 30.9 ± 1.9 | .227 ± .016 | 83.0 ± 2.3 | 81.5 ± 2.0 |
| Males | 9 | 6.9 ± .3 | 32.0 ± 1.3 | .225 ± .016 | 81.9 ± 2.0 | 81.3 ± 1.9 |
| Females | 5 | 5.7 ± .7 | 27.3 ± 3.0 | .181 ± .021 | 85.6 ± 2.0 | 86.3 ± 2.4 |
| Mean | | 6.4 ± .3 | 30.3 ± 1.4 | .209 ± .013 | 83.2 ± 1.5 | 83.1 ± 1.6 |

[a]WCB = weight of the calves at calving.
[b]$WC_{105}$ = weight of the calves at 105 d.
[c]$CI_{105}$ = conversion index = ($WC_{105}$ − WCB)/milk production up to d 105.
[d]WHB = weight of the hinds at calving.
[e]$WH_{105}$ = weight of the hinds at 105 d.

ings in the latter two reports constitute far greater productions of milk that those of the Iberian subspecies used in our study.

Type I curves showed the typical pattern of a mammalian lactation curve, which peaks at 2.1 times the calf weight at birth, when milk produced by the dam is no longer able to sustain the calf's energetic requirements and it has to start taking solid feed (Lee et al., 1991). The peak in our study appears between wk 2 to 4, which coincides with results in other subspecies of red deer (Arman et al., 1974; Krzywinski et al., 1980; Loudon et al., 1983, 1984) and other deer species (Robbins et al., 1987). It is more difficult to explain the cause of Type II curves. Loudon et al. (1983, 1984) found these curves in hinds feeding on poor pastures, which explained their smaller milk production. However, Arman et al. (1974) also found Type II curves in hinds with the same diet and feed availability as those showing Type I curves.

There was no association of curve type with sex of the calf, birth weight, or weaning weight. However, this contrasted with findings of Loudon et al. (1984), who found calves of hinds Type II curves to be lighter. Perhaps the calves were lighter due to a markedly lower nutrient intake. Our results showed a nonsignificant trend for dams showing Type I curves to lose more weight at birth ($P$ = .089), but as lactation progressed these differences were greatly reduced ($P$ = .242).

Sex of the calf did not seem to exert an effect on most variables. However, males showed a nonsignificant trend ($P$ = .090) to be more efficient at growing, and the weight of their mothers fell progressively below that of dams of females, almost reaching significance level at d 105 ($P$ = .063). The latter result, in contrast with those concerning sex effects, seems to be consistent with those of Clutton-Brock (1982a), who found several lines of evidence showing that in a more competitive situation (i.e., free-ranging deer inhabiting an island) hinds having male calves bear greater costs than those having female calves.

Date of birth did not seem to exert an effect on weight of the calves, either at birth or at 105 d. This contrasts with findings of Adam and Moir (1987) and Fisher et al. (1989), who found that early-born calves are heavier or grow faster. In our study, calving took place over a short span of time and might have been too short to allow for significant differences.

Although we used only 14 hinds, Arman et al. (1974) used six hinds, Krzywinski et al. (1980) five, Sadleir (1980) seven, and Loudon and others (Loudon et al., 1983, 1984; Loudon and Kay, 1984) 17. Small numbers are used due to the difficulties involved in handling wild animals. Despite such constraints, experimental studies on lactation are greatly valued as a more solid estimate of nutrient transfer compared to observational studies (Cameron, 1998), which are currently thought to be erroneous (Cameron et al., 1999).

One of the problems that remains to be addressed in this and other studies is whether calves suckle from other hinds in addition to their dams. Such a situation would imply that the lactation curves in those studies are, in fact, intake curves and not milk production curves. Although alloparental suckling does not seem to be very common in our deer (unpublished observations), further investigation is needed to assess its relative importance, particularly by comparing double weighing data with that of milking estimates.

## Implications

Sex differences revealed by suckling behavior may not imply differences in milk production, as suggested in some literature. However, hind weight losses during lactation suggest that there may still be sex differences in rearing costs. The correlation between calf weight at birth and that at 105 d might have implications for management. It might be used to select individuals that will be kept as stags, because body weight influences antler weight. The correlation found between weight gained by the calf during lactation and amount of milk consumed might also be useful for management. Any factor that increases milk production would be likely to increase weight gains of the calf.

## Literature Cited

Adam, C. L., and C. E. Moir. 1987. A note on the effect of birth date on the performance of suckled red deer calves and their dams on low-ground pasture. Anim. Prod. 44:330–332.

Arman, P., R.N.B. Kay, E. D. Goodall, and G.A.M Sharman. 1974. The composition and yield of milk from captive red deer (*Cervus elaphus* L.). J. Reprod. Fertil. 37:67–84.

ASAB. 1991. Guideline for the use of animals in research. Anim. Behav. 41:183–186.

Beal, W. E., D. R. Notter, and R. M. Akers. 1990. Techniques for estimation of milk yield in beef cows and relationships of milk yield to calf weight gain and postpartum reproduction. J. Anim. Sci. 68:937–943.

Brelerut, A., A. Pingard, and M. Thériez (Ed.). 1990. Le cerf et son élevage. INRA, Paris.

Brown, K. H., R. E. Black, A. D. Robertson, N. A. Akhtar, G. Ahmed, and S. Becker. 1982. Clinical and field studies of human lactation: Methodological considerations. Am. J. Clin. Nutr. 35:745–756.

Butte, N. F., C. Garza, E. O. Smith, and B. L. Nichols. 1984. Human milk intake and growth in exclusively breast-fed infants. J. Pediatr. 104:187–195.

Cameron, E. Z. 1998. Is suckling behaviour a useful predictor of milk intake? A review. Anim. Behav. 56:521–532.

Cameron, E. Z., K. J. Stafford, W. L. Linklater, and C. J. Veltman. 1999. Suckling behaviour does not measure milk intake in horses, *Equus caballus*. Anim. Behav. 57:673–678.

Clutton-Brock, T. H., F. E. Guinness, and S. D. Albon. 1982a. Red deer: Behavior and Ecology of Two Sexes. Edinburgh University Press, Edinburgh, U.K.

Clutton-Brock, T. H., G. R. Iason, S. D. Albon, and F. E. Guinness. 1982b. Effects of lactation on feeding behavior and habitat use in wild red deer hinds. J. Zool. 198:227–236.

Fisher, M. W., P. F. Fennessy, and G. H. Davis. 1989. A note on the induction of ovulation in lactating red deer hinds prior to the breeding season. Anim. Prod. 49:134–138.

Gauthier, D., and C. Barrette. 1985. Suckling and weaning in captive white-tailed and fallow deer. Behaviour 94:128–149.

Holleman, D. F., R. G. White, and J. R. Luick. 1975. New isotope methods for estimating milk intake and yield. J. Dairy Sci. 58:1814–1821.

Jenkins, T. G., and C. L. Ferrell. 1984. A note on lactation curves of crossbred cows. Anim. Prod. 39:479–482.

Jiménez, J. 1992. Biología y problemática del ciervo en la Espan~a Mediteránea. Quercus 68:17–20.

Kelly, R. W., P. F. Fennessy, G. H. Moore, K. R. Drew, and A. R. Bray. 1987. Management, nutrition, and reproductive performance of farmed deer in New Zealand. In: C. M. Wemmer (Ed.) Biology and Management of the Cervidae. pp 450–460. Smithsonian Institution Press, Washinghton, DC.

Krzywinski, A., K. Krzywinska, J. Kisza, A. Roskosz, and A. Kruk. 1980. Milk composition, lactation and the artificial rearing of red deer. Acta Theriol. 25:341–347.

Lee, P. C., P. Majluf, and I. J. Gordon. 1991. Growth, weaning and maternal investment from a comparative perspective. J. Zool. 225:99–114.

Loudon, A.S.I., A. D. Darroch, and J. A. Milne. 1984. The lactation performance of red deer on hill and improved species pastures. J. Agric. Sci. 102:149–158.

Loudon, A.S.I., and R.N.B. Kay. 1984. Lactational constraints on a seasonally breeding mammal: The red deer. Symp. Zool. Soc. Lond. 51:233–252.

Loudon, A.S.I., A. S. McNeilly, and J. A. Milne. 1983. Nutrition and lactational control of fertility in red deer. Nature (Lond.) 302:145–147.

Meddis, R. 1984. Statistics Using Ranks. Basil Blackwell Publisher LTD, Oxford, U.K.

Robbins, C. T., O. T. Oftedal, and K. I. O'rourke. 1987. Lactation, early nutrition, and hand-rearing of wild ungulates, with special reference to deer. In: C. M. Wemmer (Ed.) Biology and Management of the Cervidae. pp 429–442. Smithsonian Institution Press, Washinghton, DC.

Sadleir, R.M.F.S. 1980. Milk yield of black-tailed deer. J. Wildl. Manage. 44:472–478.

Wood, P.D.P. 1967. Algebraic model of the lactation curve in cattle. Nature (Lond.) 216:164–165.