

PAPER

Modeling lactation curves of “Barrosã” beef cattle with Wood’s model

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Abstract

This study aimed to investigate the lactation curve properties of primiparous and multiparous Barrosã cows, using two different milking systems. A data set with 2518 daily milk yields of 15 primiparous (107 test day records by lactation) and 11 multiparous (83 test day records by lactation) cows was individually fitted with the Wood’s model by the application of a non linear procedure. Milk yield measurements were recorded using a weigh-suckle-weigh technique in half of the cows and the remaining cows were hand-milked. Average daily milk yield of primiparous and multiparous suckled cows were 4.9 and 5.2 kg, respectively, while correspondent scores on milked cows were lower (2.4 and 3.0 kg). All 26 fitted lactations followed the typical curve shape with high goodness of fit. Analysis performed on Wood’s parameters indicated that milked cows have a peak yield of 3.5 and 4.6 kg reached at lactation day 23 and 16, for primiparous and multiparous, respectively. On the other hand, suckled cows reached later (56-63 d) their peak of lactation and the peak yield (5.3-5.7 kg) was greater than milked cows. The absence of the calf and the cow’s difficulty in adapting to the hand-milking can explain differences between milked and suckled cows. Barrosã cows, in their traditional production system, have lactation yields of 805 and 843 kg in parities 1 and 2, respectively.

Introduction

Barrosã is a cattle breed that plays an important role in beef production throughout Portugal. Cows and their calves are typically raised in an environmental-friendly extensive system on the mountains of the North of Portugal within Barroso and the National Park of Peneda-Gerês. Except for some large herds, the Barrosã cattle is traditionally kept in small herds (<5 heads) by smallholder farmers. The cows and their calves are housed together at night and only the cows have free access to pasture during the day. The Barrosã breed has no seasonal reproductive activity and the calves are reared by restricted suckling from birth until just before the slaughter at 5-7 months of age (Araújo, 1996; Almeida, 2000). Calf carcasses are light (~100 kg) and, since 1996, the European Union has granted this meat a Protected Designation of Origin, “Carne Barrosã” (European Commission, 1996). Milk production of beef cows is one of the most important factors affecting the growth rate and weaning weight of beef calves and the profitability of the cow-calf producer. The effect of parity in milk yield of dairy cattle is actually well documented (Hansen *et al.*, 2006). The Wood’s model (Wood, 1967) is one usual method applied in the study of lactation curves in dairy cows (Tekerli *et al.*, 2000; Macciotta *et al.*, 2005; Silvestre *et al.*, 2006; 2009). Nevertheless, studies of lactation curves in beef cows are scarce and particularly Wood’s model parameters have never been published for Barrosã breed. Therefore, the objectives of this study were to investigate the influence of parity and milking system on the lactation curve of Barrosã cows.

Materials and methods

Data

Data included 2518 daily milk yields of 26 lactations that were classified in two groups (suckled group and milked group), including primiparous (P1) and multiparous (P2) cows, calving between January and April (Table 1). The study was conducted at the experimental farm of the University of Trás-os-Montes and Alto Douro, Vila Real, Portugal (milked group) and at the “Quinta da Veiga”, an experimental farm of the Portuguese Agriculture and Fisheries Ministry, located in Montalegre, Portugal (suckled group). The animals of milked group were fed from two months before

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the expected calving date to 150 days after calving, in order to maintain the target level of body condition score. The diet consisting of *ad libitum* meadow hay, 6% crude protein (CP) and 68% neutral detergent fibre (NDF), adjusted with individually administration (3 to 5 kg/cow/day) of commercial concentrate (19% CP and 22,7% NDF). The calves of suckled group were fed and housed following the traditional production system for this breed (cows on pasture during diurnal period and cows and calves housed at night). Integration of grassland was carried out for animals at pasture allowing them to free access to meadow hay at the stables, and no commercial concentrate was used. All the animals had free access to water and mineral salts blocks. From 10 d before expected calving date until the first week post calving, all the cows were housed in individual maternity pens. The calves of the milked group were raised apart from their mothers, which were hand-milked twice a day (06:00 h and 18:00 h). The calves from the suckled group were penned alone during the cows period of pasture; at night, the calves remained in cubicles adjacent to their dams’ resting area, and they were allowed to only 2 suckling periods of 20 min a day (just before the cows leave to pasture and immediately after they return to the stable). Therefore, in suckled group milk yield measurements were recorded using a weigh-suckle-weigh technique (Jenkins *et al.*, 2000; Minick *et al.*, 2001). Before each measurement, calves were separated from the dams for at least a 12 h period. The differences between pre- and post-suckling calf weights were recorded as milk yield measurements. On average, in suckled

group there was roughly 63 test-days per lactation, collected every 2 to 3 d, while data were collected daily for the milked group. Average daily milk yield of primiparous and multiparous suckled cows were 4.9 and 5.2 kg, respectively, while correspondent scores on milked cows were lower (2.4 and 3.0 kg), as reported in Table 1.

Statistical analysis

The incomplete gamma function (Wood, 1967) was used to characterize the individual lactation curves:

$$Y(t) = a t^b e^{-ct} \quad [1]$$

where $Y(t)$ is the trait in lactation day t , e is the Neper number, a , b and c are positive parameters determining the curve's shape. Wood's model represents the peak in lactation day $t=b/c$, which means that parameters b and c define the pre-peak and post-peak shape of the curve, respectively. Peak values are independent of a , which represents a scale factor. Persistency (s) definition in Wood's model is a dimensionless quantity [2]. However, it can be used for curves comparison (Rekik *et al.*, 2003; Santos and Silvestre, 2008).

$$s = - (b+1) \ln c \quad [2]$$

Individual curves were fitted with the non linear module of Systat program (Wilkinson *et al.*, 1992). This module applies the Quasi-Newton method and the convergence criterion has a precision of 5×10^{-5} . Total milk yield (TMY) was estimated as the sum of all daily yields [3].

$$TMY = \sum_{t=1}^{LL} a t^b e^{-ct} \quad [3]$$

The model [4] was used to analyze the effects of parity and milking system on Wood's model adjusted coefficient of determination (R^2_a), lactation parameters (a , b , c), peak (day and yield), persistency (s), lactation length and total milk yield (SAS, 2003):

$$y_{ijl} = \mu + \text{parity } i + \text{milking system } j + (\text{parity} \times \text{milking system})_{ij} + \varepsilon_{ijl} \quad [4]$$

where y_{ijl} = a lactation curve trait based on lactation l on parity i ($i=1, 2$) for milking system j ($j=1, 2$) and the interaction between parity and milking system; μ = overall mean; and ε = random residual with an expected value of 0 and a variance of σ^2_ε . Least-square means differences at interaction level (parity

x milking system) was performed using the Bonferroni test and statistical significance was considered at P values <0.05 (SAS, 2003).

Results and discussion

The estimated parameters (a , b and c) for the model [1], lactation traits (peak day, peak yield, persistency, lactation length, total milk yield) and the corresponding R^2_a are given in Table 2 for the four groups of lactations curves, according to parity and milking system. Statistical differences between these groups are also showed. The model [1] fitted all lactation groups with similar R^2_a value (≈ 0.99 , $P>0.05$). According to Macciotta *et al.* (2005), goodness of fit is high when R^2_a is higher than 0.8. This score is also in agreement with previous results reported for dairy cattle (Olori *et al.*, 1999; Macciotta *et al.*, 2005). All fitted lactations followed the typical curve shape for milk yield. The occurrence of lactations curves with atypical shapes is documented in dairy cows. Rekik and Gara (2004) and Macciotta *et al.* (2005) reported the incidence of 25 and 20% of atypical curves, respectively. Monthly test-days are used in dairy cattle and the occurrence of atypical patterns is more a mathemat-

ical issue that arises from the date at first test but also from the peculiar combinations of TD values and their distribution throughout the whole lactation (Macciotta *et al.*, 2005; Silvestre *et al.*, 2009). In the present study, the lack of an occurrence of atypical curves can be explained by the database properties, since the interval between test-days is less than 4 and the number of test-days by lactation is greater than 54 (Table 1), representing well the individual lactation curves

Neither milking system (i.e. suckled vs. hand milking) nor parity (P1 vs. P2) showed different values for the parameter a of Wood's incomplete gamma function, which represents the increasing phase of lactation. Also, no significant differences were found on b . However, P2 milked cows have higher score of c than P1 and P2 suckled cows ($P<0.05$). Suckled cows have, in general, longer lactations than milked cows, being lactation length of P1 suckled cows higher ($P<0.05$) than lactation length of P2 milked cows (178 and 111 days, respectively). P1 and P2 suckled cows have higher ($P<0.05$) peak yield than P1 milked cows (5.3, 5.7 and 3.5, respectively). Peak yield of other beef breeds, such as Angus or Hereford (Minick *et al.*, 2001), is quite similar to scores attained by Barrosã breed. For both parities, suckled cows have higher ($P<0.05$) peak day and persistency than milked cows (Table 2). Milked cows

Table 1. Summary of test-days, interval between tests and daily milk yield (DMY) by lactation (means $\pm$ SD).

Group	Parity	Lactations number	Number of daily yields	Test-days	Intervals, d	DMY
Suckled	Primiparous	8	569	71 $\pm$ 22.5	2 $\pm$ 1.6	4.9 $\pm$ 1.0
	multiparous	5	272	54 $\pm$ 19.4	3 $\pm$ 1.7	5.2 $\pm$ 0.9
Milked	Primiparous	7	1032	147 $\pm$ 50.9	1 $\pm$ 0	2.4 $\pm$ 1.3
	multiparous	6	645	108 $\pm$ 58.7	1 $\pm$ 0	3.0 $\pm$ 1.5

Table 2. Least-square means ($\pm$ standard error) of adjusted coefficient of determination (R^2_a), estimated Wood's model parameters (a , b , c), peak (day and yield), persistency (s), lactation length (LL) and total milk yield (TMY) for primiparous (P1) and multiparous (P2), according to milking system.

	Suckled cows		Milked cows	
	P1 (n*=8)	P2 (n*=5)	P1 (n*=7)	P2 (n*=6)
R^2_a	0.987 $\pm$ 0.002	0.989 $\pm$ 0.003	0.986 $\pm$ 0.002	0.986 $\pm$ 0.002
a	2.75 $\pm$ 0.41	2.09 $\pm$ 0.52	1.53 $\pm$ 0.44	2.11 $\pm$ 0.48
b	0.247 $\pm$ 0.084	0.340 $\pm$ 0.107	0.379 $\pm$ 0.090	0.598 $\pm$ 0.097
c	0.481 $\pm$ 0.580	0.552 $\pm$ 0.734	1.925 $\pm$ 0.620	4.007 $\pm$ 0.670
LL ^a , d	178 $\pm$ 15	170 $\pm$ 18	149 $\pm$ 16	111 $\pm$ 17
Peak day ^b	56 $\pm$ 7	63 $\pm$ 9	23 $\pm$ 7	16 $\pm$ 8
Peak yield ^c , kg	5.3 $\pm$ 0.37	5.7 $\pm$ 0.46	3.5 $\pm$ 0.39	4.6 $\pm$ 0.42
Persistency (s) ^d	6.730 $\pm$ 0.220	6.993 $\pm$ 0.278	5.589 $\pm$ 0.235	5.311 $\pm$ 0.254
TMY ^e , kg	804.7 $\pm$ 67.8	843.3 $\pm$ 85.8	349.4 $\pm$ 72.5	318.7 $\pm$ 78.3

^aLeast-square means in the same row with different superscripts are significantly different ($P<0.05$); ^bn = number of lactations;

^cc1 = c. 10-2. ^dCalculated on data. ^ePeak day = b/c. ^fPeak yield = a (b/c) b e - c. ^gs = - (b+1) ln c. ^hTMY = $\sum_{t=1}^{LL} a t^b e^{-ct}$

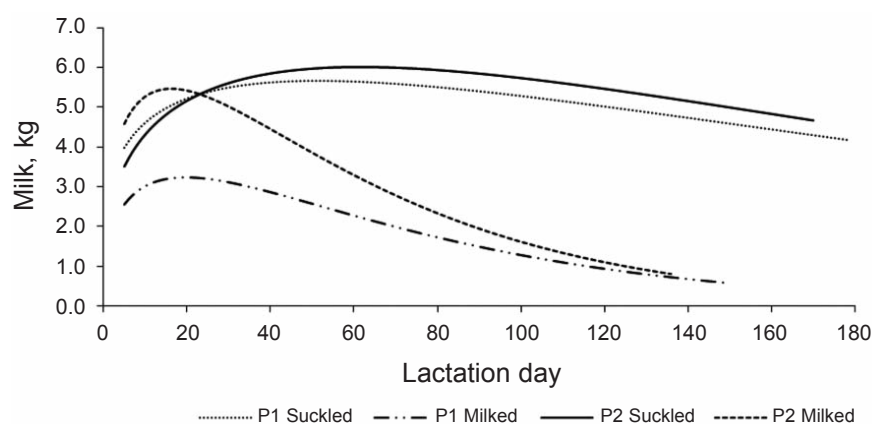


Figure 1. Lactation curves for primiparous (P1) and multiparous (P2) cows, according to milking system (milked and suckled).

have better environmental conditions for milk yield, since their diet was supplemented with a commercial concentrate feed. Even so, P1 and P2 suckled cows have higher ($P < 0.05$) total milk yield than P1 and P2 milked cows (804.7, 843.3 and 349.4, 318.7, respectively). Grings *et al.* (2008) reported 190-d yields ranging from 849 to 1233 kg, while Minick *et al.* (2001) reported lower yields (ranging between 664 and 911 kg), even for lactations length of 210-d. In our study, suckled cows produced greater yields than milked cows throughout their lactations and were also more persistent.

Figure 1 shows average lactation curves for milked and suckled cows on primiparous and multiparous and illustrate that lactation curves of suckled and milked cows are different, mainly due to significantly ($P < 0.05$) differences found in peak day, persistency and total milk yield (Table 2). The absence of the calf and the cow's difficulty in adapting to the hand-milking can explain their lower peak yields and total milk yield. These results can be used to advice that the hand-milking is not a suitable method to quantify milk yield in Barrosã breed. Moreover, lactation curves shape of primiparous and multiparous are more similar in suckled cows compared with milked cows (Figure 1). These results for suckled cows are in disagreement with earlier findings in dairy cows. First lactation dairy cows produced lower yields than older cows at the beginning of the lactation and were more persistent (Teklerli *et al.*, 2000; Rekik *et al.*, 2003). Multiparous dairy cows reached their peak yield earlier in the lactation than primiparous did.

In addition, the peak yield is greater for older than for primiparous cows (Teklerli *et al.*, 2000; Rekik *et al.*, 2003). This similarity between P1 and P2 on suckled group was nor-

mal in this breed (≈ 891 days, Almeida, 2000), probably due to the late first calving age, and particularly, in the cows used in this study (910 days). On the other hand, milked multiparous cows have lactation curves with early day of peak, greater peak yield, and lower persistency than milked primiparous cows, as described before for dairy cattle (Figure 1). This result indicates a minor adaptation of primiparous cows to the hand milking system.

Conclusions

Daily milk yields of Barrosã cows were higher on suckled cows and on multiparous. The application of Wood's model in Barrosã lactation curves showed a high goodness of fit. In this study, all lactations followed the typical curve shape for milk yield. Also, lactation curve of milked cows was different from the lactation curve of suckled cows. For both parities, lactation curves of suckled cows produced greater yields than milked cows along all lactation days and were also more persistent. Moreover, suckled cows reached their peak yield later (56-63) and the peak yield (5.3-5.7) was greater than in milked cows. Lactation curves of milked cows showed more differences between primiparous and multiparous than in suckled cows. Barrosã cows, in their traditional production system, have lactation yields of 889 and 906 kg in primiparous and multiparous, respectively. Hand-milking causes an overall 60% reduction in daily milk yield. Consequently, this study does not validate the hand-milking as a practical method to quantify milk yield in Barrosã breed.

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