

The Estimation of Lactation Curve Parameters according to Season of Calving in Holstein Cows under North Africa Environmental Conditions: The case of Tunisia

M. KHALIFA^{*1}, A. HAMROUNI¹, M. DJEMALI¹

¹ Animal Genetic Resources and Feed Resources Research Lab: National Agronomy Institute- Tunis, 43 Avenue Charles Nicolle, Tunis 1082

*Corresponding author: moniakhlifi3h@gmail.com

Abstract – In the most of lactation curve studies, lactation curves are habitually developed using the average test day data on milk yield within parity (primiparous, multiparous) and age of calving without considering the effect of calving season. In Tunisia, Holstein dairy cattle produced differently according to their calving month. The objectives of this study were 1) to identify the different shapes of lactation curves of Holstein cows under North Africa (Tunisia) prevailing production environments and 2) to estimate parameters of the most dominant lactation curves found by season. The incomplete gamma function was used to adjust milk lactation curves per calving season. A total of 836 901 milk test days of 67 137 cows in 2885 herds during 2003-2015 was used in this study. A linear model was developed, including herd-test day, farm ownership, calving month, calving year, and lactation number, test year, age of cow and milk test number. The main results showed that daily milk average per calving season ranged from 15 ± 7 kg/d to 20.33 ± 8 kg/d in season 1 (September to January), 15 ± 7 kg/d to 20.26 ± 8 kg/d in season 2 (February to May) and between 15 ± 7 kg/d to 19.74 ± 8 kg/d in season 3 (June to August). Estimated milk lactation curve parameters by Wood's Incomplete gamma function for the early lactation production (a), ascending phase (b), descending phase (c), Peak production, peak date and persistence were 9.72kg; 0.291; 0.00382; 23.31kg; 84 days and 7.36, respectively in the first season (autumn-winter), 10.06kg; 0.281; 0.00377; 23.15kg; 82 days and 7.31, respectively in season 2 (February to May), 9.59kg; 0.287; 0.00368; 23.01kg; 87 days and 7.40, respectively for season 3 (June to August).

Keywords: Holstein cows, lactation, Wood, Gamma, season of calving.

1. Introduction

Various studies on the lactation curve have focused only on milk production (Tekerli et al., 2000; Rekik et al., 2003; Macciotta et al., 2005). Typical lactation curves for dairy cows show a peak or maximum daily output between 4 and 8 weeks after calving, followed by a daily decrease in the amount of milk (persistence rate) until drying, where the lactation will be naturally terminated (Keown et al., 1986 ; García and Holmes, 2001; Macciotta et al., 2005). Environmental sources of variation affecting milk yield of dairy cattle have been reported in many geographical regions in the world. Djemali and Berger (1992) reported that Holsteins in Tunisia produced differently according to their calving month. It is then worth exploring shapes of lactation curves of cows in relation to their calving season. The objectives of the study were: 1) to identify the different shapes of lactation curves of Holsteins under North Africa (Tunisia) prevailing production environments and 2) to estimate parameters of the most dominant lactation curves found by season.

2. Material and Methods

Data were supplied by the National Centre for Genetic Improvement (CNAG) of Livestock and Pasture office (OEP). A total of 836 901 daily milk records of 67 137 Friesian Holstein Tunisian cows from 2885 farms recorded during 2003-2015 has been used and analyzed.

The Incomplete Gamma function (IG) (Wood, 1967) (1) was used to describe the different lactation curves of cows and to estimate lactation curve parameters per calving season. The adjustment of the curves was carried out using the Gauss-Newton algorithm in the NLIN procedure of the SAS (1989). The quantity of daily milk observed was modeled by the following function:

$$Y(t) = a t^b e^{-ct} (1)$$



Where, $Y(t)$: daily milk production at day t ; a is a parameter associated with yield at the beginning of lactation, b is a parameter associated with the ascending phase before peak yield, and c is a parameter associated with the decreasing phase after peak yield. The peak date (DIMP) was defined as b/c and the peak was calculated as follows: $a(b/c)^b e^{-b}$. The persistency of lactation was evaluated using the following derivative expression of Wood's Gamma function: $S = -(b+1) \ln(c)$ (Tekerli et al., 2000). Table (1) shows the different forms of lactation curves adjusted by the Wood model for Holstein cattle.

It is worth mentioning (Table 1) that Wood's model can adjust curve parameters into four different forms (Wood, 1976; Rekik and Ben Gara, 2004; Macciotta et al., 2005; Gołębiewski et al., 2011), mainly in the function of the value of parameters (b) and (c), because (a) is always positive and influences the average level of production. A lactation curve is considered atypical if (b) or (c) is negative (Type A4). For example, a form of lactation curve in the Table1 does not show an increase in the first phase (Type A3). Another curve shows an increasing production of the first phase (Type A2). Type A1 represents the typical form ($b > 0$ and $c > 0$). In this study, we only look at curves that have the typical shape (Type A1).

Table 1. The different forms of lactation curves adjusted by the Wood (the parameter (a) is always greater than 0) (Macciotta et al., 2005).

Forms of curve	The parameters of Wood model		Description of curve
	b	c	
A1	$b > 0$	$c > 0$	Standard curve
A2	$b > 0$	$c < 0$	Continuously increasing curve
A3	$b < 0$	$c > 0$	Continuously decreasing curve
A4	$b < 0$	$c < 0$	Reversed standard

3. Results and discussions

3.1. Adjustment of lactation curves

Typical lactation curves have positive b and c , and curves with negative b or c correspond to atypical lactations (Tekerli et al., 2000)(Table1).The lactation curves examined in this study revealed atypical curves (with negative parameter b or c) with a percentage of 25.10%. The occurrence of atypical forms, characterized by the absence of a lactation peak, accounts for 15-42% (Tekerli et al., 2000; Atashi et al., 2009; Boujenane and Hilal, 2012; Jeretina et al., 2013; Chegini et al., 2015). However, Shanks et al. (1981) were the only ones who found a small proportion equivalent to 0.73% (840 atypical lactations of 113 705 lactations).This form of curves corresponds to cows with problems due to incorrect data, lack of information or management problems. Rekik and Ben Gara (2004) reported that the appearance of atypical curves is mainly due to frequent changes in the quantity and quality of the ration, as well as physiological and health problems related to difficult environmental conditions.

The descriptive statistics of the studied traits are reported in Table 2. The daily milk output increased from calving to peak production of 23.17 kg reached on day 84.86 and then decreased gradually to dryness with a persistency of lactation of 7.35. In this study, the overall average of the estimated initial production value is low ($a = 9.79 \pm 6$ kg) compared to that reported by Rekik et al. (2006) ($a = 16.6$ kg), Tekerli et al. (2000) ($\ln(a) = 2.71$) in Turkey, Boujenane and Hilal (2012) in Morocco (17kg) or Chegini et al. (2015) in Iran (15.08 kg). But it is higher than that found by Gradiz et al. (2009) for Holstein \times Brahman, Holstein \times Brown Swiss and Brown Swiss \times Brahman crossbred cows ($a = 4.67 \pm 3.35$) in Honduras, and result ($a = 1.9$ kg) observed by Abdel-Salam et al. (2011) in Egypt. Differences in the value of (a) may be due to differences in genetic groups or in herd management (Osorio-Arce and Segura-Correa, 2005). The average for b and c (0.287 and 0.00377, respectively) was in the scale of the previous work (Ferris et al., 1985; Ali et al., 1996; Tekerli et al., 2000; Rekik and Ben Gara, 2004; Gradiz et al., 2009; Chegini et al., 2015).

The production at the peak estimated in this study (23.17 ± 7 kg) was low compared to the study by Tekerli et al. (2000) and Chegini et al. (2015),but high compared to the previous work on Holstein cows (Gradiz et al., 2009; Cankaya et al.,2011). However, the date at the peak after calving (84.86 days) was

less than that reported by Chegini et al.(2015) and longer to those found by Dedkova et Nemcova (2003); Gradiz et al.(2009); Ali et al. (1996); Tekerli et al. (2000); Boujenane (2010); Cankaya et al.(2011) and Boujenane and Hilal (2012). Similarly, the persistency of lactation found in this study (7.35) (Table 2) was higher than that found for Holstein cattle (Tekerli et al., 2000; Atashi et al., 2006; Rekik et al.,2006; Atashi et al., 2007). Existing differences in these parameters are probably the result of a combination of genetic effects, management type and diet as well as the specific climatic conditions available in the studies of (Fleischer et al., 2001; Rekik and Ben Gara, 2004; Macciotta et al., 2006).

The higher coefficient of variation (CV) among the lactation curve traits was for (a) and the smallest for (s) (Table2). The average age at first calving in this population (28.52 months) was greater than previous values reported everywhere; by Djemali and Berger (1992) (26.7months), Berry and Cromie (2009) (25 months), Hare et al., (2006) (26.9 months) and Nilforooshan and Edriss (2004) (26.84 months).

Table 2. Average performances and variation of the studied traits

	Number of observations	Mean	SD	CV(%)
Age of first calving (month)	325186	28.52	3.08	10.82
Age of calving (month)	836901	45.41	18.87	41.52
MY	422110	18.92	7.84	41.46
MYe	422110	18.97	7.08	37.34
a	422110	9.79	6.23	63.67
b	422110	0.287	0.125	43.79
c	422110	0.00377	0.00215	56.98
DIMP (d)	422110	84.86	38.51	45.38
Peak (kg)	422110	23.17	7.58	32.71
S	422110	7.35	0.917	12.46

MY=milk yield, MYv=milk yield estimated, DIMP=days in milk at peak production, S =persistency, SD=Standard deviation, CV=coefficient of variation

3.2. Lactation curves traits according to season of calving

The calving season effect is a widely known and well studied variation factor. It has a considerable effect on dairy production and the shape of cattle lactation curve and it affects their daily yield (Wood, 1969; Djemali et al., 1992; Tekerli et al., 2000; Rekik et al., 2003; Rekik et Ben Gara, 2004; Macciotta et al., 2006; Roshanfekar et al., 2010; Boujenane and Hilal, 2012; Bouallegue et al., 2013).

The value of initial production reported by parameter (a) of the lactation curves is higher in cattle calving in spring (10.06 kg) followed by fall-early winter and summer (9.72kg and 9.59kg, respectively) (Table3). This can be explained by the difference between feeding levels depending on the seasons, as in winter, the grass is abundant and its digestibility is maximum. The animal consumes large quantities and this high level of feeding allows it to produce high production of milk. On the other hand, in summer the grass is less abundant and it is generally of less nutritive value which results in a decrease in production as it has been reported by Bouallegue et al. (2013) that the favorable calving season for dairy production is winter followed by spring. However, parameter (b), which is the growth rate associated with the upward phase of average milk curves of winter-calving cattle is low (0.291) compared those of spring-calving cattle (0.281) and summer-calving cattle (0.287). We conclude that autumn and winter calving is the most favorable periods for a better ascending phase. The calving season also affects parameter (c), where the decay rate associated with the downward phase of the average milk curves was high in autumn-early winter (0.00382) and low in summer (0.00368).

The seasonal effect acts upon the characteristics of the lactation curve. Indeed, the highest peak was obtained in cows that calved in autumn-early winter. Tekerli et al. (2000) and Bouallegue et al. (2013) found similar results. Cows calving in summer have low production at peak. Similar results have been reported by Rekik et al. (2004), who argue that cows calving in summer have small amounts of milk at peak lactation. This is due to the Tunisian summer conditions which are characterized by very limited forage availability and a high heat stress. Cows calving in spring reach their peak sooner. Similar results have been reported by Tekerli et al. (2000) and Rekik et al. (2003). Persistency lactation was the higher in cows that had calved in autumn-early winter and those who calved in the summer. But the lowest value was observed in cows calving in spring. These results show that cows that calve in summer and fall-early winter are more persistent.

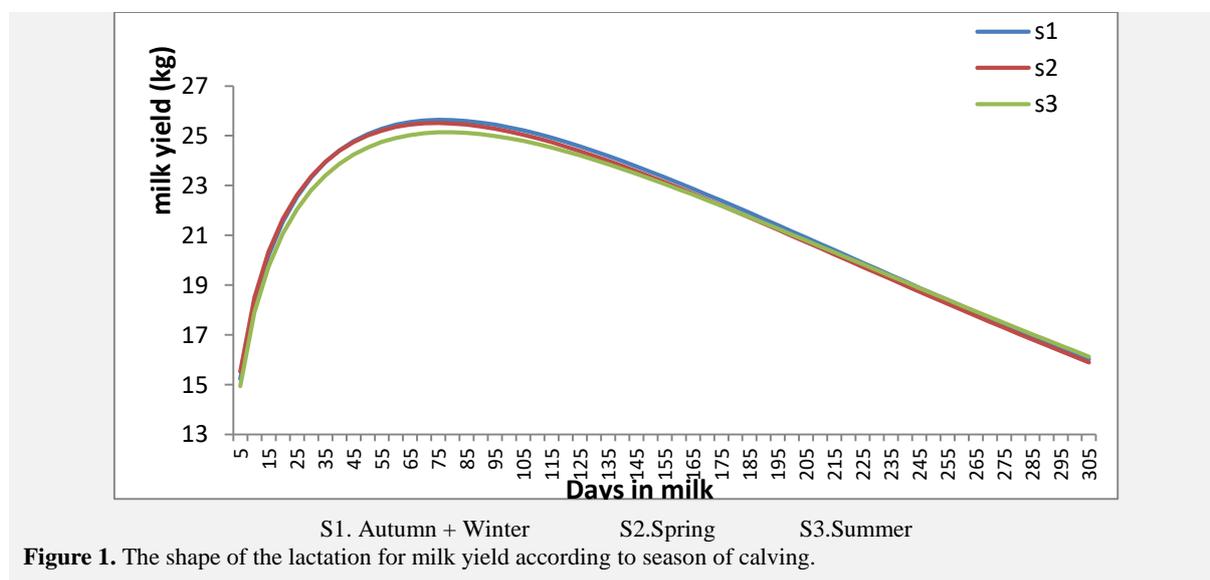
The relationship between the calving season and the parameters of the lactation curve can be explained by the temperature on the one hand and by the rainfall variations on the other hand, which affect forage production, especially in summer when food resources are reduced and the effect of thermal stress is aggravated. Indeed, Bouraoui et al. (2002) reported that summer heat stress minimizes the amount of milk and affects the physiological functions of Holstein cows.

Table 3. Estimated lactation curve parameters per calving season

	Lactation Curves Traits					
	a	b	c	Peak (kg)	DIMP(d)	S
S1 Autumn/winter	9.72	0.291	0.00382	23.31	84.98	7.36
S2 Spring	10.06	0.281	0.00377	23.15	82.49	7.31
S3 Summer	9.59	0.287	0.00368	22.91	87.73	7.40

DIMP= days in milk at peak production, S= persistency

Three lactation curves were identified based on the main calving seasons of Holstein cows in Tunisia (Djemali et Berger, 1992). Lactation curves fitted for milk yield per season of calving was presented in Figure 1. The shapes of the lactation curves of three seasons are similar. They have practically assumed the typical form where the daily yield of milk has increased from calving to a peak in which the production reaches its maximum. It persists for a certain time on this level, and then it gradually decreases towards the end of the lactation. Analysis of these curves shows that cows calving in autumn-early winter (September-January), spring (February-May) and summer (June-August) started their lactation with the same level of production. This aspect is probably explained by the body condition of the animal at calving and by the feeding level of the cow as well as the seasonal effect. Indeed, the lowest peak was recorded in cows calving in summer as food resources are reduced and heat stress is high. These results were confirmed by many works in Tunisia (Bouraoui et al., 2002; Rekik et al., 2003; Rekik and Ben Gara, 2004; Bouallegue et al., 1984) and in the world (Ray et al., 1992; Lee et al., 2000; Tekerli et al., 2000). These authors report that daily milk production is disrupted for summer calving. Persistency of lactation was high in cows that had calved in autumn-early winter, and those who calved in the summer, became more persistent around 165DIM (Figure 1). On the other hand, autumn-early winter calving showed the higher peak yield with a slow decay rate and persistency until late lactation. This is the favorable season for dairy production.



4. Conclusion

The direct modeling of test-day (TD) yield was reliable in generating lactation curve estimates for milk. The Wood model showed a satisfactory fit to the data. The calving season is an important factor of the variation of the shape of lactation curves. The dairy cow produces differently during the calving period. The highest peak and persistency were observed in cows that calved in fall and winter followed by spring and summer. Cows which calved in summer presented the lowest peak.

Acknowledge

The National Centre for Genetic Improvement of Tunisia (CNAG: Sidi Thabet, Tunis) is greatly acknowledged for providing the data used in this study.

5. References

- Ali, A. K. A., R. S. Al-Juaah and E. Hayes.1996** .Lactation curve of Holstein Friesian cows in the Kingdom of Saudi Arabia. *AJAS*.Volume 9(no.4) 439-447.
- Atashi H., M. Moradi, Shahrabak and A. Moghimi Esfandabadi . 2007**. Investigation on the trend of milk yield over lactation time using mathematical functions in Holsteins cows of Iran. *Iranian J. Agric. Sci.* 38(1), 67-76.
- Atashi, H., M. Moradi Sharbabak, A. Abdolmohammadi.2006**.Study of some suggested measures of milk yield persistency and their relationships. *Int J Agric Biol* 3, 387-390.
- Atashi, H., M. Moradi Sharbabak, H. Moradi Sharbabak .2009**. Environmental factors affecting the shape components of the lactation curves in Holstein dairy cattle of Iran. *Livest .Res.Rur.Dev.* 21, Art. 60. <http://www.lrrd.org/lrrd21/5/atas21060.htm> [last accessed 17.09.2012].
- Berry, D.P., and A.R. Cromie.2009**. Associations between age at first calving and subsequent performance in Irish spring calving Holstein–Friesian dairy cows. *Livestock Science* 123, 44–54.
- Boujenane, I., and B. Hilal .2012**. Genetic and non genetic effects for lactation curve traits in Holstein-Friesian cows.*Archiv Tierzucht* 555, 450-457, ISSN 0003-9438.
- Bouallegue,M., B .Haddad, M S. Aschi and M .Ben Hamouda.2013**.Effect of environmental factors on lactation curves of milk production traits in Holstein-Friesian cows reared under North African conditions.*Livestock Research for Rural Development*, 25(5), ISSN 0121-3784.
- Bouallegue, M., N. M’hamdi, M. Ben Hamouda, B. Haddad. 2014** .Study of non-genetic factors on the shape of lactation curves for milk yield, fat and protein percents of Holstein-Friesian cows under hot Mediterranean climate. *Archiva Zootechnica* 17:1, 55-75.
- Cankaya, S., A.Unalan and E. Soydan.2011**. Selection of a mathematical model to describe the lactation curves of Jersey cattle. *Archiv Tierzucht* 541, 27-35, ISSN 0003-9438.
- Chegini, A., A.A.Shadparvarand N. Ghavi Hossein-Zadeh. 2015**.Genetic Parameter Estimates for Lactation Curve Parameters, Milk Yield, Age at First Calving, Calving Interval and Somatic Cell Count in Holstein Cows.*Iranian Journal of Applied Animal Science* 5(1).61-67.
- Dedkova, L., and E. Nemcova. 2003**. Factors affecting the shape of lactation curves of Holstein cows in the Czech Republic.*Czech J. Anim. Sci.*, 48, (10): 395–402.
- Djemali M., and P.J.Berger.1992**. Yield and Reproduction Characteristics of Friesian cattle Under North African Conditions. *J.Dairy Sci.*75:3568-3575.
- Ferris, T. A., I. L. Mao, and C. R. Anderson. 1985**. Selecting for lactation curve and milk yield in dairy cattle. *J. Dairy Sci.* 68, 1438-1448.
- Fleischer, P., M. Metzner, M. Beyerbach, M. Hoedemaker and W. Klee .2001**.The relationship between milk yield and the incidence of some diseases in dairy cows. *J. Dairy Sci.* 84: 2025–2035.
- Garcia, S.C., C.W .Holmes. 2001**. Lactation curves of autumn- and spring-calved cows in pasture-based dairy systems. *Livestock Production Science* 68, 189–203.
- Golebiewski,M.,P.Brzozowski, L.Golebiewski.2011**. Analysis of lactation curves, milk constituents, somatic cell count and urea in milk of cows by the mathematical model of Wood. *ACTA VET. BRNO.* 80: 073–080.
- Gradiz, L., L. Alvarado, A.K. Kahi and H. Hirooka. 2009**. Fit of Wood's function to daily milk records and estimation of envi-ronmental and additive and non-additive genetic effects on lactation curve and lactation parameters of crossbred dual pur-pose cattle. *Livest. Sci.* 124,321-329.
- Hare, E., H.D., Norman, and J.R., Wright. 2006**. Trends in calving ages and calving intervals for dairy cattle breeds in the United States. *J. Dairy Sci.* 89, 365–370.

- Jeretina, J., Babnik D and D. Škorjanc.2013.** Modeling lactation curve standards for test day milk yield in Holstein, Brown Swiss and Simmental cows. *Journal of Animal and Plant Sciences* 23 (3): 754–62.
- Keown, J. F., R. W. Everett, N. B. Empet, and L. H. Wadell. 1986.** Lactation curves. *J. Dairy Sci.* 69:769–781.
- Lee D.H., Han K.J and Park B.H., 2000.** Genetic Relationship between milk yields, calving ease and days open at first lactation of Holstein cows in Korea. *Bulletin 26. 2001 Proceedings of Interbull Technical workshop in Verdun, Germany, October 22-23 2000.*
- Macciotta, N. P. P., D. Vicario, and A. Cappio-Borlino. 2005.** Detection of Different Shapes of Lactation Curve for Milk Yield in Dairy Cattle by Empirical Mathematical Models. *J. Dairy Sci.* 88:1178–1191.
- Macciotta, N.P.P., D.Vicario and A.Cappio-Borlino. 2006.** Use of multivariate analysis to extract latent variables related to level of production and lactation persistency in dairy cattle. *J. Dairy Sci.* 89:3188-3194.
- Nilforooshan, M.A., and M.A., Edriss.2004.** Effect of age at first calving on some productive and longevity traits in Iranian Holsteins of the Isfahan province. *J. Dairy Sci.* 87, 2130–2135.
- Olori, V.E., S. Brotherstone, W.G.Hill and B.J. McGuirk. 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.
- Osorio-Arce, M.M. and J.C. Segura-Correa. 2005.** Factors affecting the lactation curve of *Bos Taurus* × *Bos indicus* cows in a dual purpose system in the humid tropics of Tabasco, Mexico. *Technol. Pecu. Mexico.* 43, 127-137.
- Ray, D.E., T.J. Halbach and D.V. Armstrong, 1992.** Season and lactation effects on milk production and reproduction of dairy cattle in Arizona. *J. Dairy Sci.* 75, 2976–2983.
- Rekik, B., A. Ben Gara, M. Ben Hamouda and H .Hammami .2003.** Fitting lactation curves of dairy cattle in different types of herds in Tunisia. *Livest Prod Sci* 83, 309-315.
- Rekik, B., and A.Ben Gara. 2004.** Factors affecting the occurrence of atypical lactations for Holstein-Friesian cows. *Livest. Prod.Sci.* 87:245–250.
- Shanks, R.D., P.J. Berger Freeman and A.E. Dickinson FN. 1981.** Genetic aspects of lactation curves. *J Dairy Sci* 64, 1852-1860.
- Tekerli, M., Z. Akinci, I. Dogan and A. Ackan. 2000.** Factors affecting the shape of lactation curve of Holstein cows from the Balikesir Province of Turkey. *J. Dairy Sci.* 83, 1381– 1386.
- Wood, P.D.P., 1967.** Algebraic model of the lactation curve in cattle. *Nature (London)* 216, 164– 165.
- Wood, P. D. P., 1969.** Factors affecting the shape of the lactation curve in cattle. *Anim. Prod.* 11:307–312.
- Wood, P.D.P., 1976.** Algebraic models of lactation curves for milk, fat and protein production, with estimates of seasonal variation. *Anim Prod* 22: 35-40.