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Influence of Types of Ration on Modeling of Lactation Curves in Tunisia

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Abstract: Lactation curve traits were determined for Holstein-Friesian cows in five dairy bovine farms in Tunisia two public farms and three Cooperative Units of Agricultural Production (UCPA) using Wood's incomplete gamma function to lactation records by non-linear regression in 1967 model. A total of 49950 test day records during the period between 1997 and 2007 were used in the analysis. Six types of basal ration were identified in these farms (distributed during 1 month minimum) on the base of the roughages used in the basal ration (R1: Concentrate (CC) + Dry Forages (DF)+Silage (S); R2: CC+DF+S+Sugar Beet Pulp (SBP); R3: CC+DF+S+Summer Green Forages (SGF) R4: CC+DF+S+Spring Green Forages (SPGF); R5: CC+DF+S+SPGF+SP; R6: CC+DF+S+SPGF. The parameters of Wood model (a is the estimation of initial milk yield, b and c are respectively the increasing and the decreasing slopes of the curve) were estimated. The model included herd x year, herd x month, DIM x age x season of calving as fixed effects, herd x test day as random effect and random regression coefficients for animal herd x parity, herd x year, herd x year and ration effects which were defined as modified quadratic Legendre coefficients. Results suggested peak milk yield increased from 18.7-20.92 kg and 22.92, respectively from the first lactation to the second and the third. However, the highest persistency was observed in the first lactation. The R2 type rations including the sugar beet pulp, presented late peak milk and allowed high peak milk yield production while this ration allows a low persistency.

Key words: Lactation curve, test day model, incomplete gamma, types of ration, UCPA, Tunisia

INTRODUCTION

In Tunisia, milk production is a strategic sector of the agricultural policy particularly because of its economic and social role. This sector contributed in 2006 to 26% of the value of livestock production and 9.2% of the total value of agricultural production, 7.2% of food industry and occupies 32% of the whole farmers and 68% of workers permanent employees in the agricultural sector. It should be noted that the organized sector which owns 86% of the herd of pure race carries around 82% of the total milk production. For the stockbreeder who seeks to increase the income of his activity or at least to maintain it two levers of action are offered to him: on the one hand a good selection and on the other hand improvement of the management of its herd. However although, this sector is an important source of income for farmers in Tunisia its profitability in recent years has been increasingly discussed.

For the farmer who wants to increase the income of his activity or at least to maintain it two levers of action are offered to him: on the one hand a good selection and on the other hand improvement of the management of its herd. But in Tunisia, the absence of genetic evaluation program represents a major handicap for the selection on the national level (Rekik *et al*., 2003) while in most countries of the world's genetic evaluation program, performance of dairy cattle is based primarily on test days model.

TD models were used by several researchers in order to estimate the parameters and the evolution of lactation curves as well as the variation in the populations (Kettunen *et al*., 1997; Strabel and Misztal, 1999; Druet *et al*., 2003, 2005; Zavadilova *et al*., 2005; Muir *et al*., 2007). Although, this model represents an important source of information, little attention has been paid to its application at ends management (Auvray and Gengler, 2002; Mayeres *et al*., 2002, 2004; Caccamo *et al*., 2008). However, some researchers showed that the use of TD in the random regression test day model RRTDM could provide a solid base for advising farmers in the management of herds. The potential of the TD model for management use depends on its ability to describe the variation within and between herd may be related to specific management practices, some of which may be short term as in the case of a change of feed ration.

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Food management remains the driving factor most limiting for milk production and constitutes the principal item of expenditure in terms of the profitability of the dairy cattle.

Majority of the studies that integrate the food in the modeling of lactation are to interest either in the mixed rations and fodder separate (Gordon *et al.*, 1995; Bargo *et al.*, 2002; Yrjanen *et al.*, 2003; Caccamo *et al.*, 2008) or at the rate of incorporation of the concentrate in the ration (Min *et al.*, 2005).

The objective of this study was to estimate the components of variation of the lactation curve by using a random regression model. The used model integrate the common types of ration in the organized sector in Tunisia as a factor of variation at the end to serve as technical support in order to guide and advise the farmers in the management of dairy herds.

MATERIALS AND METHODS

Data: A total of 7335 lactation records of 4111 Holstein-Friesian cows were used in the analysis. Data collected during the period between 1997 and 2007 were provided by the National Centre for Genetic Improvement (CNAG) at Sidi Thabet, Tunis for 5 dairy bovine farms in Tunisia (Two public farms and three Cooperative Units of Agricultural Production (UCPA)). Each lactations was required to have at least 10 consecutive test-day yields to be considered in the analysis in addition to the cow's identification number, type of herd, date of calving, lactation number and test-day dates.

Records obtained before 5 or after 360 DIM were also discarded. Four seasons (Fall, Winter, Spring and Summer) and 3 subclasses for age at calving for the first lactation (<28, 28-31, 32-44 mo), 2 classes for the second lactation (35-44, 45-66 mo) and 1 classe for the third lactation were defined.

Identification and definition of the types of rations: The types of rations used for the food of the milk cow were defined on the basis of combination of the ingredients used in the rations. Concentrate (CC); Dry Forages (DF); Silage (S); Sugar Beet Pulp (SBP); Summer Ggreen Forages (SGF) and Spring Green Forages (SPGF). Thus 6 types of ration were identified:

- R1: CC+DF+S
- R2: CC+DF+S+SBP
- R3: CC+DF+S+SGF
- R4: CC+DF+S+SPGF
- R5: CC+DF+S+SPGF+SBP
- R6: CC+DF+S+SPGF+SGF

The feeding systems were defined on the basis of combination of these types of food along 1 year with minimal use during 1 month.

Analysis

Lactation curves: Data were analyzed with a single trait-multi-lactation random regression test day model based on Gillon *et al.* (2010) with an addition of a ration effect. The matrix notation of the model is:

$$Y = Xb+Cc+Hh+Za+Rr+e \quad (1)$$

Where:

- Y = A vector of milk yields
- b = A vector of the fixed effects: herd x year, herd x month, classes of 15 DIM x age at calving x season of calving
- c = A vector of random herd x test-date effect = a vector of herd x year of calving random regression coefficients
- a = A vector of animal x parity random regression coefficients
- r = A vector ration random regression coefficients
- e = A vector of residual effects and X, C, H, Z
- R = Incidence matrices relating observations to various effects

Fitting lactation curves: The gamma function described by Wood (1967) is one of the most popular models used to describe the lactation curve:

$$Y_t = at^b e^{-ct} \quad (2)$$

For all models, Y_t is the average milk yield in lactation day t. In model 2, parameter is a scaling factor to represent yield at the beginning of lactation and b is the parameter associated with increase rate of yield during the inclining phase until peak and c is the parameter associated with declining slopes of the lactation curve. Persistency and peak yield were calculated as; -(b + 1) in (c) and $a(b/c)^b e^{-b}$, respectively (Tekerli *et al.*, 2000).

RESULTS AND DISCUSSION

Lactation curves: Figure 1 shows the trend of means residual over DIM of milk yield in the first lactation. The residuals were scattered about the horizontal axis. These results indicate a satisfactory description of the lactation curve and an adequate representation of the data by the proposed model.

The incomplete gamma function IG was also a good fit for lactation curves. The means absolute error which is

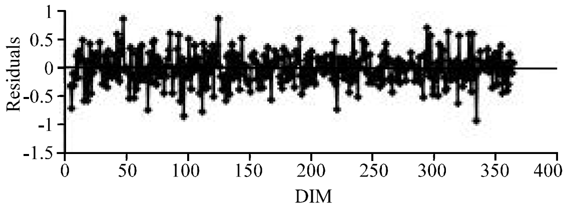

Fig. 1: Distribution of residuals among DIM for first parity

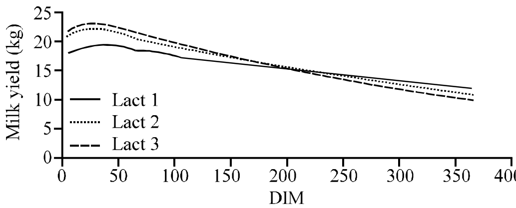

Fig. 2: Effect of parity on lactation curves for milk yield for the first-third parities animals

the means of predicted test day yield in a production sector minus the actual test day yields of a cow in the same test day and in the same type of herd ranged from 1, 5-3.2 kg. Those of first lactation were on average lower and were less dispersed than those of later lactation. They are comparable with those found by Scott *et al.* (1996). They adjusted IG to fat corrected milk produced by 383 cows with a required minimum of 900 kg milk per cow.

Effect of parity on lactation parameters: The effect of parity on lactation curves for milk yield for the first-third lactation are shown in Fig 2. The effect of parity on the component of gamma function (a-c), milk persistency, peak and days to reach peak yield are shown in Table 1. The estimated initial yield a reached its maximum value in the third lactation (17.99 kg) while the minimum value was obtained in the first lactation (16.46). The decreasing slope of the curves (c) was significantly ($p<0.001$) the lowest in the first lactation (0.016) and highest in the third lactation (0.0031). Horan *et al.* (2005) reported than the third parity cows had the highest milk production intercept post calving (a), greatest incline between calving (b) and peak milk production and greatest rate of milk yield decline between peak production and the end of the lactation. On the other hand, peak yield, increased significantly ($p<0.001$) along parities. The minimum value was obtained in the first lactation (18.7) while the maximum in the third lactation (22.4). Similar finding are shown in earlier research (Rekik *et al.*, 2003; Silvestre *et al.*, 2009; Atashi *et al.*, 2009).

The first lactation was significantly ($p<0.001$) more persistent (6.84) than the next ones which were similar (6.43). In connection with this, several researchers found that milk yield persistency decreased from the first lactation to the next others in Holstein cows when this parameter was calculated using Wood model (Rekik *et al.*, 2003; Fadlelmoula *et al.*, 2007; Rao and Sundareson, 1982; Atashi *et al.*, 2009). Indeed, the studied curves showed that in the first lactation the initial yield was lower than which in the others following lactations and that cows in that case were more persistent. In addition, the peak was greater for multiparous than in primiparous cows. These results agree with those of several earlier studies on Holstein Wood-fitting lactations (Stanton *et al.*, 1992; Tekerli *et al.*, 2000; Rekik *et al.*, 2003; Silvestre *et al.*, 2009, 2010; Keown *et al.*, 1986). Wood (1967) suggested that older animals start their lactation at a higher level but because the inhibition effect of pregnancy occurs at about the same stage of lactation whatever the level of production, the rate of decline is higher in older cows. Similar results have been reported previously by Horan *et al.* (2005).

Table 1: The effect of parity number on the component of gamma function (a-c), degree of persistency of yield (P), peak yield (Peak) and peak to reach peak yield (DIMP)

	Parameters[1]					
Lactation	a	b	c	P[2]	Peak[3]	DIMP[4]
1	16.46[b]	0.045[c]	0.0016[c]	6.84[a]	18.7[c]	29.26[b]
2	17.85[a]	0.069[b]	0.0024[b]	6.52[b]	20.92[b]	28.12[c]
3	17.99[a]	0.09[a]	0.0031[a]	6.35[b]	22.37[a]	29.77[a]

[a-c]Means of variable levels with different superscripts for each lactation curve trait are significantly different (p, 0.001); [1]Modeled as: $Y_t = a\, t^b e^{-ct}$ where Y_t = milk yield on day t, a = A factor to represent yield at the beginning of lactation; b and c = Factors associated with the ascending and decreasing phases of the lactation curve; [2]Peak yield calculated as: $a(b/c)^b\, e^{-b}$; [3]Persistency calculated as: $-(b+1)*\text{Ln}(c)$; [4]DIMP: DIM at peak yield calculated as: (b/c)

This study showed also that first parity animal reached the peak yield later (29.8 days) than those in second parity (28.1 days). Similar finding were reported in earlier research (Rekik *et al.*, 2003; Tekerli *et al.*, 2000; Rao and Sundareson, 1982). In connection with this, Tekerli *et al.* (2000) working on Turkish HF cows concluded that the milk secretary tissue in primiparous takes longer time to reach its full activity. By another hand when comparing the second parity to the third one, researchers found that the third parity animals took a longer period of time to reach the peak of production (29.77 and 28.12 days). Keown *et al.* (1986) reported that the higher is the level of production, the later is the peak reached. Similar finding were advance by Tekerli *et al.* (2000).

Effect of type of ration on lactation parameters: The effect of type of ration on lactation parameters are shown in Table 2. This factor had a significant effect ($p<0.001$) on

Table 2: Effect of type of ration on the components of lactation curves Holstein cows

Lactation	Parameters[1] a	b	c	P[2]	Peak[3]	DIMP[4]
1	17.15[e]	0.077[c]	0.0026[c]	6.43[a]	20.71[d]	29.73[b]
2	17.7[b]	0.088[a]	0.0029[a]	6.36[d]	21.91[a]	29.95[a]
3	17.5[c]	0.072[d]	0.00253[d]	6.44[a]	20.83[d]	28.51[e]
4	17.9[a]	0.072[d]	0.00258[cd]	6.41[b]	21.24[b]	28.11[f]
5	17.3[d]	0.081[b]	0.028[b]	6.38[c]	21.02[c]	29.04[c]
6	16.7[f]	0.082[b]	0.028[b]	6.37[c]	20.4[e]	28.93[d]

Ration 1: CC+DF+S; 2: CC+DF+S+SBP; 3: CC+DF+S+SGF; 4: CC+DF +S+SPGF; 5: CC+DF+S+SPGF+SBP; 6: CC+DF+S+SPGF+SGF); [a-f]Means of variable levels with different superscripts for each lactation curve trait are significantly different (p, 0.05); [1]Modeled as: $Y_t = a\, t^b e^{-ct}$ where Y_t = milk yield on day t, a = A factor to represent yield at the beginning of lactation; b and c = Factors associated with the ascending and decreasing phases of the lactation curve; [2]Peak yield calculated as: $a(b/c)^b\, e^{-b}$; [3]Persistency calculated as: -(b+1)*Ln (c); [4]DIMP: DIM at peak yield calculated as (b/c)

all the parameters of the lactation curves as fitted using Wood model. The estimated initial yield (a) reached its maximum value (17.9) with ration 4 composed of Concentrate (CC); Dry Forages (DF); Silage (S) and Spring Green Forages (SPGF). On the other hand, this type of ration presented the significantly ($p<0.001$) low increasing (b) and decreasing (c) slope of the curves (respectively 0.072 and 0.00258). The minimum value of estimate initial yield (a) was obtained with ration 6 (16.7) composed of CC, DF, S, SPGF and SGF. Also, this ration induced the lowest and the earliest ($p<0.001$) peak of production (respectively 20.4 and 28.93).

Ration 2 composed of CC, DF, S and SBP presented the significantly ($p<0.001$) highest production and earliest peak (21.9) but the lowest persistence (6.36). The highest persistency (6.44) were founds when using ration 3 composed of CC, DF, S and SGF.

The studies of milk production curves using the type of ration as a variation factors are quite inexistent since this factor is generally associated to management effect (Rekik and Gara, 2004). However, these results could be discussed on the base of the efficiency of the used rations. Indeed, the beet pulp characterizing the ration type 2 high in energy (kg DM), poor in protein (90 g MAT per kg DM) but high in digestible fiber (0.88-0.9) and very palatable. These characteristics make this byproduct comparable to concentrates (Kelly, 1983). The forage intake was higher in case to use beet pulp in different forms (ensiled, molassed or pressed) for other type of forage (Murphy, 1986; Bell *et al.*, 2007). Humphries *et al.* (2003) indicate the replacing grass silage with press sugar beet pulp marked improvements in DM intake (+41%) and rumen environment more conducive to the efficient utilization of ingested fiber. In another hand, these researchers showed that milk yield of cows fed on diets based on beet pulp compared to those fed maize or wheat (Karalazos and Giouzeljannis, 1987, 1988). Murphy (1986) relate that milk yield of cows fed on a diet based on grass silage plus pressed sugar-beet pulp was not significantly different from that of cows fed on a diet based on grass silage plus concentrates or barley when included in the concentrate portion of diet giving to milking dairy cows (Karalazos and Giouzeljannis, 1988). In this study, the use of beet pulp seemed to have allowed the satisfying of energy constraint since energy is the most limiting factor in feeding dairy cows, especially in the critical stage of the beginning of lactation. In this connection, Hoden and Sansoucy reported that sugar beet pulp is equivalent to concentrate and its incorporation in dairy diets usually allowed significant increases in milk yield.

In addition in Tunisia, researchers frequently observed variations of production mainly in Spring green forage based rations caused by the rains which reduce accessibility to forage parcel. The use of SBP seemed to reduce this effect and provide a relative stability of dairy feeding since this byproduct is conserved by ensiling for relatively long period. Despite the fact that the ration type 6 contains Winter and Summer forage, it gives a low production. This type of ration is the one researchers find in the lean period between late Summer crops and beginning Winter crops. This period is known for its quantitative and qualitative lack of green forage even they are recorded in the ration. In Tunisia, this period to line up the year low production phase. Since the 90s, the production of beet pulp was dropped and actually brought back for several reasons and most of all for the need of sugar beet pulp in livestock food.

First lactation: The effect of type of ration on the components of first lactation curves were shown in Table 3 and Fig. 3. In the first lactation, the second type of ration allow the highest initial milk production (16.96), greatest increasing (0.0552) and decreasing (0.00203) slope and peak milk yield (19.47) but low persistency (6.59). Conversely, the lowest initial production (15.94), the better persistence of the curve (6.7) and later date of peak (31.72) falls with first type of ration. The lowest peak milk (18.15 kg) and the worst persistency (6.55) and earlier pick (27.33) were obtained with sixth type of ration. The lowest increasing and decreasing slope were respectively obtained with fourth (0.0496) and third (0.00172) type of ration.

Second lactation: The effect of type of ration on the component of second lactation curves were shown in Table 4 and Fig. 4. In the second lactation, the highest

Table 3: Lactation curve components for primiparous Holstein Frieson cows by of ration

Ration	Parameters[1] a	b	c	Persistency[2]	Peak[3]	DIMP[4]
1	15.94	0.0552	0.00174	6.70	18.26	31.72
2	16.96	0.0632	0.00203	6.59	19.47	31.13
3	16.49	0.0497	0.00172	6.68	18.54	28.89
4	16.69	0.0496	0.00179	6.63	19.03	27.70
5	16.42	0.0556	0.00194	6.59	18.72	28.65
6	16.00	0.0544	0.00199	6.55	18.15	27.33

Table 4: Lactation traits for second parity by of ration

Ration	Parameters[1] a	b	c	Persistency[2]	Peak[3]	DIMP[4]
1	18.2548	0.0720	0.00271	6.33	21.51	26.56
2	18.5539	0.0868	0.00303	6.30	22.76	28.64
3	18.1155	0.0717	0.00260	6.37	21.38	27.57
4	18.1481	0.0758	0.00265	6.38	21.69	28.60
5	17.7916	0.0825	0.00288	6.33	21.60	28.64
6	17.0908	0.0847	0.00294	6.32	20.87	28.80

Table 5: Lactation traits for third parity by of ration

Ration	Parameters[1] a	b	c	Persistency[2]	Peak[3]	DIMP[4]
1	17.2601	0.1066	0.00345	6.59	18.72	28.65
2	17.7504	0.1167	0.00388	6.33	21.60	28.64
3	18.0044	0.0956	0.00329	6.23	22.74	29.83
4	18.5146	0.0933	0.00333	6.55	18.15	27.33
5	17.5966	0.1071	0.00359	6.32	20.87	28.80
6	17.0161	0.1095	0.00357	6.25	22.18	30.67

Ration 1: CC+DF+S; 2: CC+DF+S+SBP; 3: CC+DF+S+SGF; 4: CC+DF+S+SPGF; 5: CC+DF+S+SPGF+SBP; 6: CC+DF+S+SPGF+SGF); [1]Modeled as: $Y_t = a\, t^b e^{-ct}$ where Y_t = milk yield on day t, a = A factor to represent yield at the beginning of lactation; b and c = Factors associated with the ascending and decreasing phases of the lactation curve; [2]Peak yield calculated as: $a(b/c)^b\, e^{-b}$; [3]Persistency calculated as: $-(b+1)*\mathrm{Ln}(c)$; [4]DIMP: DIM at peak yield calculated as: (b/c)

initial production (18.55), parameters associated with increasing (0.087) and decreasing (0.303) phase of lactation curve and uppermost peak milk yield (22.76) was obtained with second type of ration. The peak milk production was increased by 16% between first and second lactation with second type of ration in another hand, the worst persistence of curve falls with second type of ration (6.3) and the better with fourth ration (6.38). The persistency was declined by 4.7% between first and second lactation. Peak milk yield was reached earliest with the first type of ration (26.56 days), latest in the sixth type of ration (28.8 days).

Third lactation: The effect of these factors on the component of third lactation curves were shown in Table 5 and Fig. 5. The second type of ration allowed the highest initial production (18); increasing (0.117) and decreasing (0.00388) slop of curve and the highest In the third lactation, the highest peak milk yield (23.49 kg). The lowest with sixth ration (22.18 kg). But the better the

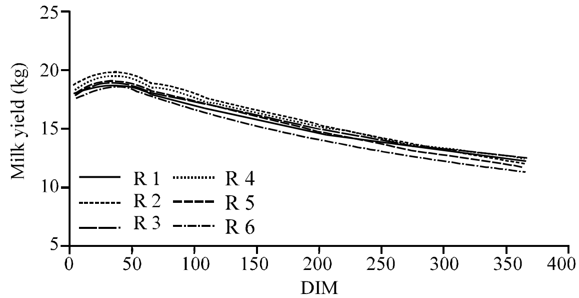

Fig. 3: Effect of ration on lactation curves for milk yield for the first parity animals

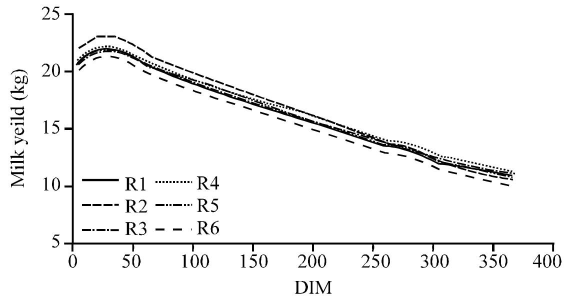

Fig. 4: Effect of ration on lactation curves for milk yield for the second parity animals

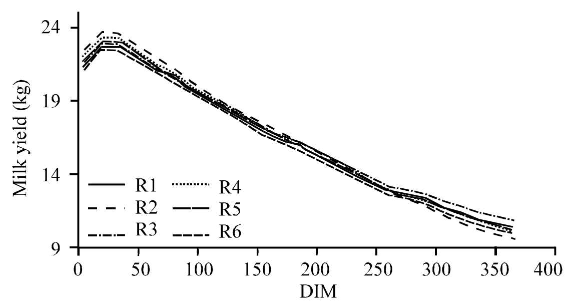

Fig. 5: Effect of ration on lactation curves for milk yield for the third parity animals

persistence of the curve falls with first ration (6.27), the worst with second ration (6.19). Peak milk yield was reached earliest post partum in the fourth ration (28.01 days), latest in the first ration (30.89 days).

CONCLUSION

In first-third lactation, the second type of ration allows always the highest production in the beginning of lactation and the best production during peak but a lower persistency to carry a fall production around the 250th day. In this date, the fourth type of ration allows the highest production explained by highest persistency despite of the low production in beginning of lactation. Therefore, combining the second type of ration at beginning of lactation and the fourth type of ration towards the end of lactation optimizes milk production. The use of the modeling of lactation curves proves to be tools reliable for management to direct the stockbreeders in the choice of the feeding system appropriate to optimize the milk production.

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