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ABSTRACT

The aim of this study was to determine the effect of a calving season on the Wood's model parameters of the lactation curve and its characteristics in Czech Fleckvieh cows.

The observed Czech Fleckvieh cows (with minimum 75% of CF breed in the genotype) born in 1994-2007 formed three parity groups: parity 1 - 350 853 cows, parity 2 - 269 276 cows and parity 3 - 175 029 cows. All the parity groups were further classified by the calving season: winter (December-February), spring (March – May), summer (June-August) and autumn (September-November). The Wood's function parameters (*a, b, c*) were calculated and the lactation characteristics estimated: partial milk yields per 1-100 days, 100-200 days and a total milk yield 305-d, the peak yield – amount and day, IP (index of persistency) 2:1 and a coefficient of the declination rate of the lactation curve. The calving season significantly affected the parameters (*a, b, c*) of the lactation curve, the persistency of lactation and the number of days-in-milk at peak yield; it had no significant effect on the other characteristics. In general, the cows which calved in winter and autumn had more persistent lactations, regardless of the number of lactation. The first-parity cows reached the peak yield sooner if they calved in summer, the older cows in summer and autumn.

Key words: cow, Czech Fleckvieh, milk yield, lactation curve, persistence.

INTRODUCTION

The shape of the lactation curve impacts a dairy herd breeding and management scheme. It was analysed e.g. by Macciotta et al.(2005) or Dematawewa et al.(2007). Atashi et al. (2009) described the effect of the calving season on lactation. A number of mathematical models and methodical techniques were designed to explain the shape of the lactation curve. One of the most frequently used mathematical models is the Wood’s model (Wood, 1967). It is appreciated for its simplicity and accuracy of the lactation curve description. It is used worldwide by animal scientists to describe the lactation curves in cattle and other farm animals (e.g. Cankaya et al. 2011). The parameters of the Wood’s function define the shape of the lactation curve and estimate the milk yield in a particular stage of lactation and thus the persistency index of lactation. Kocak et al. (2008) or Grzesiak et al. (2003) compared several mathematical models of the lactation curve.

Mariam et al. (2008) or Jamrozik et al. (1997) used random regression test-day model for describing the lactation curve and for estimating genetic parameters of lactations. Swalve and Guo (1999) compared variation of lactation curves stratified by herd, lactation number and total milk yield. The results showed difficulties of differentiation of cows into groups according to total milk yield. Kawonga et al. (2012) used Wood model, critical exponential and double exponential model for describing lactation curve for breeding management of smallholders dairy farms.

Many authors pointed to the influence of calving season on milk traits (e.g. Řehák et al. 2012, Ray et al. 1992). The goal of this paper was to determine the effect of a calving season on the shape of lactation curve and its characteristics in Czech Fleckvieh cows. Wood's model was used for descibing the shape of lactation curve.

MATERIAL AND METHODS

The observed Czech Fleckvieh cows (with the minimum 75% of CF breed in the genotype) born between 1994-2007 formed three parity groups: parity 1 - 350 853 cows, parity 2 - 269 276 cows and parity 3 - 175 029 cows. The cows lactated for a minimum 240 and maximum 360 days and were tested (milk-recording) at least six times in the course of lactation. All the parity groups were further classified by the calving season (see Table 1).

The Wood's function parameters (*a, b, c*) were calculated and the lactation characteristics estimated (milk yield per 1-100days, 100-200 days and 305 days, IP 2:1, the peak yield – amount and day, the coefficient of the declination rate).

Table 2 (Nasri et al. 2008) shows some parameters of the lactation curve: t – days at the peak yield, y_m - peak milk yield, r – a coefficient describing the degree of declination between the peak and the end of the lactation, *a, b, c* – estimated parameters of the Wood's model. These parameters determined the shapes of lactation curves for the parity groups 1, 2 and 3, with respect to the calving season; the total and partial (305 days, 1-100 days and 100-200 days) milk yields were calculated. The partial milk yields determined the index of persistency of lactation IP = (100-200 days yield\1-100 days yield) * 100.

The applied Wood's mathematical model was as follows:

$$y = at^{b}e^{-ct},$$

a, b, c – estimated parameters of the function; y - milk yield on the test day (kg); t - test day; e - the base of the natural logarithm. The Wood's model parameters were estimated by a procedure PROC NLIN in SAS 9.1. The effect of the calving season on the lactation curve characteristics was tested by the analysis of variance procedure of PROC ANOVA in SAS 9.1.

RESULTS AND DISCUSSION

The parameters and the peak yield day varied significantly in the observed calving seasons in all lactations (Tab. 3 and 4). On the contrary, cows in all lactations produced a similar amount of milk at peak, regardless of the calving season.

The first-parity cows which calved in summer had the greatest *a* parameter and smallest *b* and *c* parameters. They reached the peak milk yield faster than the other groups – in 38 days. These values indicate that the summer-calvers produce more milk at the onset of lactation and come to the peak earlier. At the same time, the declination of milk production is slower (*r* value) which means a better persistency of lactation compared to the winter and spring calvers. Figures 1, 2 and 3 show the lactation curves of cows in lactation 1, 2 and 3.

The Wood's model parameters and *t* values varied between calving seasons in lactations 2 and 3. Summer and autumn calvers had significantly lower *t, b* and *c* values and a higher *a* value. They reached the peak yield early and the amount of milk was slightly (non-significantly) lower.

Macciotta et al. (2005) estimated Wood's model parameters for Fleckvieh cows in Italy. They analysed the data over the period 1989 - 2002 and determined parameters *a* (11.36), *b* (0.267) and *c* (-0.00564). Třináctý et al. (1990) estimated the parameters for Czech Fleckvieh cows: *a* 12.74, *b* 0.143 and *c* 0.0046. Dematawewa et al. (2007) assessed lactation curves in Holstein cows born between 1997 – 2003 with the following parameters: *a* 15.6862, *b* 0.2081 and *c* 0.002. Golebiewski et al. (2011) calculated the parameters in Montbeliarde cows: *a* 28.44, *b* 0.24 and *c* -0.13. Macciotta et al. (2005), Třináctý et al. (1990) and Dematawewa et al. (2007) presented lower values of the parameters, while Golebiewski et al. (2011) found higher values (except for *c*).

Nasri et al. (2008) observed that the first-parity cows reached the peak yield of 33.6 kg 63 days post-partum, the second-parity cows 39.5 kg 46 days and the third-parity cows produced maximum of 41.8 kg of milk 42 days post-partum. Similarly to Nasri et al. (2008), we also found that later-parity cows reached maximum sooner and produced more milk at peak than younger cows. In the study of Dematawewa et al. (2007) cows produced maximum of 33.35 kg milk 102 days post-partum.

Table 4 presents an estimated 305-d milk yield and partial yields per 1-100 days and 100-200 days. The persistency of lactation index IP2:1 was calculated. Only the IP2:1 significantly varied between calving seasons in all parity groups. Autumn and winter calvers had a significantly greater IP2:1 than spring calvers; the IP2:1 in summer calvers did not differ from the rest in all parity groups. A calving season did not significantly affect either the partial or total milk production. Třináctý et al. (1990) calculated the IP2:1 between 74.2 and 77.2, regardless of the number of lactation, which is slightly lower than our values (Table 4). Nasri et al. (2008) estimated 305-d milk production as 8068 kg (lactation 1), 9233 kg (lactation 2) and 9323 kg (lactation 3) in Holstein cattle population in Iran.

Neither milk yield per day nor the total or partial milk yields significantly differed between calving seasons in all parity groups. The maximum milk yield per day ranged between 20.2 - 27.67 kg milk. The maximum yield was higher in older cows (lactation 2 and 3) and so were the total and partial milk yields. The total milk production in the first lactation ranged between 5125 and 5161 kg, in later lactations between 5696 and 5821 kg milk per 305 days.

The lactation was more persistent in younger cows (the 1st parity, IP2:1 86.23 - 89.71) compared to older ones (the 2nd and the 3rd parity, IP2:1 74.59 - 79.24). First-calvers also produced less milk (maximum, partial and total yield) and reached the peak later (38 – 50 days) than older cows (peak 28 - 37 days).

Our results demonstrated the effect of a calving season on the shape of the lactation curve, especially on the day of the peak yield, the index of persistency and the declination rate. On the other hand, the milk yield, whether peak, partial or total, was not affected by the calving season. The assessed parameters and the shapes of the lactation curves revealed the differences between younger (the 1st parity) and older (the 2nd and the 3rd parity) cows.

The lactations of the autumn and winter-calvers were significantly more persistent than those of spring-calvers. The first-parity cows which calved in summer had different Wood's model parameters and were the fastest to reach the peak. Older cows (the 2nd and the 3rd parity) which calved in summer and autumn had a significantly smaller *t* and different *a, b, c* compared to the cows which calved in winter and spring.

In general, the cows which calved in winter and autumn had more persistent lactations, regardless the parity. The first-parity cows reached the peak yield sooner if they calved in summer, the older cows in summer and autumn. The results showed the influence of calving season on the shape of lactation curve, particularly peak yield and index of persistency was influenced by calving season. This factor should be considered comparing lactation parameters of cows calved in different seasons.

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Figure 1: Lactation curves with respect to the calving season – parity 1 (axis y: kg of milk, axis x: days in milk).

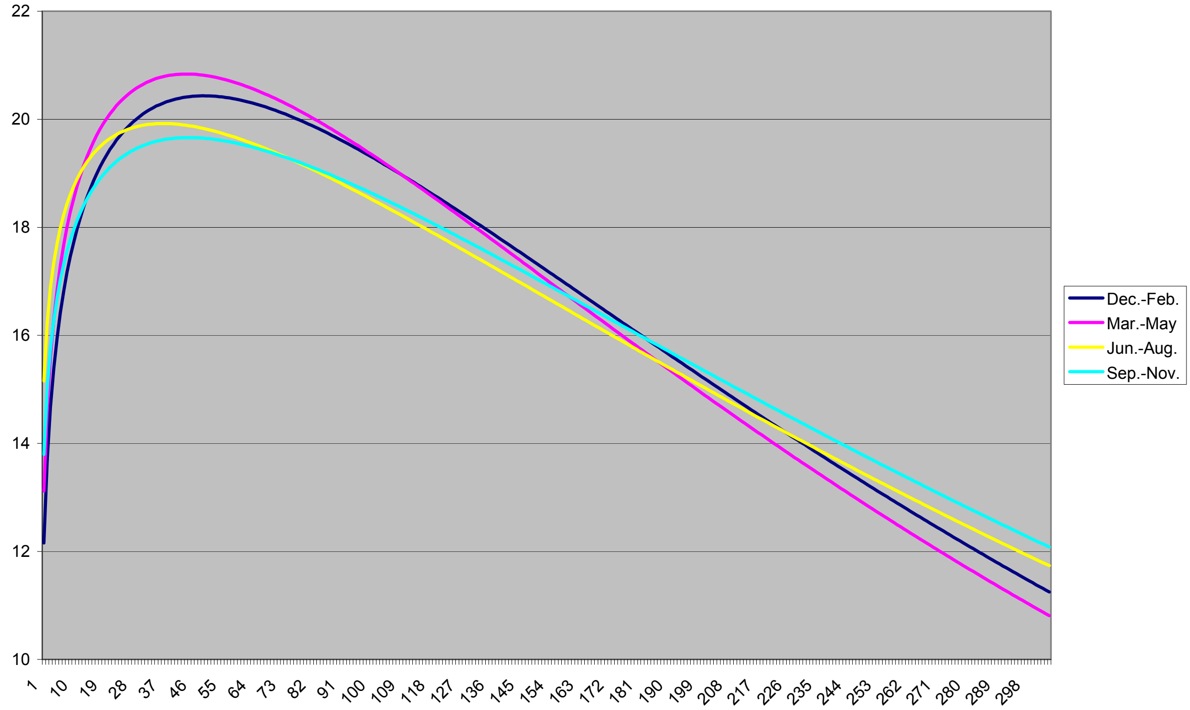

Figure 2: Lactation curves with respect to the calving season – parity 2 (axis y: kg of milk, axis x: days in milk).

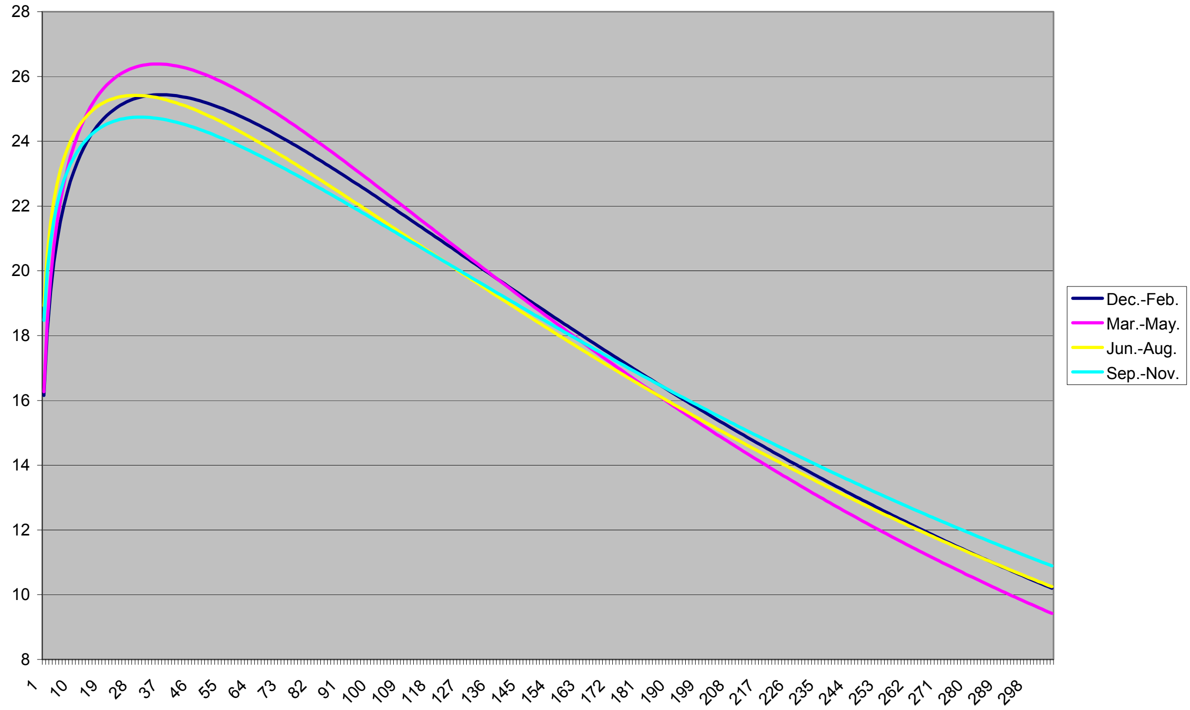

Figure 3: Lactation curves with respect to the calving season – parity 3 (axis y: kg of milk, axis x: days in milk).

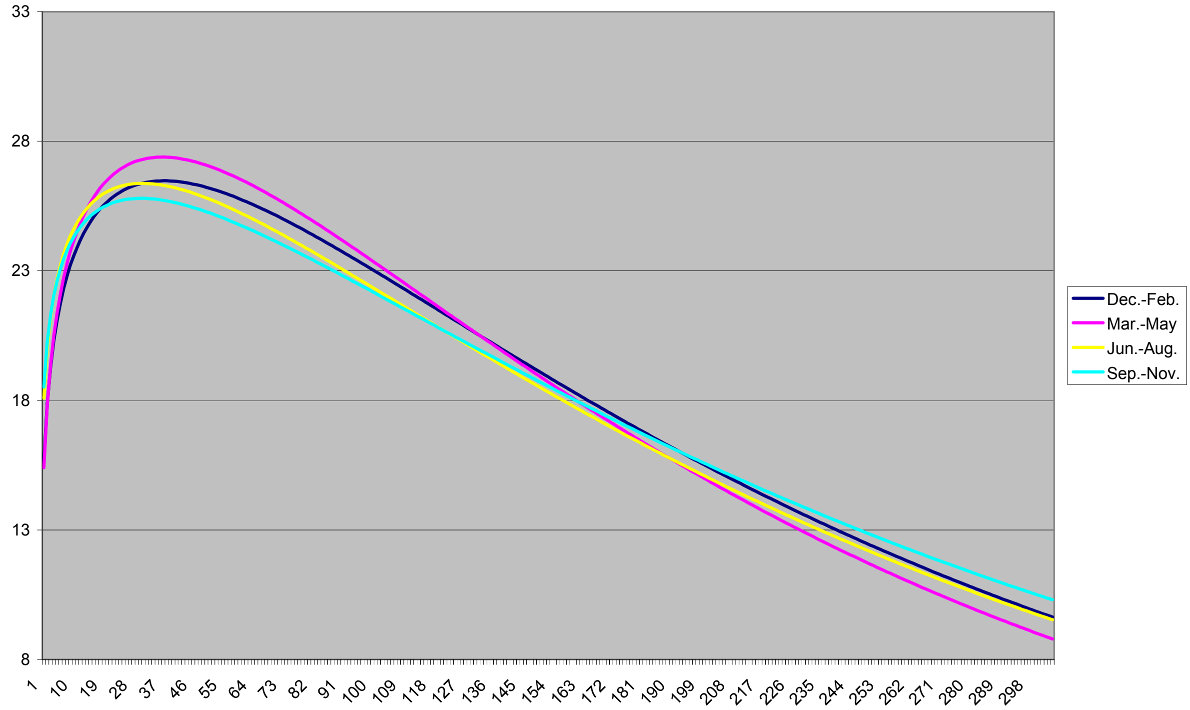

Table 1 Numbers of cows and their classification by parity and calving season.

Parity	Calving season	Month of calving	Number
1	Winter	December-February	94 104
	Spring	March-May	89 465
	Summer	June-August	83 207
	Autumn	September-November	84 077
2	Winter	December-February	72 808
	Spring	March-May	68 796
	Summer	June-August	64 661
	Autumn	September-November	63 107
3	Winter	December-February	46 554
	Spring	March-May	43 671
	Summer	June-August	43 177
	Autumn	September-November	41 627

Table 2 The estimation of some characteristics of the lactation curve

Parameter	Formula
t	b/c
y_m	$a(b/c)^b e^{-b}$
r	b/((t+305)/2) - c

Table 3: Wood's model parameters (a, b, c), peak milk yield (ym), days in milk at peak (t) and the coefficient of a declination rate (r)

Parity	**Season**	**Number**	**a**	**b**	**c**	**t**	**ym**	**r**
1	Winter	94 104	12.2002^{b}	0.1779^{a}	0.0036^{a}	49.56^{a}	20.76	-0.00260385^{a}
	Spring	89 465	13.1649^{a}	0.1648^{a}	0.0037^{a}	44.94^{a}	21.10	-0.00280385^{a}
	Summer	83 207	15.1987^{c}	0.1035^{b}	0.0028^{b}	37.82^{b}	20.34	-0.00218654^{b}
	Autumn	84 077	13.8365^{a}	0.1253^{c}	0.0028^{b}	44.38^{a}	20.20	-0.00208846^{b}
2	Winter	72 808	16.2276^{a}	0.1734^{a}	0.0048^{a}	36.37^{a}	25.90	-0.00376538^{a}
	Spring	68 796	16.3558^{a}	0.1868^{a}	0.0053^{b}	35.48^{a}	26.67	-0.00421923^{b}
	Summer	64 661	18.9978^{b}	0.1239^{b}	0.0043^{c}	28.82^{b}	25.82	-0.00360577^{a}
	Autumn	63 107	18.5441^{b}	0.1201^{b}	0.0040^{d}	29.95^{b}	25.27	-0.00328269^{c}
3	Winter	46 554	15.7457^{a}	0.1986^{a}	0.0053^{a}	37.33^{a}	26.91	-0.00417692^{a}
	Spring	43 671	15.4909^{a}	0.2189^{b}	0.0060^{b}	36.96^{a}	27.67	-0.00468654^{b}
	Summer	43 177	18.1806^{b}	0.1534^{c}	0.0050^{c}	31.08^{b}	26.78	-0.00408654^{a}
	Autumn	41 627	18.5928^{b}	0.1358^{d}	0.0045^{d}	30.43^{b}	26.30	-0.00368269^{c}

Within a parity (1, 2, 3), values marked with different superscripts (a, b, c, d) differ ($p<0.05$).

Table 4: Wood's model estimations of the total (305-d) and partial (1-100 and 100-200 days) milk yield and the persistency of lactation index (IP2:1)

Parity	**Season**	**Number**	**305-d milk yield (kg)**	**IP2:1**	**1-100 yield (kg)**	**100-200 yield (kg)**
1	Winter	94 104	5161.00	88.79[a]	1972.18	1766.67
	Spring	89 465	5149.20	86.23[b]	2009.61	1751.30
	Summer	83 207	5125.50	87.28	1951.58	1722.58
	Autumn	84 077	5151.60	89.71[a]	1926.05	1744.97
2	Winter	72 808	5758.30	78.80[a]	2439.57	1938.92
	Spring	68 796	5735.30	76.18[b]	2499.74	1922.77
	Summer	64 661	5696.10	77.00	2429.19	1890.82
	Autumn	63 107	5731.10	79.24[a]	2388.07	1911.08
3	Winter	46 554	5821.90	77.16[a]	2520.30	1962.20
	Spring	43 671	5779.60	74.59[b]	2576.07	1940.88
	Summer	43 177	5735.30	75.22	2506.31	1906.93
	Autumn	41 627	5792.80	77.20[a]	2473.19	1929.43

Within a parity (1, 2, 3), values marked with different superscripts (a, b, c, d) differ ($p<0.05$).