The quarter milk flow parameters influenced by stage of lactation and milkability in multiparous dairy cows

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Summary

The effect of stage of lactation, peak flow rate, parity, bimodality and teat position on quarter milk production and milk flow parameters was studied. A total of 25 Holstein multiparous cows (in their second to sixth lactation) were investigated during ten months of lactation. Quarter milk flows were recorded daily at morning (5:30 h) and evening (15:30 h) milking. In total more than 52 000 of quarter flow curves were obtained. The peak milk yield was reached at second month of lactation. Peak flow rate was relatively stabile with slight reduction after seventh month of lactation but mean flow rate continuously reduced. Increase phase tended to increase throughout lactation. Decline phase decreased from the first to second month and then from fourth month continuously increased. Overmilking phase increased from first to third month and then decreased. There was no relation between peak flow and milk yield, milk yield of plateau phase and duration of increase phase. Quarters with high peak flow had longer decline and shorter overmilking as compared with low peak flow ones. All parameters were higher during morning milking except the duration of increase and decline phases, where data were higher during evening milking. Quarter with bimodal milk flow showed lower milk yield and higher peak flow, longer increase and decline phases. Quarter position influenced all parameters of milk yield and milk flow. Front quarter had shorter increase and decline and longer overmilking phases than rear ones. Quarter milk flow traits deserve further investigation to give new knowledge if biological needs of quarter should be considered in developing new machines.

Key words: *cow, quarter, milk, flow, factors*

Introduction

The intensive and fast development of new dairy machines with partial or full automation and with very sophisticated control systems of milking process allow us to minimise the possible aversive effects of machine on the animals. However, even with high level of technical development of milking machine, the biological potentials and limitations of the animals have to be considered if milking should be fast, complete and good udder health maintained.

Milk production and parameters of milk flow from whole udder are economically very important for many reasons (Bruckmaier et al., 1995, Thomas et al. 1991, Marnet and McKusick, 2001) indicating the efficiency of milk ejection (Tancin and Bruckmaier, 2001). However, partially earlier and mainly more recent studies have clearly indicated that quarter milk flow recording promises the faster advances in milking technology, efficiency of milk removal and health of udder (Grindal and Hillerton, 1991, Ipema and Hogewerf, 2002). However, due to technical limitation only limited analysis of quarter milk flows are available in literature.

The aim of this work was to study more in detail the effect of stage of lactation, peak flow rate, parity, teat position on the milk production and milk flow parameters at quarter levels.

Material and methods

The trial was conducted at the IMAG experimental farm "De Vijf Roeden" in the Netherlands. A total of 25 Holstein multiparous cows (in their second to sixth lactation), were investigated during ten months of lactation. Cows were free of clinical symptoms of mastitis. The cows were fed *ad libitum* and received additional concentrates according to their milk production levels.

The cows were milked twice daily at 5:30 a.m. and 3:30 p.m. in the 2 x 3 open tandem milking parlour equipped with quarter milk flow recording device (Ipema and Hogewerf, 2002). Quarter milk flows were recorded daily. Premilking udder preparation was performed for a period of about 8-10 s per udder. Milking and pulsation vacuum was set at 43 kPa. Pulsation ratio was 65:35 at a rate of 60 c/min. The cluster (all four teat cups) was automatically removed 4 s after the whole udder milk flow had decreased below 0.3 kg/min for a period of 12 s. The detail explanation of quarter milk flow parameters are described in Tancin et al. (2003).

In total more than 52 000 of quarter milk flow curves were obtained for statistical evaluation (Table I). A general linear model with fixed effects was used to identify the main sources of variation for studied traits in preliminary statistical analyses. Statistical significance of the effects included in the model was tested by using Fisher's F-test. Differences between the levels within effects were tested by Scheffe multiple range test. In statistical model we have tested the effect of stage of lactation, parity, peak flow rate, time of milking (morning, evening), position of four quarters, bimodality (with or without bimodal milk flow). Stage of lactation was divided into ten periods representing ten months of lactation. Parity represented two groups: second - cows on second lactation, and multi - cows on their third and more lactation. Peak flow factor represents three groups of cows selected on the base of average peak flow rate of whole udder flow during lactation (lower – less than 3.1 kg/min, middle – between 3.2 to 4.1 kg/min, high over 4.2 kg/min). Milk yield and milk flow parameters were analysed by the mixed model (SAS, ver. 8.2, 2001). The statistical model can be written in the following form:

$$y_{ijklmn} = \mu + PAR_i + STAGE_j + PEAK_k + BIMO_l + TIME_m + QUAR_n + Z_u + e_{ijklmn}$$

where: y -were the measurements for a milk yield and flow traits, μ - ***overall mean,*** PAR_i -the fixed effects of parity (i=1, 2), $STAGE_j$ fixed effect of stage of lactation (j=1, 2, 3, 4, 5, 6, 7, 8, 9, 10), $PEAK_k$ fixed effect of udder peak flow - milkability (k=1, 2, 3), $BIMO_l$ fixed effect of bimodality (l=1, 2), $TIME_m$ fixed effect of time of milking (m=1, 2), $QUAR_n$ fixed effect of quarter position (n=1, 2, 3, 4), u -random effect of cow, $\mathbf{u \sim N(0, I\,\sigma_c^2)}$, e -random error, assuming $\mathbf{e \sim N(0, I\,\sigma_e^2)}$ X,Z – incidence matrices for fixed effects and random cow effect, resp.

Results

The stage of lactation significantly influenced all studied parameters (Table 1). The peak milk yield was reached at second month of lactation and then milk production decreased. Peak flow rate was relatively stabile with slight reduction after seventh month but mean flow rate continuously reduced from second month. The duration of increase phase tended to increase but milk yield of increase phase corresponded with the milk yield changes. The duration of decline phase decreased from the first to second month and then from fourth month continuously increased, but milk yield of the decline phase was similar throughout lactation. The duration of overmilking phase increased from first to third month and then decreased.

Parity did not influence measured parameters and data were not shown. There was no relation between milkability and milk yield, milk yield of plateau phase and duration of increase phase (Table 2). Quarters of cows with high peak flow rate had longer duration of decline and shorter overmilking as compared to quarters of cows with low peak flow.

The milking time (morning and evening milking) significantly influenced all studied parameters. All parameters were higher during morning milking except the duration of increase (78s vs. 79s) and decline phases (59s vs. 64s) and milk yield of decline phase (400g vs. 424g), where data were lower (complete data not shown). Quarters with bimodal milk flow showed lower milk yield and higher peak flow rate. Quarters with bimodality had 12s longer increase phase and 11s longer decline phase (Table 2).

Quarter position influenced all measured parameters of milk yield and milk flow (Table 2). Rear quarters had significantly higher milk yield, longer time of milking, higher peak and mean flow rate than front ones. Front quarter had shorter duration of increase and decrease phases than rear ones. The duration of overmilking phase was double for front quarters.

Discussion

From our experimental data we could demonstrate that the stage of lactation significantly influenced all studied parameters. The effect of stage of lactation on milk yield and milking time was similar as published by many other scientists (Rotshchild et al., 1980, Firk et al., 2002). Peak flow rate decreased in the first months of lactation, was then relatively stabile during four months and decreased again in the last months of lactation. Mean flow rate significantly reduced in the course of lactation in our data set.

The duration of increase phase and recorded milk yield indicate the milk ejection efficiency in the commencement of milking. Because of short udder preparation by milker the main part of milk ejection reflex developed after cluster attachment resulting in longer duration of increase phase in our cows than it can be expected (Wellnitz et al., 1999). Though there was slight tendency of prolongation of the increase phase, the amount of obtained milk in increase phase significantly reduced from third month. It was found that basal intramammary pressure was stabile during first three months of lactation and then decreased intensively (Mayer et al. 1991).

The duration of decline phase decreased from the first to second month and then from fourth month continuously increased during following parts of lactation. The reason for the longer decline phase of quarters at the beginning and end of lactation is not easy to explain. One of the explanations for the beginning of lactation could be related to the possible milk removal disturbances induced by adaptation of cows to milking (Tancin and Bruckmaier, 2001) and readiness of cows for milking (Wellnitz et al., 1999). Last mentioned authors showed in pictures that milking without stimulation prolonged the duration of increase and decline phase. We could also demonstrate the longer duration of decline phase in bimodal milk flows.

Peak flow rate was not affected by milk yield in our study. It is more related to the breed effect or readiness of cows for milking than milk production within breeds (Bruckmaier et al., 1995). Peak flow rate influenced the course of milk flow. Quarters with high peak flow showed the longest decline phase and shortest overmilking phase as we have already demonstrated earlier with limited amount of data (Tancin et al., 2002, 2003). Naumann and Fahr (2000) and Weiss et al., (2004) found the longest duration of decline phase from teats with shortest canal length that also had highest milk flow.

The quarter position influenced all measured parameters of milk yield and milk flow as described by other authors (Rotschild et al., 1980). In our earlier studies (Tanèin et al., 2002, 2003) we have partially confirmed the results obtained in this work that clearly indicated shorter duration of increase and decrease phases and longer overmilking of front quarters than rear ones.

References

Bruckmaier, R.M., Rothenanger, E., Blum, J. W., 1995: Milking characteristics in dairy cows of different breed from different farms and during the course of lactation. J. Anim. Breed. Genet. 112: 293-302.

Firk, R., Stamer, E., Junge, W., Krieter, J., 2002: Systematic effect on activity, milk yield, milk flow rate and electrical condictivity. Arch. Tierz. Archv. Anim. Breeding, 45: 213-222.

Grindal, R.J, Hillerton, J.E., 1991: Influence of milk flow rate on new intramammary infection in dairy cows. J. Dairy Res., 58, 263-268.

Ipema, B., Hogewerf, P. H., 2002: Detachment criteria and milking duration. In: Proceeding of the first North American Conference on Robotic milking. Plenary II, Toronto, 33-44.

Marnet, P.G., McKusick, B. C., 2001: Regulation of milk ejection and milkability in small ruminants. Livest. Prod. Sci., 70, 125-13.

Mayer, H., Bruckmaier, R., Schams, D., 1991: Lactational changes in oxytocin release, intramammary pressure and milking characteristics in dairy cows. J. Dairy Res., 58: 159-169.

Naumann, I., Fahr, R. D., 2000: Investigation of milk flow from udder quarters. Arch. Tierz., Dummerstorf, 43, 431-440.

Rothschild, M. F., Bodoh, G. H., Pearson, R. E., Miller, R. H., 1980: Source of variation in quarter milk flow measures. J. Dairy Sci., *63*, 1138-1144.

Tancin, V., Bruckmaier, R.M. 2001: Factors affecting milk ejection and removal during milking and suckling of dairy cows. Vet.Med.-Czech, *46*, 108-118.

Tancin, V., Ipema, B., Hogewerf, P., Groot Koerkamp, P., Mihina, Š., Bruckmaier, R., 2002: Milk flow patterns at the end of milking analysed on the udder or quarter levels: relationship to somatic cell count. Milchwissenschaft, *57*, 306-309.

Tancin, V., Ipema, I.H., Peskovicova, D., Hogewerf, P.H., Macuhová, J., 2003a: Quarter milk flow patterns in dairy cows: factors involved and repeatability. Vet. Med.-Czech., s. 275-282.

Thomas, G. V., Force, D.K., Bremel, D. H., Strasser, S., 1991: Effect of pulsation ratio, pulsation rate and teat cup liner disign on milking rate and milk production. J. Dairz Sci., 74:1243-1249.

Weiss, D., Weinfurtner, M., Bruckmaier, R. M., 2004: Teat anatomy and its relationship with quarter and udder milk flow characteristics in dairy cows. J. Dairy, Sci., 87, 3280-3289.

Wellnitz, O., Bruckmaier, R. M., Blum, J.W., 1999: Milk ejection and milk removal of single quarters in high yielding dairy cows. Milchwissenschaft, *54*, 303-306.

Table 1.Least squares means of measured parameters during lactation.

	Stage of lactation, months									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Number of quarters	4922	5078	4746	5548	5369	5193	5552	5708	5138	3247
Milk yield, g	4499^{a}	5407^{b}	5171^{c}	4760^{d}	4437^{a}	4014^{e}	3604^{f}	3251^{g}	2798^{h}	2255^{i}
	85	85	85	85	85	85	85	85	85	85
Total milking time,s	475^{a}	536^{b}	541^{b}	496^{c}	465^{d}	430^{e}	413^{f}	388^{g}	366^{h}	351^{i}
	8	8	8	8	8	8	8	8	8	8
Milk flow time, s	395^{a}	452^{b}	456^{b}	421^{c}	395^{a}	365^{d}	350^{e}	328^{f}	309^{g}	295^{h}
	6	6	6	6	6	6	6	6	6	6
Peak flow, g/min	1021^{a}	1008^{b}	982^{c}	973^{c}	967^{c}	984^{c}	950^{d}	935^{d}	884^{e}	801^{f}
	46	46	46	46	46	46	46	46	46	46
Mean flow rate, g/min	700^{a}	761^{b}	731^{c}	718^{d}	705^{a}	686^{e}	644^{f}	616^{g}	555^{h}	471^{i}
	29	29	29	29	29	29	29	29	29	29
Phases of milk flow, s										
increase	70^{a}	76^{b}	79^{cd}	78^{bc}	77^{bc}	80^{d}	80^{d}	80^{d}	83^{de}	84^{e}
	2	2	2	2	2	2	2	2	2	2
plateau	243^{a}	321^{b}	320^{c}	288^{d}	263^{e}	227^{f}	209^{g}	186^{h}	162^{i}	142^{j}
	5	5	5	5	5	5	5	5	5	5
decline	84^{a}	53^{b}	53^{b}	54^{b}	55^{b}	59^{c}	60^{ce}	62^{ef}	65^{fg}	68^{g}
	3	3	3	3	3	3	3	3	3	3
overmilking	78^{a}	84^{b}	86^{b}	75^{a}	70^{c}	64^{d}	63^{d}	59^{de}	57^{e}	55^{f}
	4	4	4	4	4	4	4	4	4	4
Phases of milk flow, g										
increase	548^{a}	607^{b}	597^{b}	567^{c}	547^{ac}	516^{a}	478^{d}	450^{e}	419^{f}	348^{g}
	15	15	15	15	15	15	15	15	15	15
plateau	3391^{a}	4369^{b}	4146^{c}	3754^{d}	3457^{a}	3032^{e}	2669^{f}	2339^{g}	1927^{h}	1479^{i}
	80	80	80	80	80	80	80	80	80	80
decline	506^{a}	379^{b}	384^{b}	392^{b}	393^{c}	425^{dg}	414^{eg}	421^{fg}	413^{cg}	389^{bc}
	19	19	19	19	19	19	19	19	19	19

abcdefghij – within one line without a common superscript letter were significantly different at $P<0.05$

Table 2. Least squares means of measured parameters related to effect of peak flow (miklability), bimodality and quarter position.

	peak flow rate			bimodality		teat position			
	high	middle	low	no	yes	FL	RL	RR	FR
Number of quarters	16391	18353	15793	27557	22963	12579	12689	12659	12594
Milk yield, g	4178	4044	3984	4073^{a}	3967^{b}	3351^{a}	4653^{b}	4511^{c}	3565^{d}
	148	42	150	84	84	84	84	84	84
Total milking time, s	354^{a}	421^{b}	540^{c}	449^{a}	444^{b}	446	446	446	447
	16	16	17	8	8	8	8	8	8
Milk flow time, s	304^{a}	359^{b}	455^{c}	387^{a}	367^{b}	362^{a}	403^{b}	400^{c}	342^{d}
	14	14	14	6	6	6	6	6	6
Peak flow, g/min				904^{a}	1001^{b}	846^{a}	1004^{b}	1004^{b}	953^{c}
				46	46	46	46	46	46
Mean flow rate, g/min				653^{a}	664^{b}	578^{a}	711^{b}	701^{c}	644^{d}
				28	28	28	28	28	28
Phases of milk flow, s									
increase	74	81	79	73^{a}	85^{b}	77^{a}	81^{b}	81^{b}	76^{a}
	3	3	3	2	2	2	2	2	2
plateau	156^{a}	213^{b}	327^{c}	257^{a}	215^{b}	228^{a}	257^{b}	250^{c}	209^{d}
	12	12	12	5	5	5	5	5	5
decline	73^{a}	66^{a}	45^{b}	56^{a}	67^{b}	56^{a}	65^{b}	68^{c}	56^{a}
	5	5	5	3	3	3	3	3	3
overmilking	50^{a}	70^{b}	85^{b}	62^{a}	77^{b}	83^{a}	42^{b}	46^{c}	104^{d}
	6	6	6	4	4	4	4	4	4
Phases of milk flow, g									
increase	651^{a}	519^{b}	359^{c}	446^{a}	568^{b}	426^{a}	569^{b}	559^{c}	473^{d}
	25	24	25	14	14	14	14	14	14
plateau	2930	3041	3175	3216^{a}	2897^{b}	2542^{a}	3600^{b}	3432^{c}	2651^{d}
	146	141	148	80	80	80	80	80	80
decline	550^{a}	444^{b}	257^{c}	374^{a}	449^{b}	328^{a}	455^{b}	484^{c}	345^{d}
	37	34	36	18	18	18	18	18	18

abc – within one line without a common superscript letter were significantly different at $P<0.05$
FL, FR - front left and right
RL, RR - rear left and right