Chapter 14

Results of Automatic Milking System and Milk Performance on Selected Farms

Miroslav Maršálek, Jarmila Voříšková and Jana Zedníková

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1. Introduction

Milking times differ considerably in different countries based on the type of agriculture used. In US, where farms often hold large herds of dairy cows and the milking process is performed by specialised personnel a non-stop three-shift-milking production is not unusual. However, this type of production is economical only for large herds. In Western Europe, on the other hand, where small farms dominate and most work is performed by the farmer and his family members, the aim is to perform milking in as short time as possible (Sychra, 2001).

The first attempts at full automation of the milking process were made in the 1970's in several developed countries at the same time. The development was fastest in the Netherlands. The first fully automated milking system (Automatic Milking System- further AMS) was put into operation in 1992. Given the ever increasing average milk performance of cattle in the Czech Republic (6,870 l in 2009) and the increasing number of farms with average annual milk performance exceeding 10,000 litres of milk per cow, the first robotic milking machine in the country was installed in 2003. By 2009 the number had risen to 102. On 35 investigated farms Single Lely robots were the most frequent type used (Machálek, 2009).

Rotz et al. (2003) recommend the installation of milking robots on small family farms with the main motivation of achieved flexibility of working hours and therefore improved quality of life for the farmers, better working conditions and independence from outside-farm help. Rodenburg (2002) recommends machine milking for cattle herds from 60 to 200 cows based on lower costs of using milking robots as compared to using milking parlours.

Key factors for a successfully operating system in a dairy farm include breed, nutrition, and the environmental and human issues. When using AMS the management of dairy farming is transformed into so-called individual management. The flexibility and responsibility of such management as well as their ability to use PCs are important factors for the operation of the whole system (Havlík, 2007). Robotic milking requires no physical presence of an operator, thereby increasing productivity several times (Fleischmanová, 2005). It has been shown that robotic milking leads to 30–40% savings in physical labour as compared to conventional milking.

Most keepers are aware of the increased welfare after AMS has been installed. This effect can be further emphasised by installation of rubbing brushes in the stables. Although the acquisition cost is not insignificant, it is fast redeemed by the fact that the otherwise inevitable damage on fencing, gates, barriers and water troughs can be thus avoided, although the main factor for the acquisition of brushes is cleanness and health of the animals (Doležal et al., 2004). Also the absence of aggression from the care takers can often play an important part in the animal welfare and although the reaction of a cow toward an aggressive person is highly individual, experimental results show that milking production in older cows has decreased by 10 %, while the amount of residual milk has doubled as compared to the controlling sample cared for by a kind keeper. Therefore, it is clear that cows do recognise human character and their anxiety is mirrored not only in their behaviour but also in the internal reactions of their organisms, where the development of a stress load increases cortisol levels in the bloodstream thus decreasing milk production of the individual animal (Tančin & Tančinová, 2008).

Milk performance of dairy cows increases continuously from the first to the fifth lactation. This potential needs to be utilized by increasing the number of milking times using the milking automation system (Debrecéni et al., 1999). According to Přikryl (1997) and Stelwagen (2001) correct regulation of the milking process using the automation system enables milking several times per day which is especially significant in case of high performance animals. Doležal (2000) furthermore mentions a positive effect of multiple milking in cows with milking performance of over 35 kg of milk (increase by 18.9 %) in contrary to cows with milking performance below 25 kg of milk (increase by 1.4 %). This author therefore recommends utilisation of multiple milking for an average performance of cattle higher than 9.500 l of milk (Doležal, 2002). Kopeček and Machálek (2009) show an increase in milk performance after the introduction of AMS by up to 25%. By contrast, Kvapilík (2005) estimates the economic efficiency of the introduction of milking robots in the Czech Republic and calculates the expected increase in milk production per cow and year to be 8% on average as compared to the conventional parlour milking. Doležal (2002) and Kruip et al. (2002) also note that multiple milking results in worsened reproduction factors.

A voluntary visit to the milking robot box several times per day can only be achieved through correctly working motivation system. According to Šťastny (2010) such situation can be established by feeding each cow that has come for a correctly timed milking with granulated feed with higher (by 10%) energy value than what normal quantity feed contains. This makes the cows want to replenish their energy deficit in the AMS. Weisse et al. (2005) also state that offering concentrated feed represents the strongest motivation for a cow visiting the AMS.

Although the milking procedure in the AMS robot is very gentle (Debrecéni et al., 1999), a positive approach and no use of force toward the animal to be milked is still necessary during an adaptation period (about 15 days) after AMS installation. Furthermore, there are always a certain number of animals that will not adjust and voluntarily accept new behavioural routines. These cows will ignore the AMS completely and in such case it is necessary for the farmer to reserve time to manually lead these individuals to the milking boxes, or eventually exclude them from the milking system. The number of cows that must be led to the box usually increases with the number of individuals designated for each AMS station. There is also a risk of such cows getting used to the procedure and further expect such service. Another cause of cows getting excluded from the AMS system is their increased aggressively or anxiety (kicking, ducking away from the robot). Kic and Nehasilová (1997) state that up to 15% dairy cows must be excluded from the AMS system based on the above mentioned causes. The behaviour of animals, their quiet and balanced temperament, thus becomes one of the selection criteria when specialised herds suitable for the AMS system are being put together. Wagner-Storch and Palmer (2003) followed the activity of cows milked by the AMS system throughout the day and found that higher number of individuals is being milked between 8am to 1pm and 3pm to 7pm. On the other hand, the lowest frequency of milking was shown between midnight and 6am.

Another important decision factor for the introduction of AMS is economy. Building costs for a stable including milking parlour and milkhouse are according to Vegricht (2002) 7% higher than those for building a stable with AMS system. On the other hand, the cost for technical equipment of such stables is 185% higher as compared to that for stables with a milking parlour. The total investment costs for a stable with 300 dairy cows are 62 % higher than for stable with traditional milking technique. These investments are later incorporated into the total production costs of the stable and the total costs for the production of 1 litre of milk and thus the annual cost for 300 dairy cows being milked by the AMS system is 9.9% higher than for a similar farm using traditional parlour milking method. Maršálek et al. (2009) argue that although stables with AMS production report higher costs per feeding day they exhibit positive economic effect due to higher production and better quality of milk. At the same time cows in free stables using AMS milking also show positive results concerning reproduction. The increase in milk production through breeding can on the other hand induce the occurrence of many functional disorders, mostly of metabolic character or concerning milk secretion by decreasing the natural resistance in cows towards conditions of the outer environment (Hanuš et al., 2006).

On modern farms, the individual approach is to a great extent replaced by automatic data collection, radiotransmision of information and computer evaluation. Much of this received data can be used not only for production, reproduction and economy management but also as signalisation of possible health problems and thus for their early detection and treatment. It is important to state that this indirect individual care with the help of technical equipment for monitoring and evaluation does not rid the farmer of the obligation to secure at least one physical check of all animals daily (Doležal et al., 2004).

In the Czech Republic there are according to Kvapilík et al. (2011) 113 004 closed lactations for the Czech Fleckvieh dams and 157 634 closed lactations for Holstein dams in the production control procedure, where the milk productivity for these breeds is on average 6 472 kg and 8721 kg respectively. The Czech Fleckvieh cattle belongs to the world population of Fleckvieh Cattle with common phylogenetic origin, currently spread on all continents. The requirements for this breed are of dual performance with high milk production, medium to large body stature, excellent muscling and harmonic appearance (Bouška, 2006).

2. Results of the use of milking robots

The aim of this study was to evaluate the productivity of breeding cows kept on farms that use the AMS according to breed, number of robots used and the type of company ownership. Part of this study also considered the behaviour of the cows during the milking procedure, where thorough analyses of lactation curves for different productivity levels, the content of milk components during lactation process, correlation between milk productivity and fertility and between milking frequency and reproduction results were conducted.

Seven agricultural companies mostly from the Southern Bohemia region that use the progressive technology of automated milking system (AMS - Dutch made model Astronaut A3 from producer Lely) were included in this study. The chosen companies were divided according to the number of milking robots used into following categories: small (one robot – company nr. 1, 2 and 3), medium (two and three robots – farm nr. 4 and 5) and large (seven and eight robots – company nr. 6 and 7). According to the ownership the companies were designated as private (1 to 3) and cooperative (4 through 7). In companies 2, 3 and 7 the breed of dairy cows was the Czech Fleckvieh cattle (C), while the Holstein breed was kept in farms 1, 6 and 7 (H). Both breeds were kept in companies 4 and 5. These parameters were followed in the breeding cows: reproduction parameters (insemination interval, service period and meantime), the average amount of milk per cow and day (in kg), the average number of milking times per cow and day, the average number of refused milking times per cow and day, numbers of problematic cows (refusing being milked by the robot).

Basic data background was acquired from each company from program T4C (Time for cows), the steering unit of AMS that serves as the communication device and enables the back check of the milking data. The data set was consequently analysed by statistical programs Statistica.cz, Statsoft Co. and Statsoft CR Ltd. 200. Information for the analysis of problematic dairy cows that needed being lead to the robot was acquired directly from the keepers. Data evaluated concerned the period between 1.1.2009 and 30.11.2009 (334 days).

2.1. Results of herd reproduction and productivity

Table 1 shows an overview of breeds kept in individual companies including the average number of dairy cows, average number of cows per milking robot and chosen reproduction parameters. The Holstein breed was kept in companies 1 and 6. In company nr. 7 both breeds C and H were kept separately, while in companies 4 and 5 herds consisted of both breeds mixed together which prevented the evaluating of the followed parameters separately. The lowest number of cows was 51 in company 2, the highest 377 in company 6.

The number of robots varied from one in companies 1 and 3 to eight in company 7. The insemination interval was shown to vary greatly between 59 days (company 4) to 86 days (company 7), the service period varied from 89 (company 4) to 141 days (company 1). The length of the meantime was between 395 days (company 3 and 6) and 415 days (company 7). As a comparison Kvapilík et al. (2011) reported republic averages for dairy cows at productivity check for year 2009 to be 83.6 days for the insemination interval, 122.9 days as the length of the service period and 411 days as the length of the meantime.

Company number	Breed	Average number of dairy cows in herd (pc)	Number of milking robots	Insemination interval (days)	Service period (days)	Meantime (days)
1.	H	59	1	76	141	412
2.	C	51	1	62	97	398
3.	C	73	1	85	112	395
4.	H + C (30:70%)	97	2	59	89	401
5.	H + C (40:60%)	165	3	84	125	405
6.	H	377	7	75	118	395
7.	H	201	4	86	132	415
	C	160	4			

H - Holstein; C - Czech Fleckvieh

Table 1. Chosen reproduction factors in followed herds

The average daily production of milk achieved in individual farms is shown in Table 2. The highest productivity (40.43 kg) was measured for company 1. The second largest (30.16 kg) was found in company 6. On the other hand was the lowest productivity (21.04 kg of milk) measured for company 3 with the highest number of animals per robot (73 cows). Differences between the companies were highly statistically significant (P≤0.001). The obtained results father emphasise the premises of Doležal (2000) that higher milk production induces the higher effect of milking times. Compared to the average daily milk production for year 2009 in the Czech Republic (18.82 kg of milk - Kvapilík et al. 2011), the companies followed were able to show higher values.

Dividing the farms according to size corresponds well with the division according to ownership (Table 3). The highest daily productivity was achieved in small privately owned companies with one robot (28.79 kg of milk) as compared to medium and large cooperate companies. The data were despite large variation (s_x =8.54) and differences 3.57 resp. 1.45 kg of milk found statistically significant (P≤0.001). These results correspond to the conclusions made by Rotz et al. (2003) who recommend installation of milking robots on small family farms. According to Rodenburg (2002) is automated milking great advantage for dairy cattle herds with 60 to 200 heads, as the milking parlour technology is too expensive and automated milking represents more economical solution.

Company number	Number of cows per 1 robot	n	$\bar{x}$	s_x	F test
1.	59	334	40.43	1.65	2745.0**
2.	51	334	24.83	1.71	1:2,3,4,5,6,7***
3.	73	334	21.04	1.40	2:3,4,5,6,7***
4.	49	668	22.92	3.00	3:4,5,6,7***
5.	55	1002	26.75	1.74	4:5,6,7***
6.	54	2338	30.16	2.97	5:6,7***
7.	45	2672	24.87	2.97	6:7***

Table 2. Average milk production in individual companies (in kg of milk)

Company size	Type of ownership	Number of cows per 1 robot	n	$\bar{x}$	s_x	F test
Small (1)	private	61	1002	28.79	8.54	206.2**
Medium (2)	cooperative	53	1670	25.22	2.99	1:2***
Large (3)	cooperative	49	5010	27.34	4.00	1:3*** 2:3***

Table 3. Average milk production according to size and ownership of the company (kg of milk)

Table 4 shows the average productability with regard to the breeding type of the dairy cows. Highest values were obtained for the H breed, reaching 29.97 kg of milk. The difference compared to the C cattle was l 7.17 kg (P≤0.001). Herds with both breeds have reached an average value of both (25.22 kg of milk). The number of cows per robot was identical for H breed and H and C mixed breed (53 heads), but lower for the C breed (47 heads).

Breed	Number of cows per 1 robot	n	$\bar{x}$	s_{ix}	F test
Holstein Cattle (1)	53	4008	29.97	4.33	2903.0**
Czech Fleckvieh Cattle (2)	47	2004	22.80	2.26	1:2*** 1:3***
Both breeds (3)	53	1670	25.22	2.99	2:3***

Table 4. Average milk production according to breed (kg of milk)

2.2. Milking frequency using AMS

The average number of milking times per one dairy cow per day is an important parameter for the automated milking system. In Table 5 significant differences between the companies can be seen (P≤0.001), where company 1 achieved the highest frequency of 2.67. The productability of this company is thus markedly higher which corresponds to literature (Doležal, 2000, 2002, Stelwagen, 2001) regarding the positive influence of multiple milking times for high performance dairy cows. The lowest number of milking times, namely only 1.97, was found for company nr. 3, where the number of cows per robot was the highest, 73 heads. Lowering this number by 14 resulted in an increased number of milking times, up to 2.67. It is important to state here that both companies hold different breeds of cattle.

Company number	Number of cows per 1 robot	n	$\bar{x}$	s_x	F test
1.	59	334	2.67	0.18	344.9**
2.	51	334	2.60	0.18	1:2,3,4,5,6,7***
3.	73	334	1.97	0.16	2:3,4,5,6,7***
4.	49	668	2.53	0.25	3:4,5,6,7***
5.	55	1002	2.44	0.14	4:5,6,7***
6.	54	2338	2.44	0.24	5:7***
7.	45	2672	2.41	0.21	6:7***

Table 5. Average number of milking per one dairy cow per day in individual companies

Significant differences (P≤0.001) in the number of milking times per head and day were also found for the companies when devided according to their size and ownership (Table 6) even though the differences were not large. The highest number of milking times was exhibited by medium and large companies (2.47 resp. 2.43), while the small companies put together obtained an average value of 2.34. Similar conclusions can be drawn when the ownership situation is considered simultaniously.

Company size	Type of ownership	Number of cows per 1 robot	n	$\bar{x}$	s_x	F test
Small (1)	private	61	1002	2.34	0.33	96.9**
Medium (2)	cooperative	53	1670	2.47	0.20	1:2***
Large (3)	cooperative	49	5010	2.43	0.24	1:3*** 2:3***

Table 6. Average number of milking times per one dairy cow per day according to size and ownership of the company

Significant difference in milking times was also found when considering the different breeds of cattle (Table 7). The lower average of 2.32 milking times per head and day was found for the dual productivity cattle of breed C, while the breeding cows of the dairy cattle H were milked on average 2.45 times (P≤0.001). The correlation to the productivity average of the individual breeds is therefore clear.

Breed	Number of cows per 1 robot	n	$\bar{x}$	s_x	F test
Holstein Cattle (1)	53	4008	2.45	0.23	245.2** 1:2*** 1:3** 2:3***
Czech Fleckvieh Cattle (2)	47	2004	2.32	0.26	
Both breeds (3)	53	1670	2.47	0.20	

Table 7. Average number of milking times per cow and day according to breed

When a cow enters the robot before the right milking time has come, it is refused and released, which is defined as a refusal. Ideally the number of such refusals should be around 1.5 per day, which would mean one refusal for two concluded milking times (Šťastný, 2010). The differences found for the number of refusals per head and day were very significant (P≤0.001) for the different companies (Table 8). Clearly the highest number of refusals (3.66) was found for company 4, the second highest (2.63) for number 7. Both these companies have the lowest number of cows per milking robot (49 resp. 45). Extremely low values were then calculated for farms 2 (0.72) and 3 (0.88).

Company number	Average number of cows per 1 robot	n	$\bar{x}$	s_x	F test
1.	59	334	1.74	0.51	524.1** 1:2,3,4,5,7*** 2:3,4,5,6,7*** 3:4,5,6,7*** 4:5,6,7*** 5:6,7*** 6:7*** 1:6**
2.	51	334	0.72	0.27	
3.	73	334	0.88	0.28	
4.	49	668	3.66	2.07	
5.	55	1002	1.20	0.32	
6.	54	2338	1.93	1.15	
7.	45	2672	2.63	1.31	

Table 8. Average number of rejections per dairy cow per day in individual companies

The average number of refusals according to size and company ownership is shown in Table 9. Small privately owned companies with one robot showed low refusal count at about 1.11, as compared to medium and large cooperative companies with values around 2.18 resp. 2.30. Small and privately owned farms seem to place more emphasis on working relief supplied by the AMS than on milk production results. The differences are statistically highly significant for differences between companies 1 and 2 and 1 and 3 (P≤0.001). Milking robots are used more frequently in small private companies as there usually are more cows per robot (61) as compared to larger cooperatively owned companies with several AMS (53 resp. 49 heads/robot).

Table 10 shows that breeding cows of the Czech Fleckvieh cattle were refused by the robot 2.55 times per day on average, while the breeding cows of the Holstein breed only 1.88 times per day. These differences are highly statistically significant (P≤0.001). In herds with both breeds kept together the average number of refusals was calculated to 2.18.

Company size	Type of ownership	Number of cows per 1 robot	n	$\bar{x}$	s_x	F test
Small (1)	private	61	1002	1.11	0.58	231.1**
Medium (2)	cooperative	53	1670	2.18	1.80	1:2***
Large (3)	cooperative	49	5010	2.30	1.28	1:3***

Table 9. Average number of rejections per dairy cow per day according to company size and ownership

Breed	Number of cows per 1 robot	n	$\bar{x}$	s_x	F test
Holstein Cattle (1)	53	4008	1.88	1.01	154.5**
Czech Fleckvieh Cattle (2)	47	2004	2.55	1.59	1:2***
Both breeds (3)	53	1670	2.18	1.80	1:3** 2:3***

Table 10. Average number of rejections per one dairy cow per day according to breed

2.3. Problematic dairy cows

Figure 1 to 3 show percentage counts of problematic cows needed to be lead to the milking robot for a certain amount of time. The lowest number was found for company number 3 (8.2%), the highest for numbers 7 (25.2%) and 6 (15.1%). For the rest of the companies the values fluctuated around 10 % (Figure 1). When focussing on the companies according to size and ownership (Figure 2) the percentage of problematic animals obtained tends to be quite high (20.1%) in large companies as compared to medium large (even cooperative) and small farms where the numbers were kept just above 9%. Differences found between the breeds (Figure 3) point to least problematic individuals belonging to the Fleckvieh cattle (8.8%) as compared to the Holstein breed (14.4%). Veselovský (2005) explains that it is characteristic for classic motivation that the originally neutral stimulus (robot visit) eventually activates a certain behavioural pattern (milking) when induced by a reward here in the form of extra feed. The main target is to create association or connection between a certain activity and the reward. Šťastný (2010) says that the normal state is that 5 to 10% of the cows need being led to the robot box. According to Tančin and Tančinová (2008) thorough attention must here be turned to the quality of the person – keeper, as animals strongly feel the presence of an aggressive or unkind person and his presence tends to induce changes in behaviour, and consequently due to increased stress lead to lower productivity by as much as 10%. Weis et al. (2005) found based on own studies excellent capability of the cows to learn as after three days the majority were capable of entering the robot box without physical assistance from the keepers.

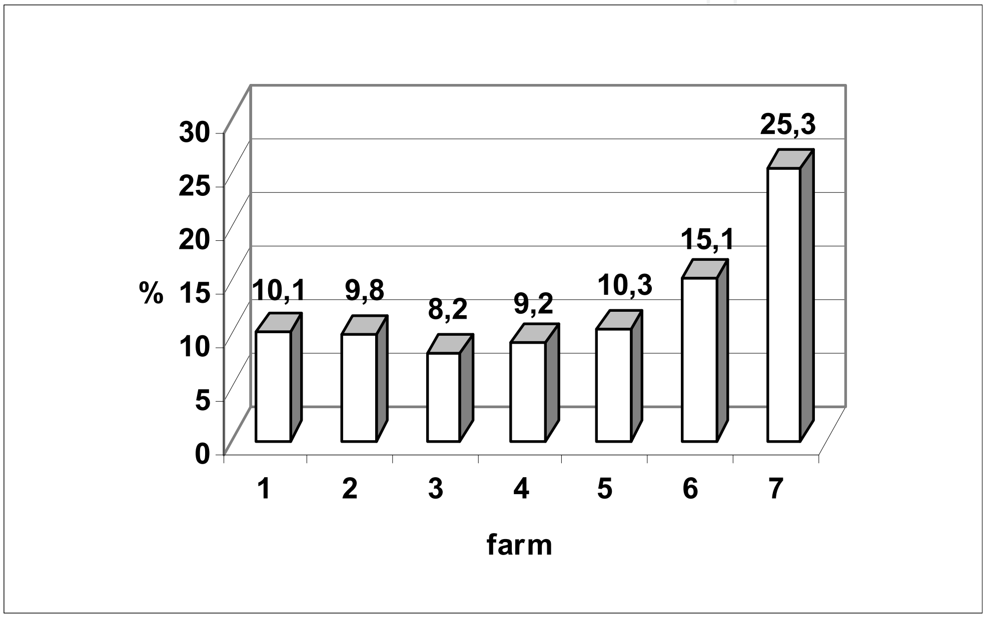


Figure 1. Number of leaded dairy cows to the milking robot in individual companies (in %)

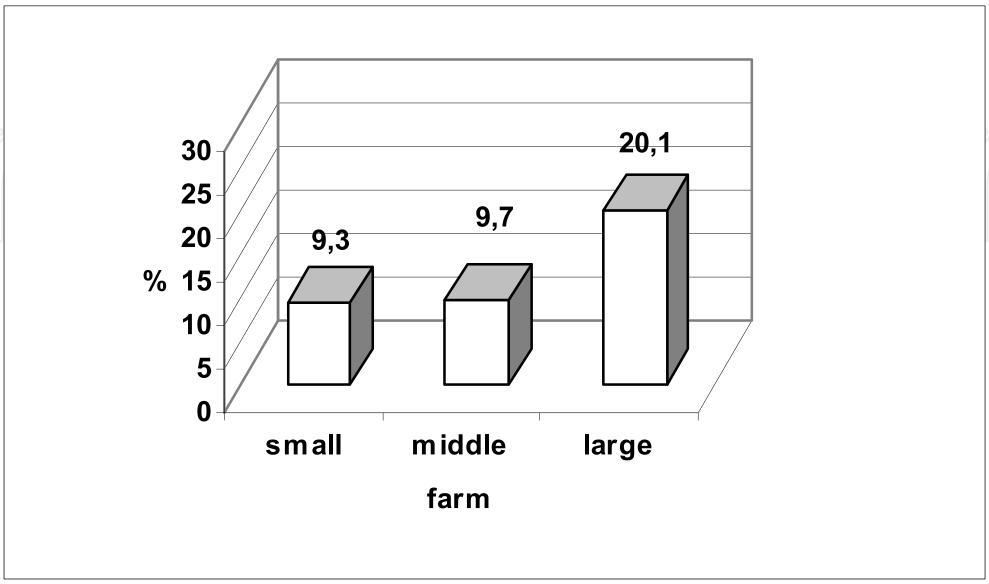
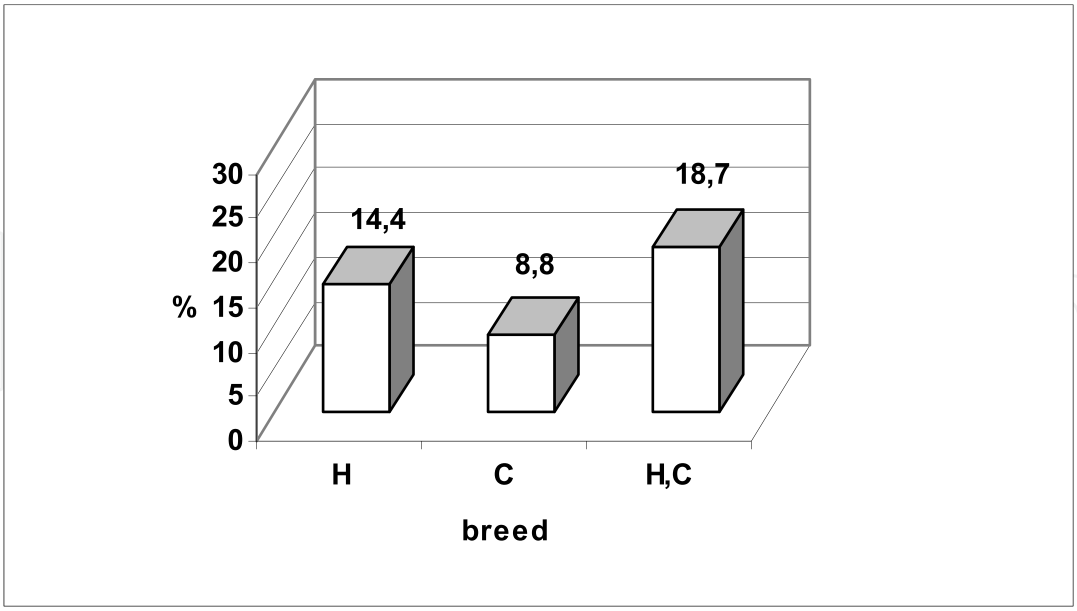


Figure 2. Number of leaded dairy cows to the milking robot according to company size (in %)



H – Holstein Cattle, C – Czech Fleckvieh Cattle

Figure 3. Number of leaded dairy cows to the milking robot according to breed (in %)

3. Analysis of milk productivity

An agricultural company with milking productivity corresponding to the average values found in the Czech Republic for the Czech Fleckvieh cattle was chosen for a thorough analysis of the milk productivity and the lactation process. Placed at an elevation of 500 to 550 m above sea-level and spread on 750 ha of agricultural land, with 600 ha being used as field lands, its production herd consists of 120 cows.

3.1. Progression of lactation curves

Lactation curves for first, second, third and following lactations are shown in Figure 4. Major differences in milking levels between the first and the remaining lactations are easily seen from the progression of the curves. The highest average milk production was found for the duration of the second lactation, about 10 kg of milk in its beginning as compared to the first lactation curve. During the third and the following lactations there is a slight decrease in milk production, although the progress of the curves resembles that of the second.

Figure 5 shows lactation curves with progression of lactation for cows with starting milk production up to 25 kg, between 25 and 30 kg and above 30 kg of milk. From the differences in the progression of the lactation curves it is possible to state that the initial milk production up to 25 kg has lactation curve very close to the optimal progression, the initial milking is higher by almost 4 kg of milk and this elevated value holds for four whole months. The lactation curve is very steep for high initial milk production where the initial milk increase is only 2.4 kg and keeps for two months which implies insufficient nutrition levels supplied by the company that does not cover the milk production in the initial lactation stage. For the group of cows with initial average milk production over 30 kg the lactation curve suggests no initial milk production stage (no production increase) and there is a continuous decrease of milk production from the beginning of lactation. This decrease is significant enough to level the milk production of this group with group 2 after just one month, thus implying that in given conditions of nutrition and care the cows with higher genetic potential towards milk production cannot make use of this potential and their production abilities are not fully used.

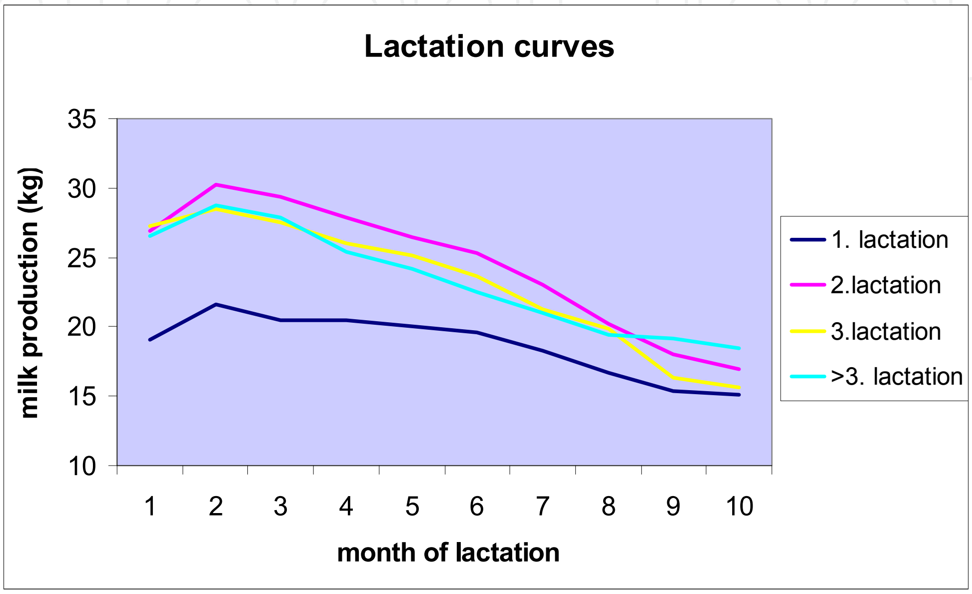


Figure 4. Progression of lactation curves according to lactation order

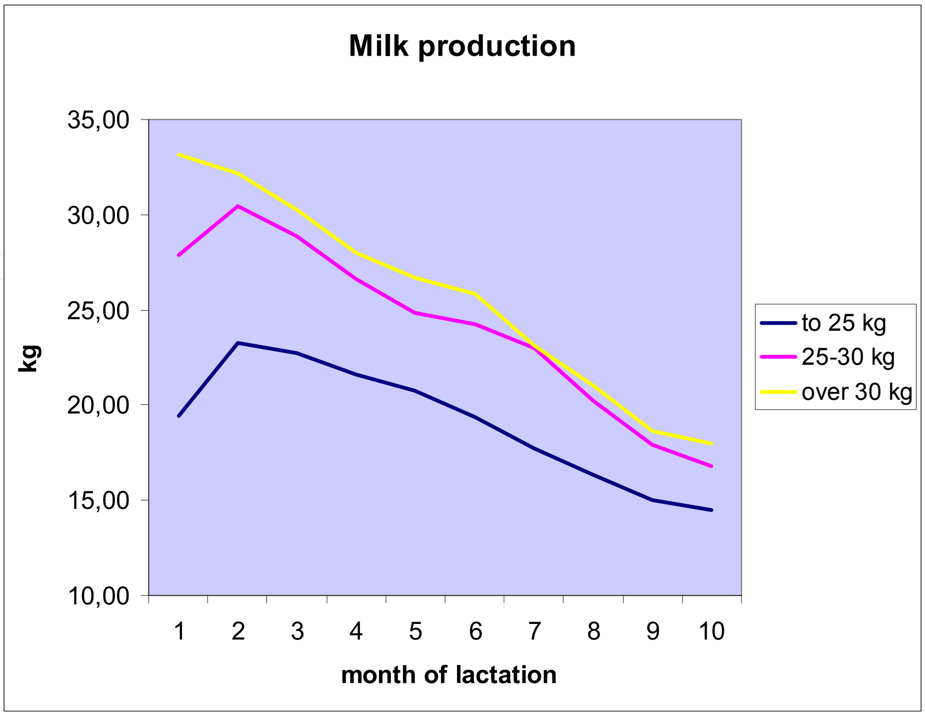


Figure 5. Progression of lactation curve for different milk production levels

Progression of lactation curves for the individual groups of cows (divided according to the initial milk production of up to 25, 25 to 30 and above 30 kg of milk) is shown individually in Figures 6 to 8. Expressing the progression of the curves linearly clarifies the differences in the slope of the individual lines and also in the fraction of the explained variability expressed by the coefficient of determination (R^2). While the fraction of variability for the lactation curve of cows with production up to 25 kg of milk in Figure 6 is 75.11%, the group depicted in Figure 7 with production between 25 and 30 kg exerts 92% and the cows with initial productivity over 30 kg reach 98.5%. This would then imply that we practically have not a lactation curve but lactation straight line. The straight-line parameters shown in Figure 8 (y = -1.7735x + 35.451) also show the relatively steep decrease of milk production for this group.

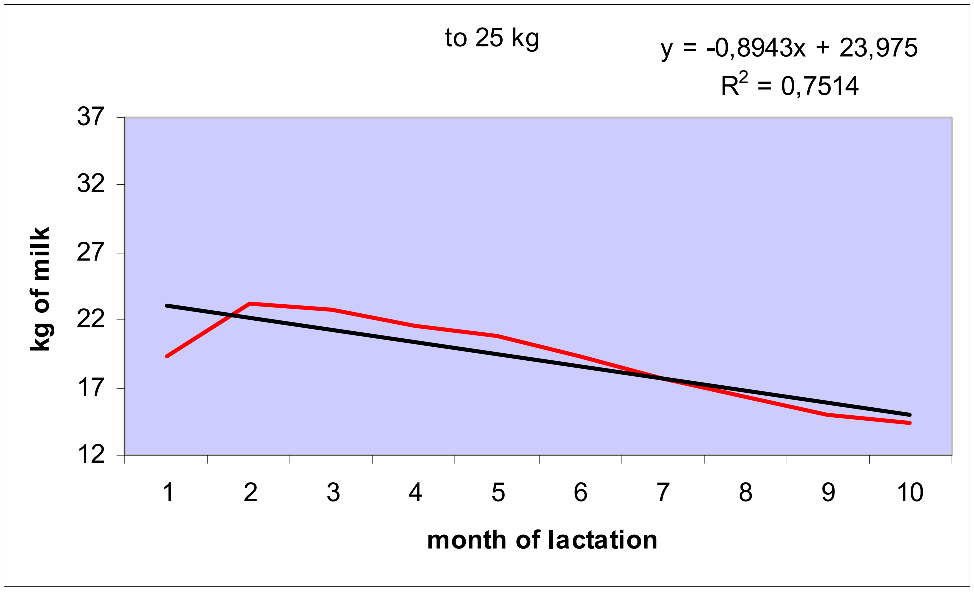


Figure 6. Progression of lactation curve for dairy cows with productivity up to 25 kg of milk

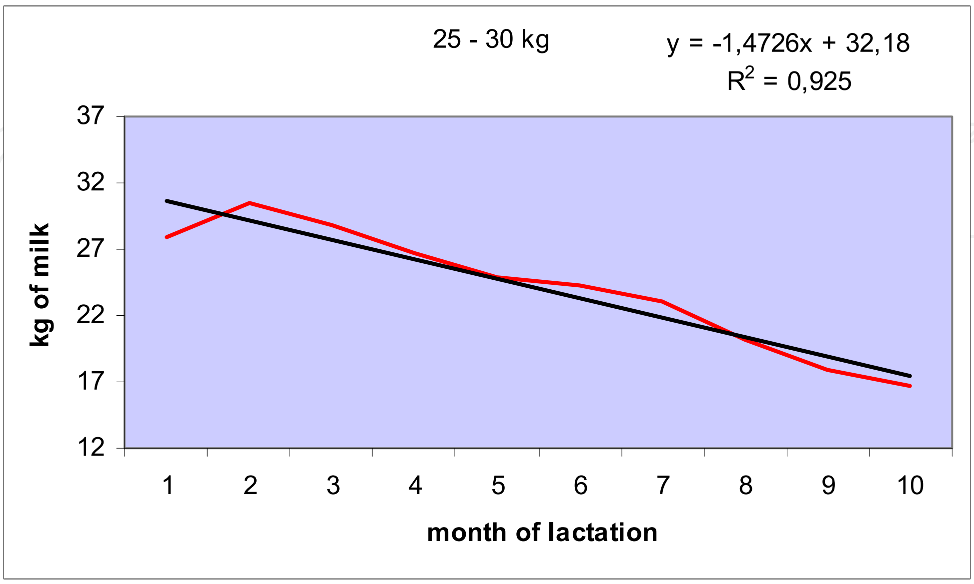


Figure 7. Progression of lactation curve for dairy cows with productivity from 25 to 30 kg of milk

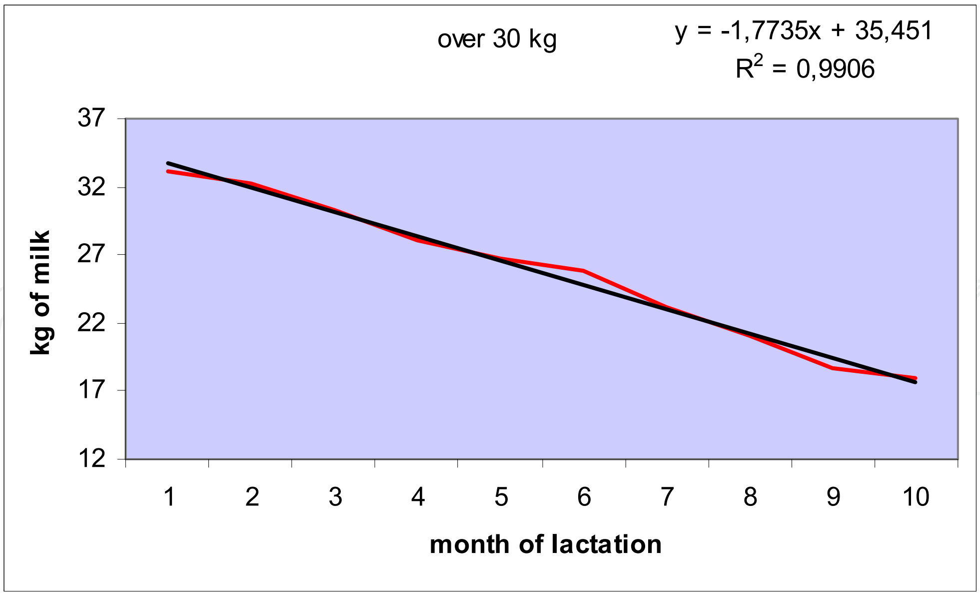


Figure 8. Progression of lactation curve for dairy cows with productivity over 30 kg of milk

3.2. Content of milk components during lactation process

Changes in milk content during the lactation process were judged based on analysis of milk samples taken during performance testing. The followed group of cows was divided according to their milk production during initial lactation into three groups with production up to 25 kg, from 25 to 30 kg and over 30 kg of milk and for each cow fat, protein and lactose content in the milk was established for a period of 10 months from initial lactation.

Values of fat content in milk samples show that there is no significant difference between the fat content for the three groups. The interesting feature are the maximum and minimum values measured for individual cows where individuals with very low fat content (2%) or quite high fat content (over 5% or even over 6%) appear in each of the three groups. These values suggest a possible use of the different fat content in milk as selection criteria for changed requirements on the quality of milk from the buyer or for changed financial evaluation for the individual milk ingredients.

The changes in fat content in milk for the individual groups are graphically represented in Figures 9 to 11. Coefficient of determination is similar for all three groups (R = 0.7623 to 0.7852) although the changes of the fat content during the lactation process resemble a parabolic curve where a continuous increase of the fat content at the end of the lactation process is clearly seen for all three groups. The progress of the theoretical curve for the individual groups changes and shows a continuous increase in fat content from the group with the lowest initial productivity ($y = 0.0196x^2 - 0.1464x + 3.9892$) to the group with the highest one ($y = 0.0085x^2 - 0.0571x + 3.8103$). The inflexion points that are characterized by the top of a parabola and represent the point when an increase in fat content appears after an initial decrease are shown to differ slightly for the three groups. The group with lowest productivity (up to 25 kg) exhibited the lowest fat content 3.71% after 3 months and 24 days of lactation, the second group showed a minimum of 3.70% after 3 months and 6 days and the third group with highest milk production (over 30 kg) reached the minimum after 3 months of lactation with 3.73% of fat.

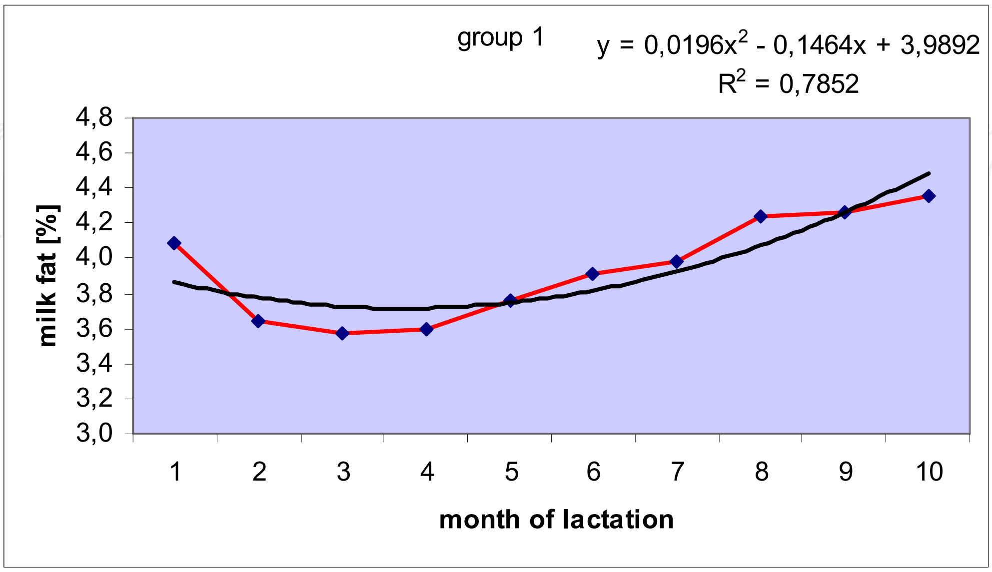


Figure 9. Milk fat during lactation in milk production up to 25 kg

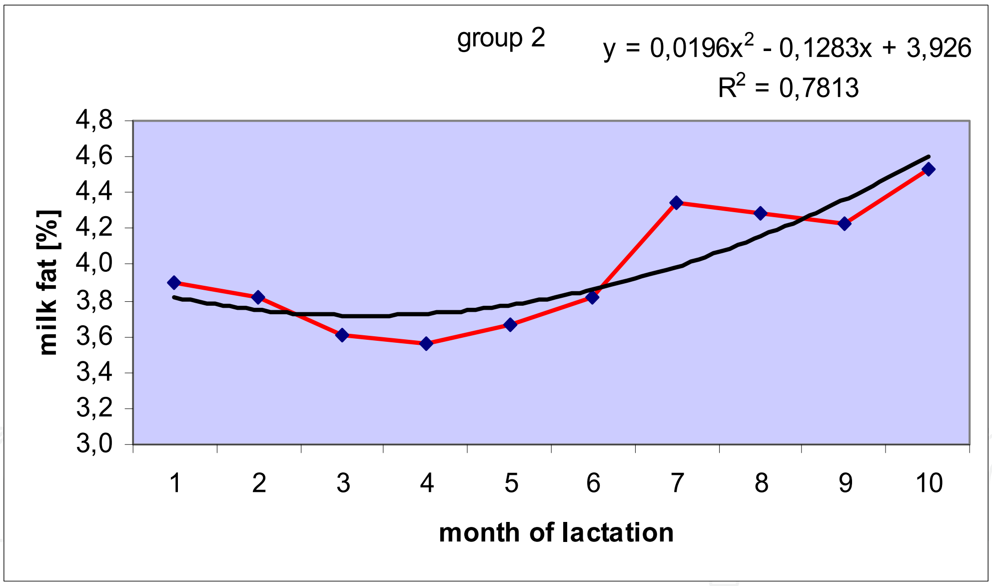


Figure 10. Milk fat during lactation in milk production from 25 to 30 kg

Protein content was analysed for the same group of cows as above. Were founded, that not only lower average values of protein content as compared to fat, but also smaller variations of the values characterised by the spread and determinant deviation. Although the maximum values of protein content found in individual cows (in some cases high above 4%) suggest a possibility of selection towards attempts to increase protein content in milk or to increase the usability of selected dairy products.

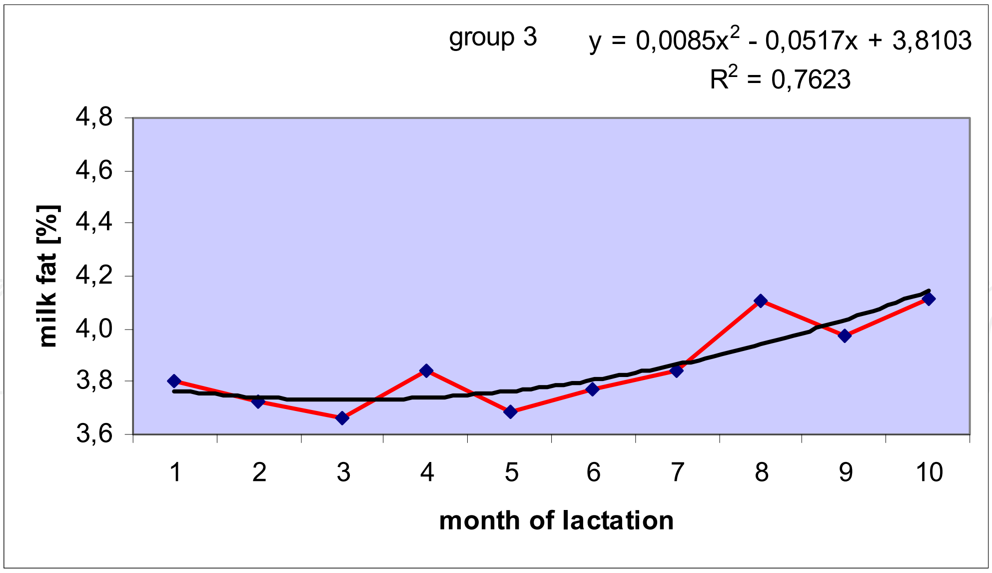


Figure 11. Milk fat during lactation in milk production over 30 kg

Graphic expression of the protein content in milk during the lactation process in Figures 12 to 14 shows a continuous increase in protein content in milk (of course under the presumption that the high protein percentage in colostrum during the first few days after calving is disregarded) with the tendency towards linearity. With increasing initial milk production after calving the real progression of the changes in protein content in milk approaches linearity also inferred by the determinant coefficient that was estimated to 0.8457 for the first group with up to 25 kg of milk, 0.884 for the second group and 0.9951 for the third group with milk production over 30 kg of milk. The slopes of the individual graph lines also indicate differing levels of protein as an inverse relation between protein content and milk production.

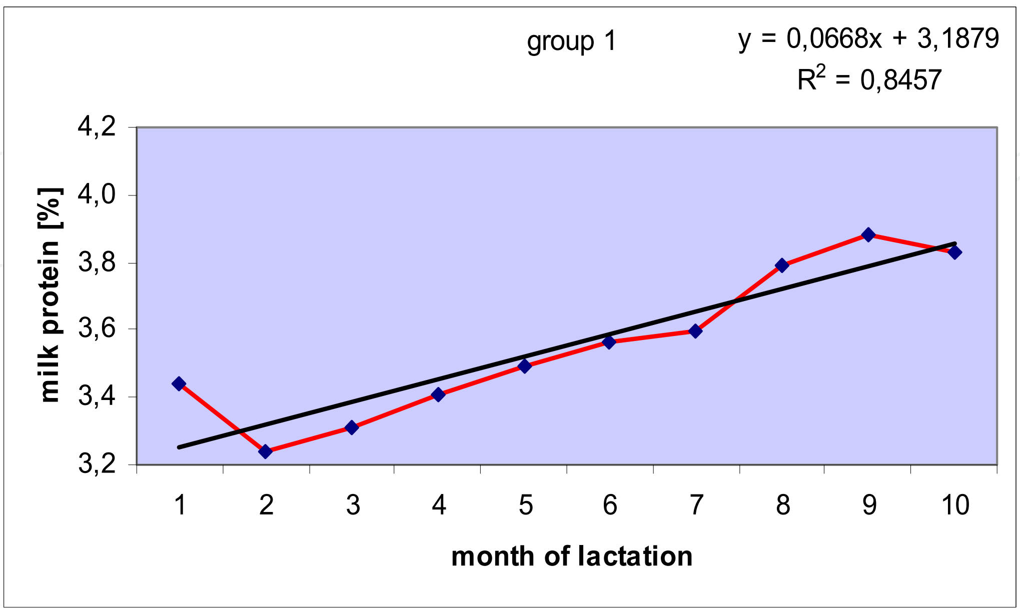


Figure 12. Protein content during lactation in milk production up to 25 kg

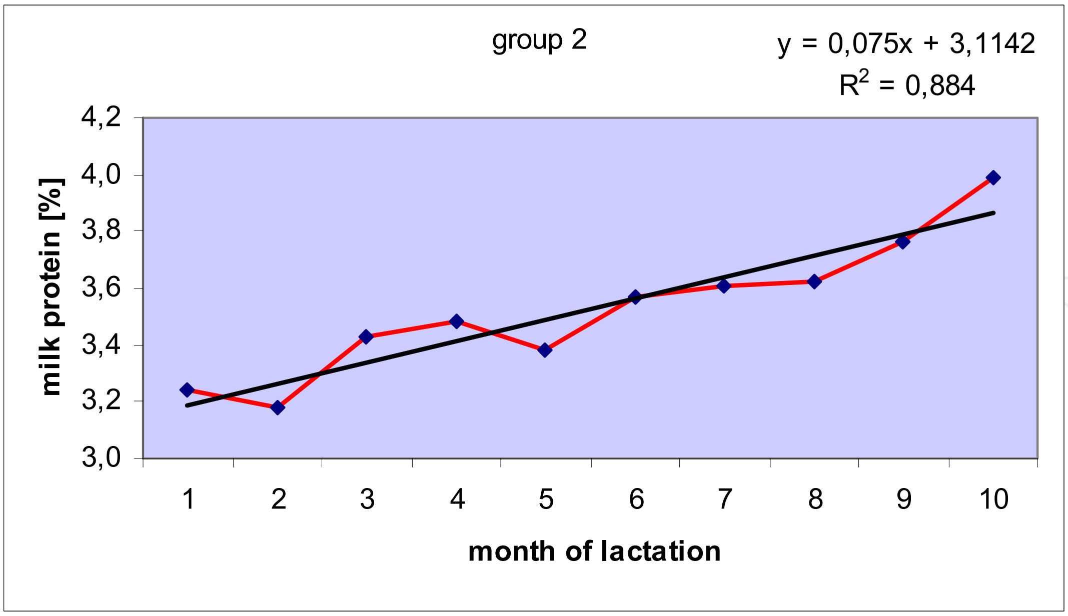


Figure 13. Protein content during lactation in milk production from 25 to 30 kg

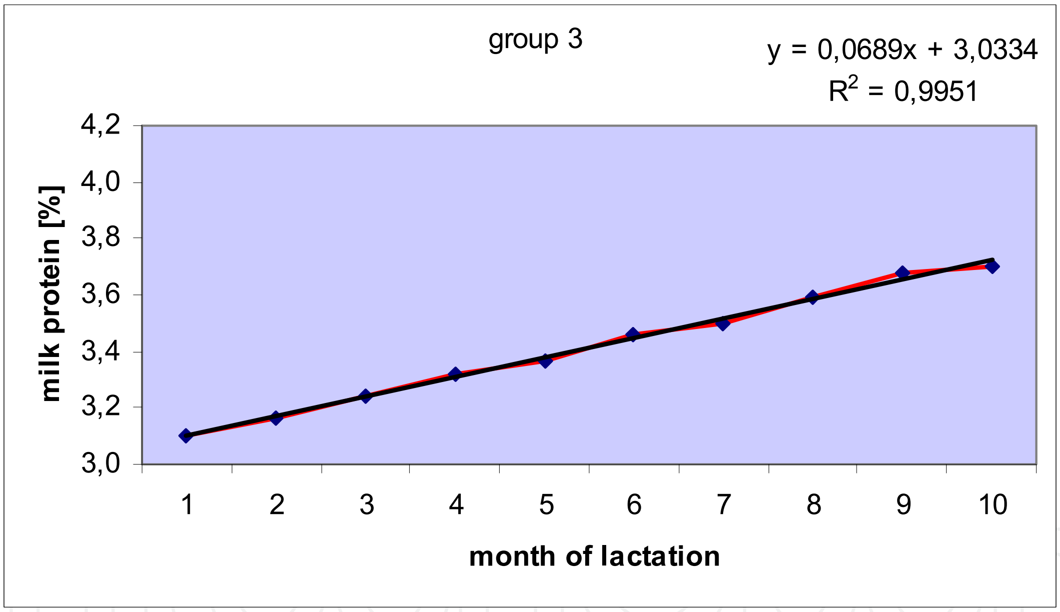


Figure 14. Protein content during lactation in milk production over 30 kg

Lactose content during lactation progress for the individual groups is shown in Figures 15 to 17. Average values of lactose content in the individual lactation months vary between 3.67 and 4.93 % and no trends among the groups or durations can be seen. The graphical expression especially shows that the lactation progression corresponds more to polynomic functions, although by different degrees and precisions (for example the group with milk production to 25 kg has determinant coefficient 0.8401). There is thus no correlation between lactose content and milk production and causes to changes in lactose levels need to be sought elsewhere.

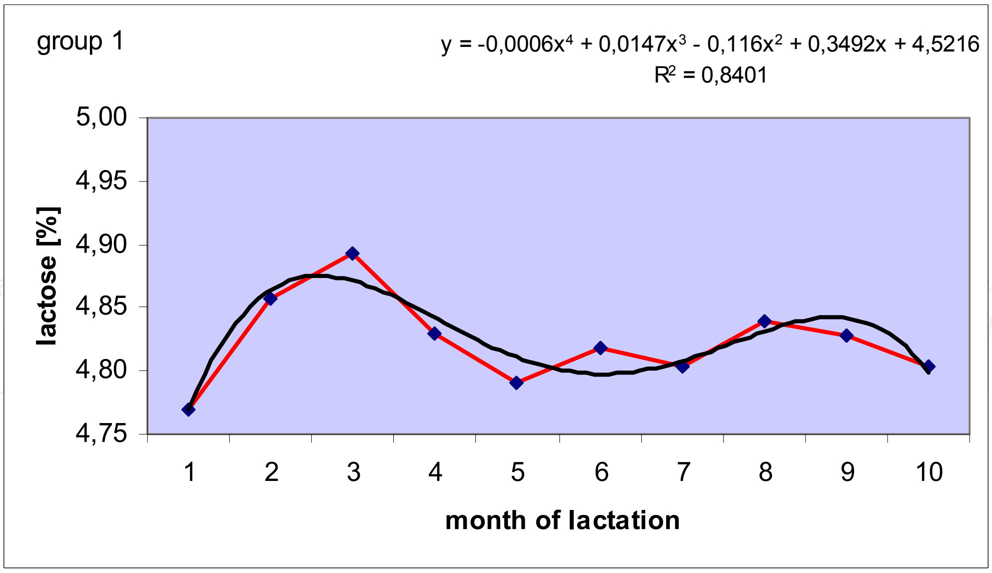


Figure 15. Lactose content during lactation in milk production up to 25 kg

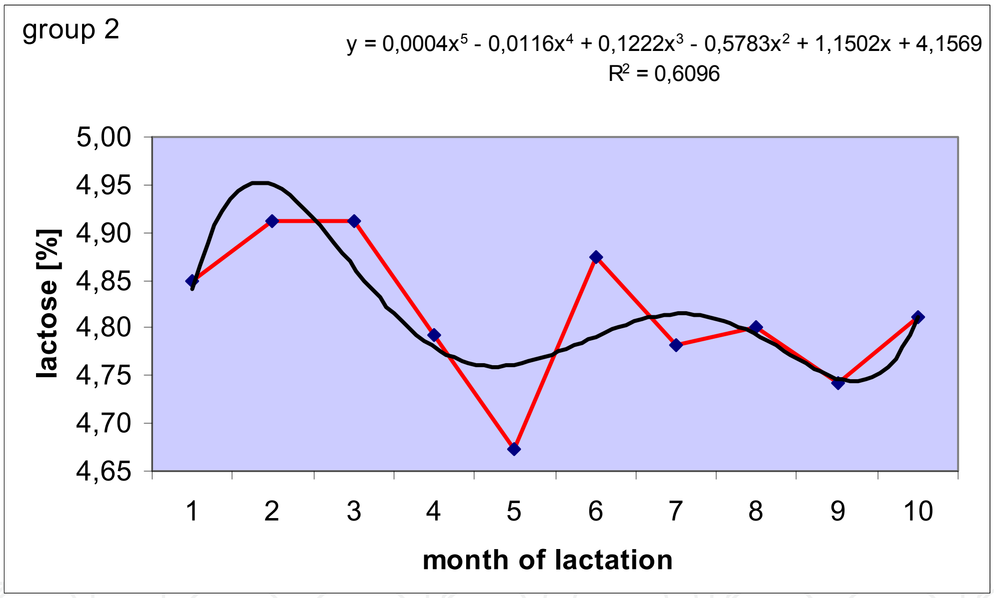


Figure 16. Lactose content during lactation in milk production from 25 to 30 kg

3.3. Correlation between reproduction parameters and milk content

Mutual dependencies between lactation order and parameters of milk productivity and fertility are shown in Table 11 expressed in terms of correlation coefficients. Statistically significant values are given in bold letters. Values in the first column show that satisfactory reproducibility was found for the experimental set (meantime of 375 days, insemination interval 64.4 days and service period of 111.94 days) and also that the milk content corresponds to the expected values. The average number of milking times per day is 2.62. It is clear from the obtained correlation coefficients that there is no connection between lactation order and the other followed parameters. Statistically significant is a positive but

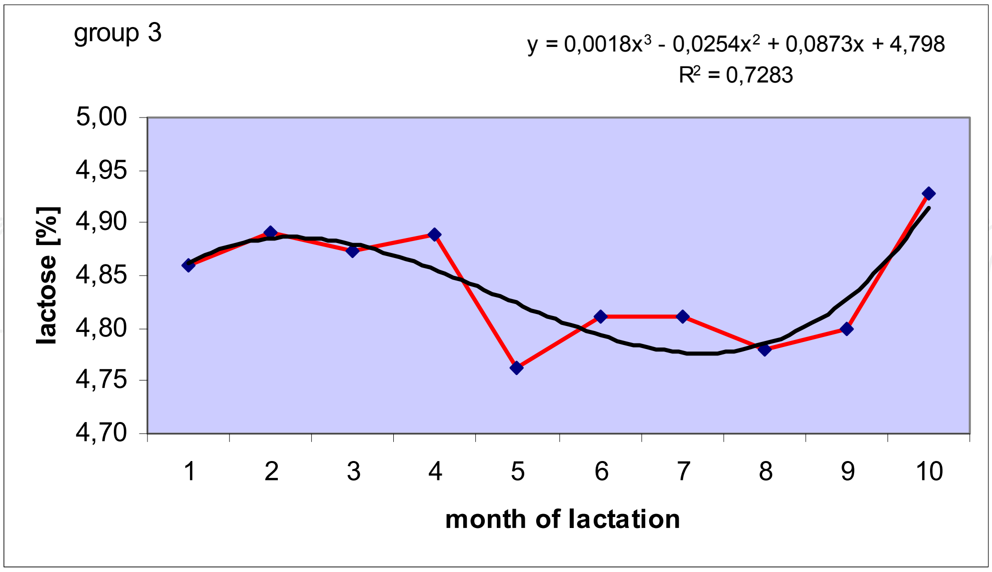


Figure 17. Lactose content during lactation in milk production over 30 kg

slight correlation between the length of insemination interval and the service period (r_{xy} = 0.309) which is quite logical. There is on the other hand a slightly negative statistically significant dependence between protein content in the milk and the length of the insemination interval (r_{xy} = -0.353) that would imply a connection to a deficit in cow nutrition after calving that is expressed by a lower protein content (also by less pronounced rutting period of the cows, their deteriorated health and therefore also in later release of the cows after calving). Low although statistically significant dependence was found between fat and protein content in milk (r_{xy} = 0.290). Increasing number of milking times is shown to have a negative impact on the fat content in milk (r_{xy} = -0.230).

Factor	Average	Standard Deviation	Lact.	Meantime	Ins.int.	SP	Fat	Protein	Number of cows
Lactation	2.50	0.796		0.056	0.039	-0.095	0.053	-0.143	-0.070
Meantime	375.78	48.669	0.056		-0.035	0.181	-0.068	**-0.264**	-0.001
Ins.int.	64.40	22.033	0.039	-0.035		**0.309**	0.131	**-0.353**	-0.080
SP	111.94	54.990	-0.095	0.0181	**0.309**		0.072	-0.214	-0.052
Fat	3.94	0.401	0.053	-0.068	0.131	0.072		**0.290**	**-0.230**
Protein	3.37	0.233	-0.143	**-0.264**	**-0.353**	-0.214	**0.290**		-0.055
Number of cows	2.62	0.305	-0.070	-0.001	-0.080	-0.052	**-0.230**	-0.055	

Table 11. Correlation between milking and reproduction parameters

4. Conclusion

Studies involving evaluation of results on milking with the help of automated milking systems (AMS) of the type Lely Astronaut A3 and finding differences that depend on size, levels of production and ownership were conducted in seven agricultural companies in the Czech Republic. The results were analysed in companies keeping dairy cows of the Czech Fleckvieh cattle (n = 2004), Holstein cattle (n= 4008) and both these breeds together (n = 1670). In a chosen company with productivity results corresponding to the average value of the Czech Republic (n = 120) a thorough analysis of relations between milk production, milk content and reproducibility was conducted. These conclusions can be drawn from the obtained results:

1. The number of cows milked by one robot should not by much exceed 60.
2. Significantly higher milk production was found in small privately owned companies as compared to large cooperative companies.
3. Disregarding the type of company where the cows are kept, the Holstein cattle breed shows significantly much higher milk production than the cows of the Czech Fleckvieh cattle.
4. Statistically significant differences in the average number of milking times per day were found between the individual farms. The frequency of milking time varied between 1.97 and 2.67 times per day.
5. Differences in the number of milking times according to the ownership are significant, though much smaller (2.34 to 2.47).
6. The Holstein cattle were statistically more often milked than the Czech Fleckvieh cattle (2.45 compared to 2.32).
7. The number of robot refusals is very individual for each stable and varies between 0.72 to 3.66 times per cow and day.
8. The refusals are much less frequent in small privately owned farms (1.11) as compared to medium (2.18) and large (2.30) cooperative companies.
9. Cows of the Czech Fleckvieh breed are significantly more often refused by the robot (2.55) in comparison to the Holstein dams.
10. The numbers of cows that need to be taken to the robot by a keeper vary between 8.2 to 25.3% in the different companies. It is much more frequent in large companies (20.1%) than in small (9.3%) and medium sized ones (9.7%).
11. The need to lead the cows to the robot is lower for the Czech Fleckvieh (8.8%) as compared to the Holstein breed (14.4%).
12. A significant difference was found in the progression height of the first lactation curve and the curves of the following lactations.
13. Only cows with initial milk production below 25 kg of milk exhibited an optimal progression of the lactation curve for an average productivity of the herd at 6450 kg of milk. Cows with milk production of 25 to 30 kg showed a steep lactation curve while the cows with milk production above 30 kg did not show any increasing milk flow and their lactation curve fell rapidly already from the beginning.

14. For high productivity cows (with over 30 kg as initial lactation) the progression of lactation resembled a straight line with a steep decreasing slope (R = 0.9875).
15. There are no significant differences found in milk fat content for the three groups of cows with different milk production (up to 25, 25 to 30 and above 30 kg). The differences in fat content in the milk of individual cows (from 2 to 6% of fat) would suggest some selective use.
16. The percentage content of fat in milk following the lactation curve resembles a parabola with the lowest point in the fourth month. This point occurs sooner (the third month after calving) for cows with higher milk production.
17. Protein content is less variable in comparison to the fat content and increases nearly linearly during the lactation progress, especially for high productivity cows (R= 0.9951).
18. Differences in lactose content during the progress of lactation are not dependent on the milk production levels and fluctuate within 0.2%.

a. Protein content in milk shows negative dependence on the meantime (r_{xy} = - 0.264) and the insemination interval (r_{xy} = -0.353).
b. Statistically significant inverse dependency was also found between the number of milking times per day and the fat content in milk (r_{xy} = -0.230).

Figure 18. Milking by AMS (photo A. Váchová)

Figure 19. Computer install into AMS allowed getting the data during lactation (photo A. Váchová)

Figure 20. Cow get concentration feed in robot (photo A. Váchová)

Author details

Miroslav Maršálek, Jarmila Voříšková and Jana Zedníková
University of South Bohemia in Ceske Budejovice, Faculty of Agriculture,
Czech Republic

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