Animal Science Papers and Reports vol. 38 (2020) no. 1, 49-59
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The impact of introduction of an automatic milking system on production traits in Polish Holstein-Friesian cows

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(Accepted October 7, 2019)

The study has been carried out on 16 Polish Holstein-Friesian dairy cattle herds across Poland. A change in the milking system from the conventional to the automatic system was implemented in these herds between 2010 and 2013. The purpose of the study was to indicate potential changes in milk production traits after automatic milking had been introduced. Milk yield and composition (fat and protein content, %) were monitored as part of the study in cows in their first (2620 cows) and second (1339 cows) full lactations between 2008 and 2015. The material used in analyses of production traits was extracted from the SYMLEK data registration system. The analysis indicated that for a majority of traits the main sources of variability of production performance in primi- and multiparous cows included the milking system, the herd and the interaction of milking system x herd. The study indicated that after the milking system had been changed from conventional to automatic the milk yield obtained from primiparous cows increased by 15%, whereas for second-lactation cows - by 9%. These changes were accompanied by a gradual decrease in fat content in milk for both lactations, while in the case of protein content it was only in the first lactation.

KEY WORDS: cows / milk traits / automatic milking system

After changing the milking system from conventional (CMS) to automatic (AMS) an increase in the milk yield is possible, but depends on many factors related to the milk production process [Sitkowska *et al.* 2015a]. This beneficial impact was also confirmed by Bogucki *et al.* [2014]. These authors noticed that the scope of this effect depends on the length of time since the introduction of AMS. De Koning *et al.* [2003] showed that the increase in milk yield after changing the milking system to automatic resulted from an increased number of milkings per day. Österman *et al.* [2005] indicated that the increase in the lactation performance resulting from an increased number of daily milkings ranged from 10 to 15%. Olechnowicz *et al.* [2006] presented a study, in which they noted a significant increase in daily milk production in a group of cows following a change from two milkings a day in a milking parlor to milking performed using milking robots (from 25.00 to 27.20 kg). At the same time, they indicated that a conversion from milking 3 times a day to automatic milking caused a change in the milk yield from 27.50 to 26.70 kg. In turn, Abeni *et al.* [2005] reported no significant differences in milk yield in the first 22 weeks of lactation among Holstein-Friesian primiparous in the CMS as compared to the use of AMS. An advantage of AMS is connected with the potential adjustment of milking frequency for individual cows by the breeder based on their production level or lactation phase, without generating any additional labour expenses [Svennersten-Sjaunja and Pettersson 2008, Hogeveen *et al.* 2001]. With AMS it is possible to determine the intervals between milkings and milking frequency, thus facilitating full utilisation of production capacity of the cows, while also ensuring correct milking progression and drying off [Węglarzy 2009].

According to many authors [Bach and Busto 2005, Lee and Choudhary 2006, Svennersten-Sjaunja and Pettersson 2008, Jacobs and Siegford 2012, Rodenburg 2017] AMS offers multiple advantages compared to CMS, but can also entail certain disadvantages. Cows voluntarily use a milking robot to a larger or smaller extent, which affects the frequency of milking for individual cows. Switching from a conventional milking system to automated milking can affect the quantity, composition and quality of milk obtained. Pirlo *et al.* [2005] observed no increase in milking efficiency after installing milking robots in barns. However, De Koning and Rodenburg [2004], Weiss *et al.* [2004] and Klungel *et al.* [2000] pointed to changes in milk parameters after converting from CMS to AMS. The fat content decreased and the hygienic quality of the milk deteriorated, as the number of somatic cells in milk increased [Hovinen *et al.* 2009]. According to a study carried out by Toušová *et al.* [2014], the application of the AMS technology causes no negative effects in terms of milk composition and quality. The milk obtained with the use of AMS was characterized by higher fat and protein contents and a lower number of somatic cells compared to milking performed in a milking parlor. Available literature does not provide an explicit answer as to which milking system, i.e. conventional or automated, is actually better [Gygax *et al.* 2007, Kooistra *et al.* 2003, Oudshoorn *et al.* 2012]. The notion of "better" typically implies a system that is more suitable for the cow, facilitating milk production, or providing better quality milk.

The purpose of the study was to analyse changes in milk quality and composition after the milking system was changed from conventional to automatic in Holstein-Friesian herds.

Material and methods

The study was carried out in 16 Polish Holstein-Friesian dairy cattle herds across Poland. A change in the milking system from the conventional (CMS) to the automatic milking system (AMS) was implemented in these herds between 2010 and 2013. Depending on the farm, one to four “Astronaut A4” milking robots manufactured by Lely were installed. Milk yield (kg) and composition (fat and protein content, %) were monitored as part of the study in 2620 cows in their first lactation (1350 in CMS, 1270 in AMS) and 1339 in their second full lactation (689 in CMS, 650 in AMS). All the cows were born in in the years 2008-2015. The material for analyses of productivity traits recorded between 2008 and 2016 was obtained from the SYMLEK data registration system made available by the Polish Federation of Cattle Breeders and Milk Manufacturers (PFHBiPM 2017).

The barns (in herds denoted with letters from A to P for the purposes of statistical analysis), in which the cows were held, were equipped with free stalls and the PMR feeding system. In herds E and I cows were kept on deep litter, while in herds F and O on shallow litter. Cow mats were used in the other herds.

Cows in the analysed lactations (1st and 2nd) in one of the compared milking systems were taken into account in the assessment of production traits. This allowed the authors to eliminate any cases, in which the milking system had been changed during the lactation period. Cows milked using CMS during the first lactation and then using AMS in the second lactation were also excluded from the study. Lactations lasting at least 240 days were considered in the statistical analysis. In the study the calving season was one of the criteria applied to divide animals into groups for the purpose of the study. Two seasons were distinguished: the summer (months: May - October) and the winter (months: November - April). The cow’s age at calving was also taken into account in statistical classification models in the form of a continuous variable (days). The calving year was the typical factor used for classification in linear models describing variability of production traits. Due to the close relationship between this factor and the year, in which the milking system was changed from CMS to AMS, is was not taken into account in the linear models.

Regarding the purpose of the study, the milking system was the most important criterion applied to classify the examined animal population. This classification was carried out according to the following scheme:

CMS – dates of successive calving and drying period < AMS implementation date

AMS – dates of successive calving and drying period > AMS implementation date

To indicate the statistical sources of variability among the studied production traits, a multi-factor analysis of variance was carried out, applying the least squares method and using the following linear model:

$$y_{ijkl} = \mu + bx_{ijkl} + a_i + b_j + c_k + (ac)_{ik} + (bc)_{jk} + (ab)_{ij} + e_{ijkl}$$

where:

y_{ijkl} – productive trait of i_{jkl}-cow;

μ – overall mean;

b – coeffcient of partial linear regression;

x_{ijkl} – the age at first (primiparous cows) or second (multiparous cows) calving;

a_i – the fixed effect of the i^{th} milking system (i=1, 2; CMS, AMS);

b_j – the fixed effect of the j^{th} herd (j= 1, 2, … 16);

c_k – the fixed effect of the k^{th} calving season (k = 1, 2; summer: May - October, winter: November - April);

$(ac)_{ik}$ – milking system by calving season interaction;

$(bc)_{jk}$ – herd by calving season interaction;

$(ab)_{ij}$ – milking system by herd interaction;

e_{ijkl} – random error connected with the *ijkl*-th observation.

The above mentioned effects were estimated applying the analysis of variance (Fisher-Snedecor test) and the Scheffé test. These computations were performed using the GLM procedure of SAS package programs [SAS Institute Inc., 2014].

Results and discussion

The primiparous and multiparous cows included in the study were characterised by high levels of monitored production traits (Tab. 1). This is justified by the fact that in Poland the average milk yield in recorded cows in 2008 was 6817 kg, with a fat and protein content of 4.14% and 3.34%, respectively. In contrast, in 2016 these values were 7865 kg, 4.11 and 3.37%, respectively [PFHBiPM, 2017]. The analysis carried out by the authors (Tab. 1) indicated higher values of milking traits in the second lactation, compared to cows in their first lactation, which is confirmed by the results of other studies [Jacobs and Siegford 2012, Edwards *et al.* 2014]. The yield and composition of milk in full lactation as well as in 305-day lactation are parameters affected by many factors, such as successive lactations, breed, herd, calving year and season, feeding level and age at calving [Pirlo *et al.* 2000, Cismaş *et al.* 2012, Sitkowska *et al.* 2015b].

Table 1. Descriptive statistics of milk production traits

Lactation	Trait	Number of cows	Mean	SD	Coefficient of variation (%)
1st	milk (kg)	2620	9287.30	2930.61	31.55
	fat (%)	2620	3.99	0.49	12.40
	protein (%)	2620	3.36	0.22	6.52
2nd	milk (kg)	1339	10051.71	3159.85	31.44
	fat (%)	1339	4.00	0.52	13.05
	protein (%)	1339	3.39	0.23	6.88

In our study the discussion concerning the results obtained focused on comparing studied traits in various milking systems. The analysis of variance indicated a statistical effect of all the main factors and interactions on milk yield of primiparous cows in full lactation (Tab. 2). It was further stated that the milking system, herd, calving season and the interactions of milking system x calving season and milking system x herd had a statistical effect on fat content in milk of primiparous cows. The statistical impact of the age at first calving, the herd and the interaction of milking system × herd on protein content (%) in milk was also confirmed. Statistical analysis concerning the second lactation indicated a significant effect of the milking system and the herd on all of the studied milking traits (Tab. 2). Furthermore, the statistical effect of age at second calving on milk yield and protein content (%), as well as the effect of the interaction of the milking system x herd on milk yield and fat content (%) in milk were examined. The effect of the studied factors, i.e. herd, age at calving and calving season on milk production, was statistically confirmed also by other authors [Cismaş *et al.* 2012, Curran *et al.* 2013, Sitkowska *et al.* 2015a, Adamczyk *et al.* 2017].

Table 2. Impact of main factors and interactions on the cows' production traits (probability)

Trait	Age at calving	Milking system (M)	Herd (H)	Calving season (S)	M × S	H × S	M × H
			1st lactation				
Milk	<0.0001	<0.0001	<0.0001	0.0010	0.0053	0.0020	<0.0001
Fat	0.0672	<0.0001	<0.0001	0.0018	0.0089	0.2057	<0.0001
Protein	0.0242	0.0704	<0.0001	0.6008	0.0519	0.1243	<0.0001
			2nd lactation				
Milk	<0.0001	<0.0001	<0.0001	0.9295	0.6597	0.2651	0.0092
Fat	0.1911	<0.0001	<0.0001	0.7607	0.4782	0.9736	<0.0001
Protein	0.0044	0.0033	0.0033	0.1536	0.6148	0.5629	0.0893

Table 3 presents values of least square means, standard errors and coefficients of variation for the analyzed traits depending on the milking systems. The study indicated that milk yield (kg) of primiparous cows milked in CMS was lower by more than 1257 kg (P≤0.01), compared to those milked by AMS. Herds assigned to automatic milking indicated the coefficient of variation lower by 6.65%, which in practice accounted for similar results for the studied animal group, compared to the preceding milking system (Tab. 3). Compared to CMS, primiparous cows milked using AMS were characterised by a much lower fat content (%) and a slight decrease in protein content (%) in milk, respectively, of 0.22 p.p. and 0.02 p.p. Multiparous cows milked using CMS produced a lower milk yield in full lactation – by 835 kg (P≤0.01), compared to cows milked using AMS (Tab. 3). Higher milk yield in multiparous cows milked using AMS was related to lower fat and protein contents compared to milking using CMS by 0.26 and 0.05 p.p. (P≤0.01) in the second lactation. Compared to CMS lower fat and protein contents in milk of primiparous cows and cows in their second lactation milked in AMS resulted probably from a markedly higher milk yield. Berry *et al.* [2013] estimated the genetic correlations between milk yield and percentages of fat and protein in milk at -0.49 and -0.51, respectively, while Ikonen *et al.* [2004] estimated this correlation at the highest, but also negative levels (-0.28 and -0.39).

The beneficial effect of switching from the conventional milking system to the automatic system, as indicated in the study, was confirmed in studies by many authors: Davis and Reinemann [2002], Wade *et al.* [2004], Bijl *et al.* [2007], Winnicki and Jugowar [2014], Petrovska and Jonkus [2014] and Sitkowska *et al.* [2015a].

Primiparous cows are preferred when comparing production traits of different milking systems, as they have not previously experienced any other milking systems. Petrovska and Jonkus [2014] carried out a study concerning milk yield of primiparous cows. In their study cows were milked in a milking parlor (CMS), standing side by side, and using a milking robot (AMS), with both milking systems manufactured by DeLaval. The authors indicated milk yield by 2 kg higher in a single milking among primiparous cows in the AMS group. At the same time, they indicated higher protein and fat contents in the milk of animals milked in the milking parlor. The results of a study carried out by Wade *et al.* [2004] confirmed the beneficial impact of switching from conventional to automatic milking. The increase provided by this change amounted to approx. 2%. Sitkowska *et al.* [2015a] also indicated that the average milk yield in lactation increased after AMS had been implemented. However, it was also determined by other factors. The aforementioned studies indicated that milk yield increased with the time interval from the introduction of AMS. In a study conducted by Winnicki and Jugowar [2014], within one year after the implementation of a milking robot the milk yield increased, depending on the herd, by approx. 70 to as much as 1430 kg.

Table 3. Milk yield, fat and protein contents in milk

Lactation	Milking system	N	Milk (kg)			Fat (%)			Protein (%)		
			LSM	SE	CV (%)	LSM	SE	CV (%)	LSM	SE	CV (%)
1st	CMS	1350	8608.24^{A}	87.61	34.21	4.17^{A}	0.02	12.54	3.38	0.01	6.38
	AMS	1270	9865.35^{A}	81.80	27.56	3.95^{A}	0.02	12.04	3.36	0.01	6.66
2nd	CMS	689	9661.41^{A}	139.59	35.22	4.19^{A}	0.03	12.91	3.43^{A}	0.01	7.03
	AMS	650	10496.44^{A}	123.61	25.95	3.93^{A}	0.02	12.86	3.38^{A}	0.01	6.66

LSM – least square means; SE – standard error; CV– coefficient of variation
^{A}Within column means bearing the same superscript differ significantly at P≤0.01.

A higher milk yield in automatic milking was also confirmed by a study carried out by Davis and Reinemann [2002], as well as Bijl *et al.* [2007], in which the beneficial effect of the robotic milking process was 538 kg. In turn, Jacobs and Siegford [2012] emphasised that the differences between milk yield produced by primiparous and multiparous cows depended primarily on their ability to adapt to the conditions in the barn and on milking conditions. Spolders *et al.* [2004] and Pettersson *et al.* [2011] indicated that, despite higher milking frequencies in primiparous cows, multiparous cows were characterised by higher milk yields in AMS herds. Edwards *et al.* [2014] indicated that primiparous cows milked by milking robots produced on average 7.23 kg of milk, whereas multiparous cows produced approximately 9 kg of milk.

Considering the significance of the interaction between the milking system and the herd in terms of investigated traits, absolute and relative (%) differences between milking levels recorded in the compared milking systems (AMS – CMS) depending on the herd are presented in Table 4. Significant differences in milk yields were found

Table 4. Changes in milk trait levels (absolute/relative (%) after implementing AMS depending on herd and milking system

Herd	1st lactation										2nd lactation						
	N	milk			fat			protein			N	milk			fat		
		kg	%	P	p.p.	%	P	p.p.	%	P		kg	%	P	p.p.	%	P
A	96	+1260	+14	0.0086	-0.54	-11	<0.0001	-0.05	-1	0.1784	48	+1568	+16	0.0254	-0.77	-16	<0.0001
B	61	+1271	+20	0.0438	-0.24	-6	0.0526	-0.05	-1	0.3787	30	-376	-5	0.6941	-0.38	-9	0.0458
C	205	+449	+5	0.1775	-0.20	-5	0.0024	-0.08	-2	0.0049	83	+1464	+15	0.0106	-0.22	-5	0.0466
D	101	+1592	+20	0.0006	-0.17	-4	0.0546	-0.06	-2	0.1617	50	+1474	+16	0.0347	+0.01	+0	0.9386
E	414	-1352	-12	<0.0001	-0.03	-1	0.4399	+0.11	+3	<0.0001	220	-93	-1	0.7981	-0.07	-2	0.3501
F	96	+1188	+13	0.0157	-0.36	-8	0.0001	-0.05	-1	0.2011	57	+1426	+15	0.0310	-0.38	-9	0.0030
G	196	+759	+9	0.0432	-0.37	-9	<0.0001	-0.12	-4	0.0005	108	+1820	+22	0.0009	-0.49	-11	<0.0001
H	92	+1373	+17	0.0059	-0.27	-6	0.0052	-0.02	-1	0.6046	36	-95	-1	0.9104	-0.52	-13	0.0016
I	268	+1933	+21	<0.0001	-0.32	-8	<0.0001	-0.08	-2	0.0139	168	+839	+7	0.1095	-0.24	-6	0.0213
J	128	+824	+8	0.0663	-0.01	-0	0.9093	+0.07	+2	0.0688	50	-146	-1	0.8379	-0.11	-3	0.4364
K	69	+2995	+45	<0.0001	-0.48	-11	<0.0001	+0.04	+1	0.4299	36	+2469	+32	0.0040	-0.51	-12	0.0027
L	145	+2900	+31	<0.0001	-0.26	-7	0.0323	-0.06	-2	0.2371	78	+1127	+12	0.2224	0.00	0	0.9847
M	100	+1708	+19	0.0062	-0.18	-4	0.1346	-0.02	-1	0.7850	56	-398	-3	0.7282	-0.19	-4	0.3903
N	145	+594	+6	0.1322	+0.11	+3	0.1351	-0.05	-1	0.1771	55	-271	-2	0.6852	+0.14	+4	0.3186
O	381	+1432	+27	<0.0001	-0.11	-3	0.0850	+0.17	+5	<0.0001	203	+2084	+38	0.0003	-0.39	-10	0.0006
P	123	+1186	+14	0.0098	-0.12	-3	0.2028	-0.05	-1	0.2101	61	+468	+5	0.5610	+0.05	+1	0.7789

P – probability.

for the full lactation of primiparous cows after milking robots had been installed in three herds. Highly significant differences were observed in ten herds (Tab. 4). An increase in milk yield from 449 to 2995 kg was recorded for sixteen of the studied herds. Herd E was an exception, as it was the only herd, in which a decrease in the milk yield by 1352 kg was recorded. Considering the average milk fat content (%) depending on the milking system and the herd, the study indicated statistically significant differences in eight of the studied herds (Tab. 4). In AMS the recorded fat content (%) was from 0.20 to 0.54 p.p. higher than in CMS. In terms of protein content (%), statistical changes were recorded in five of the analyzed herds (Tab. 4). An increase by 0.11 and 0.17 p.p. was recorded in herds E and O. In turn, in herds C, G and E, a decrease in protein content from 0.08 to 0.12 p.p. was recorded. An increase in milk yield from 1426 to 2469 kg was observed in multiparous cows. An non-significant decrease in milk yield was recorded in the other cases, whereas an increase – in three of them. In turn, statistical differences in fat content (%) were found in milk obtained from nine herds. In AMS compared to CMS milk fat content was lower by 0.22 p.p. (herd C) to 0.77 p.p. (herd A).

The results of this study indicate that the average difference in milk yields between primiparous cows in CMS and AMS amounted to 1257 kg, and from multiparous cows – 835 kg (Tab. 3). For obvious reasons, such a largely beneficial effect cannot be exclusively attributed to robotisation of the milking process. For the studied herds both the barn buildings and the milking systems were modernised, which usually involved a change in the feeding system. Furthermore, it is also necessary to consider continuous breeding in the breeding work in the dairy cattle population. In 2008-2016 the milk yield obtained in the domestic population of the Holstein-Friesian cattle increased by 1048 kg, which means that throughout the year milk production increased on average by 131 kg per cow [PFHBiPM, 2017]. For the studied herds it may be assumed that the average difference between the year of milking of primiparous cows in AMS and CMS was approx. 4 years, whereas for multiparous cows – approx. 3.5 years. For this reason we can assume that on average a one-year production progress was 314 and 239 kg, respectively, and 276.5 kg (primiparous and multiparous cows). Comparing annual changes in domestic breeding (131 kg) with the progress reported for the studied herds (276.5 kg), we can conclude that it was 2-fold higher in the latter case. However, as noted earlier, this progress depends on herd affiliation, which in turn indicates complex and diverse environmental conditions in the studied barns.

In conclusion, compared with the active population the studied Holstein-Friesian cows bred in Poland were characterised by a high production capacity in their first and second full lactations. The analysis indicated that for a majority of traits the main sources of variability in production traits of primiparous and multiparous cows included the milking system, the herd and the interaction between the milking system and the herd. This study indicates that, after the milking system had been changed from conventional to automatic, the milk yield obtained from primiparous cows increased by 15%, whereas from multiparous cows – by 9%. These changes were accompanied by a gradual decrease in milk fat contents both lactations, whereas changes in protein contents were recorded only in the second lactation. In conclusion, further implementation of the automatic milking system in high-yielding Polish Holstein-Friesian herds is fully justified. Considering the significant and highly significant interaction between the milking system and the herd in reference to all the studied production traits, it may be concluded that, apart from automating the milking process, in order to achieve full success in milk production we need to focus on the environmental conditions, in which animals are kept.

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