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THE EFFECT OF SELECTED FACTORS ON MILKING RATE IN POLISH HOLSTEIN-FRIESIAN BLACK-AND-WHITE COWS

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Abstract. The aim of the study was to investigate the effect of selected physiological factors (age, lactation stage and daily milk yield) on milking rate by Polish Holstein-Friesian Black-and-White cows. The duration of morning, evening and diurnal milking was determined. Milking rate of cows was characterized based on the mean actual and corrected milk yield per 1 minute of milking. Statistical analysis showed a lack of any dependence between the age group of cows and milking duration as well as mean actual and corrected milk yields in the minute of milking. Milking time decreased with progress in lactation. In terms of the mean milk yield the lowest value of this parameter was recorded for cows being in their first stage of lactation (≤ day 40). Cows with greater daily milk yields compared to those producing less milk were characterized by longer milking times and greater mean actual and corrected milk yields in the minute of milking. Milking rate of cows is a functional trait of considerable importance in the economics of raw milk production. The selection towards of an increase in milk yield, may have a positive effect on milking rate in cows.

Key words: Polish-Holstein-Friesian Black-and-White cattle, functional traits of cattle, milking rate.

INTRODUCTION

As a result of long-term selection works focusing on milk yield most cows at present have the genotype characterised by a high production potential. Dairy cattle breeders and milk producers need to provide animals with such environmental conditions, which would promote expression of the genetic potential resulting from the animals' genome.

Strong competition on the milk market requires continuous increase in production efficiency, which in turn results in a reduction of raw milk production costs. Increased concentration of production may be observed, along with the growing average number of cows in the herd and the adoption of advanced animal management and milking systems. An essential role is being played by functional traits of cattle, i.e. all the non-production parameters affecting the economics of raw milk production. Milking rate of cows is one of these traits, determining fast

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and efficient milking, which in turn is manifested in the rational utilisation of working time of both the milkers and milking equipment (Borkowska and Januś 2003). Gray et al. (2011) and Špehar et al. (2017) were of an opinion that the milking rate of cows is gaining in importance for herd management. According to the latter authors, slow-milking cows require more work, while those which are fast milkers are more prone to udder disease. Genetic assessment of milk let-down in view of the moderate value of its heritability coefficient is a useful tool aiding animal breeding decisions (Wiggans et al. 2007) and thus this trait should be included in selection indexes (Januś et al. 2004; Špehar et al. 2017). Zwald et al. (2005) suggested that it is possible to conduct genetic selection toward milking speed based on objective electronically recorded milking times. In turn, future research needs to focus on an improvement of reporting and data validation systems, as well as estimation of the economic value of milking time. Krogmeier at al. (2006) determined daily profits from fast milking of primiparous Brown Swiss and Simmental cows to be € 18.7 and € 22.5, respectively.

The aim of this study was to investigate the effect of selected physiological factors (age, lactation stage and daily milk yield) on the milk let-down rate by Polish Holstein-Friesian Black-and-White cows.

MATERIAL AND METHODS

Analyses were conducted on a family farm. The experiment was carried out in a herd of Polish Holstein-Friesian Black-and-White cows (20 head). Animals were in their first up to the fifth lactations and their average milk yield in a 305-day lactation was approx. 8100 kg milk. Cows were kept in a loose housing system. The feed ration for individual animals followed the recommendations of the INRA system. The analyzed cow herd was covered by performance recording (the A-4 method) of dairy and dual-purpose cattle by the Polish Federation of Cattle Breeders and Dairy Farmers. Cows were milked twice a day in a 2 x 2 herring bone milking parlour by Westfalia Surge. The interval between milkings was 12 h. During test milkings (in 2019) the duration of milking (morning and evening) was recorded for each cow using a timer. Cows were milked using alternate pulsation milking clusters. Since 4 cows are being milked simultaneously, each milking stall was equipped with a timer. The timer was turned on at the time the milking cluster was installed and turned off when the cluster was removed from the udder. This made it possible to record the actual milking time. In this experiment morning and evening milking times were determined and the duration of milking within 24 h (diurnal milking time) was calculated. Milking rate (milk let-down of cows) was determined based on the mean actual milk yield per 1 minute of milking. In order to take into account the significant relationship between the amount of milk milked and the speed milking rate, the average actual milk yield was converted into the average corrected milking. The assessment was based in primiparous on evening milking, and in older cows - all day milking. The formula given by Borkowska and Januś (2003) was used:

$$Up = Urz + b\,(Swd - Wd)$$

where:

- *Up* – mean corrected milk yield per 1 minute of milking,
- *Urz* – mean actual milk yield per 1 minute of milking,
- *b* – regression coefficient for mean 1-minute milk yield amounting to 0.1 for primiparous cows and 0.05 for older cows,
- *Swd* – mean diurnal milk yield amounting to 6 kg in primiparous cows and 16 kg in multiparous cows,
- *Wd* – amount of obtained milk.

During the experiment data concerning milking performance on the test day were recorded for each cow from the RW-2 milking performance record. The data included e.g. kg of milk, milk contents of fat, protein, casein, lactose, dry mass, urea, actual somatic cell count as well as the fat : protein ratio.

The actual somatic cell count in milk was subjected to logarithmic transformation according to Ali and Shook (1980).

Statistical calculations were conducted solely for the data concerning milking performance traits coming from cows with SCC in milk < 300 thousand/ml.

This study investigated the effect of physiological factors such as the age of cows, lactation stage and daily milk yield on milking parameters (duration of morning, evening and diurnal milking as well as mean actual and corrected milk yield) and daily milking performance traits.

The significance of the effects of experimental factors (calving group [primiparous vs. multiparous cows], lactation stage [until day 40, 41–100 days, 101–200 days and >200 days], daily milk yield group [≤30 and >30 kg]) was analyzed using three-way ANOVA applying the GLM procedure. The following linear model was used:

$$y_{ijk} = \mu + c_i + f_j + w_k + e_{ijkl}$$

where:

y_{ijkl} – phenotypic value of a trait;
μ – population mean;
c_i – fixed effect of calving group (I = 1, 2);
f_j – fixed effect of lactation stage (j = 1, 2, 3 ,4);
w_k – fixed effect of daily milk yield group (k = 1, 2);
e_{ijkl} – random residual effect.

Statistical analyses were performed using the SAS® package (2017). Basic statistical parameters were calculated applying the MEANS procedure. Statistically non-significant effects were eliminated from the linear model and then the calculations were repeated.

A detailed comparison of object means was performed using the Duncan multiple range test.

RESULTS

Statistical analysis showed no dependencies between the age group of cows and milking time and mean actual and corrected milk yields (Table 1). It was confirmed that multiparous cows were characterised by significantly higher ($P \leq 0.01$) and lower ($P \leq 0.01$) daily milk yields and lactose content in milk, respectively, compared to primiparous cows.

Table 2 presents milking parameters and daily milking performance of cows at different milking stages. A significant relationship of lactation stage was found with the analysed milking parameters and daily milking performace of cows except for the following traits: mean actual milk yield and lactose concentration in milk. It was shown that lactation stage influenced the duration of morning and diurnal milking at the significance level $P \leq 0.01$, while in the case of evening milking this dependence was recorded at $P \leq 0.05$. Milking time was observed to decrease with progressing lactation. In terms of the mean corrected milk yield it was shown that the lowest value of this parameter (1.40 kg/min) characterised cows in the first stage of lactation. In terms of mean corrected milk yields animals from this group differed significantly at $P \leq 0.05$ from cows in the other stages of lactation. In the case of daily milking performance parameters of cows several significant dependencies were observed (at $P \leq 0.01$) between individual stages of lactation. These relationships are consistent with the normal course of curves plotted for individual milking performance traits over the entire lactation period. The effect of lactation stage on

Table 1. Milking parameters and daily milking performance traits of cows divided into primiparous and multiparous cows

Specification		Significance of effects	Age groups			
			primiparous		multiparous	
			$\bar{x}$	SD	$\bar{x}$	SD
			N = 69		N = 132	
Milking time [min]	morning	NS	5.94	2.40	6.41	1.28
	evening	NS	5.52	2.27	5.70	1.19
	diurnal	NS	11.46	4.65	12.11	2.39
Average milking [kg/min]	actual	NS	2.26	0.48	2.32	0.50
	corrected	NS	1.66	0.49	1.73	0.40
Milk [kg]		**	24.1^{A}	2.9	27.7^{A}	6.60
Fat [%]		NS	4.24	0.67	4.32	0.76
Protein [%]		NS	3.52	0.22	3.47	0.44
Casein [%]		NS	2.77	0.18	2.71	0.36
Lactose [%]		**	4.86^{A}	0.13	4.71^{A}	0.17
Dry mass [%]		NS	13.49	0.72	13.45	1.13
Urea [mg/l]		NS	291	56	289	57
SCC [thous./ml]		NS	109	89	110	96
LNSCC		NS	11.21	0.95	11.17	1.00
Fat / Protein		NS	1.20	0.17	1.26	0.24

Effect influence: ** highly significant (P ≤ 0.01); NS – non-significant (P > 0.05). Means denoted with identical letters (in rows) differ statistically: A – highly significantly (P ≤ 0.01).

Table 2. Milking parameters and daily milking performance traits of cows depending on lactation stage

Specification		Significance of effects	Lactation stage [days]							
			≤40		41–100		101–200		>200	
			$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
			N = 49		N = 56		N = 51		N = 45	
Milking time [min]	morning	**	7.32^{Aa}	0.96	6.60^{b}	1.43	6.09^{a}	2.04	5.37^{Ab}	0.88
	evening	*	6.82^{ab}	1.04	5.99^{c}	1.18	5.50^{a}	1.90	4.62^{bc}	0.53
	diurnal	**	14.14^{Aa}	1.93	12.59^{b}	2.56	11.59^{a}	3.89	9.99^{Ab}	1.34
Average milking [kg/min]	actual	NS	2.21	0.39	2.44	0.43	2.32	0.53	2.07	0.43
	corrected	*	1.40^{abc}	0.33	1.67^{a}	0.45	1.77^{b}	0.45	1.74^{c}	0.26
Milk [kg]		**	30.8^{AB}	4.9	30.1^{CD}	5.2	25.6^{ACa}	5.1	20.3^{BDa}	3.5
Fat [%]		**	4.74^{Aab}	1.13	4.08^{A}	0.67	4.25^{a}	0.63	4.39^{b}	0.71
Protein [%]		**	3.34^{Aa}	0.35	3.20^{BC}	0.34	3.54^{BDa}	0.31	3.82^{ACD}	0.38
Casein [%]		**	2.59^{AB}	0.26	2.50^{CD}	0.28	2.78^{AC}	0.26	3.01^{BD}	0.30
Lactose [%]		NS	4.72	0.21	4.79	0.16	4.76	0.17	4.81	0.17
Dry mass [%]		**	13.95^{A}	1.44	12.91^{ABa}	0.75	13.45^{a}	0.88	13.98^{B}	0.95
Urea [mg/l]		*	260^{ab}	53	293^{ac}	65	298^{bd}	56	269^{cd}	35
SCC [thous./ml]		*	82^{a}	95	82^{b}	92	118	95	138^{ab}	73
LNSCC		*	10.67^{ab}	1.21	10.78^{c}	1.04	11.33^{a}	0.89	11.66^{bc}	0.66
Fat/protein		**	1.43^{ABa}	0.34	1.29^{ab}	0.28	1.20^{A}	0.15	1.14^{Bb}	0.10

Effect influence: ** highly significant (P ≤ 0,01); * significant (P ≤ 0.05); NS – non-significant (P > 0.05). Means denoted with identical letters (in rows) differ statistically: A, B, C, D – highly significantly (P ≤0.01); a, b, c, d – significantly (P ≤ 0.05).

contents of urea, SCC and LNSCC in milk was observed at the significance level P ≤ 0.05. Milk samples collected from each lactation stage contained elevated urea levels. The highest urea concentration was recorded in the second lactation stage (from day 41 to 100) and the third lactation stage (from day 101 to 200). These means differed significantly from the average urea concentation in milk coming from the first (≤40 day) and the last lactation stages (>200 day). In turn, the somatic cell counts in milk increased with progressing lactation.

Table 3. Milking parameters and parameters of daily milking performance of cows depending on milk production level

Specification		Significance of effects	Daily milk yield			
			≤30 kg		>30 kg	
			$\bar{x}$	SD	$\bar{x}$	SD
			N = 159		N = 42	
Milking time [min]	morning	**	5.93^{A}	2.05	6.59^{A}	1.24
	evening	**	5.32^{A}	1.93	6.10^{A}	1.07
	diurnal	**	11.24^{A}	3.94	12.70^{A}	2.21
Average milking [kg/min]	actual	*	2.18^{a}	0.51	2.49^{a}	0.42
	corrected	*	1.73^{a}	0.47	1.94^{a}	0.39
Fat [%]		*	4.44^{a}	0.70	4.03^{a}	0.63
Protein [%]		*	3.63^{a}	0.31	3.29^{a}	0.25
Casein [%]		*	2.85^{a}	0.24	2.57^{a}	0.20
Lactose [%]		**	4.79^{A}	0.18	4.68^{A}	0.13
Dry mass [%]		**	13.76^{A}	0.85	13.02^{A}	0.81
Urea [mg/l]		NS	289	54	290	52
SCC [thous./ml]		NS	115	91	101	95
LNSCC		NS	11.29	0.92	11.04	1.05
Fat/protein		NS	1.23	0.17	1.25	0.23

Effect influence: ** highly significant (P ≤ 0.01); * significant (P ≤ 0.05); NS – non-significant (P > 0.05). Means denoted with identical letters (in rows) differ statistically: A – highly significantly (P ≤ 0.01); a – significantly (P ≤ 0.05).

Table 3 presents results indicating that daily milk yield was a statistically significant parameter (P ≤ 0.01) modifying the duration of milking (morning, evening and diurnal milking time) as well as concentration of lactose and dry mass in milk. Moreover, a dependence was obtained at the significance level P ≤ 0.05 between daily milk production and the mean actual and corrected milk yields, as well as contents of fat, protein and casein in milk. Results obtained in this study indicate that cows with higher daily milk yields (>30 kg) compared to those producing less milk (≤30 kg) were characterised by longer milking time, greater mean actual and corrected milk yields and lower contents of lactose, dry mass, fat, protein and casein in milk.

DISCUSSION

In this study no dependence was found between primiparous and multiparous cows in the case of milking time or actual and corrected milk yields. However, investigations conducted

by Edwards et al. (2014) indicate that primiparous cows in relation to multiparous cows were characterised by differing milking rate profiles at its lower maximum value. Most probably this resulted from the difference in the capacity of the teat cisterns between both age groups of animals. In this study the duration of a single milking operation in the groups of primiparous and multiparous cows was approx. 6 minutes and it was comparable to the data recorded by Edwards et al. (2014). In turn, Samoré et al. (2011) reported that the anatomical structure of the udder may be related with milking rate, as it results from the genetic correlation coefficients calculated by those authors between milking time and rear udder height (0.92), rear udder width (0.85) and teat placement (0.73). In all milk production systems it is recommended to reduce stress to the minimum and apply pre-milking udder stimulation (Bruckmaier and Wellnitz 2008). In the opinion of Sandrucci et al. (2007), shortening of milking time is influenced by the interval between teat stimulation and teatcup placement (lag time). The latter operation needs to be performed within 60 seconds. Wieland et al. (2019) were of an opinion that depending on their shape teat tips may require different pre-milking stimulation, while extension of lag time affects the condition of teat tissue during machine milking. Weiss and Bruckmaier (2005) showed that the optimal duration of pre-milking udder stimulation required to ensure prompt and continuous milk flow varied and amounted to 90 s in glands containing small amounts of milk and 20 s in well-filled glands. In the opinion of Bruckmaier and Wellnitz (2008) the interval from the beginning of manual stimulation to milk ejection increases with the reduction in udder filling and for this reason cows at later lactation stages require prolonged stimulation.

This study showed a decrease in milking time with progressing lactation, with the lowest corrected mean yield recorded in the first stage of lactation (≤40 day). Antalik and Strapák (2011) reported the highest mean and maximum milk flow rates in the period from day 100 to day 200 of lactation. In turn, in their investigations Walsh et al. (2007) and McCarthy et al. (2007) observed longer milking time and higher values for mean and maximum milk flow in the group of cows fed a diet containing concentrates. This most probably results from greater daily milk yields of cows fed feed rations with a high nutrient concentration. Amin (2007) showed that values of correlation coefficients between milk flow rate and milk yield increased linearly with progressing lactation. According to Gray et al. (2011), genetic correlation coefficients between milking performance and milk flow traits range from low to moderate values. Samoré et al. (2010) recorded correlations between mean milk flow and the yield of milk, fat and protein amounting to 0.30, 0.24 and 0.16, respectively. This study showed a significant effect of daily milk yield on milking parameters and milking performance traits. Observations recorded by the authors of this study confirm results presented by Prendiville et al. (2010), who showed that a higher milk yield in cows was related with longer milking time and increased mean and maximum milk flow. Berry et al. (2013) suggested that cows producing more milk take longer to milk and selection towards shortening of milking time may reduce productivity of animals. In turn, Grindal and Hillerton (1991) were of an opinion that as a result of attempts to increase milk flow and milk production cows are increasingly more susceptible to *mastitis*. It was shown in this study that cows over 200 days of lactation were characterised by the shortest milking time, although their milk contained significantly greater somatic cell counts compared to milk collected from cows being in earlier stages of lactation, when milking time was longer. Such a result may have also stemmed from advanced lactation, which typically predisposes to increased SCC. However, data reported by other authors mostly indicate a relationship between milking rate and SCC in milk. Boettcher et al. (1998) and Tamburini et al. (2010) based on their studies presented an opinion that faster milking is related with increased SCC in milk, while milk flow traits may be predictive indicators of udder health. Zwald et al. (2005) claimed that fast-milking cows are characterised by greater somatic cell counts in milk and this trait is passed to their progeny. Samoré et al. (2010) estimated that the correlation between milk flow and SCC was 0.46. In turn, Rupp

and Boichard (1999) reported that the genetic correlation between milking rate and SCC in milk of primiparous Holstein cows was 0.44.

CONCLUSION

Summing up it may be stated that milking time was related to lactation stage and daily milk yield. A reduction of milking time was shown with the progressing lactation, while it increased in cows with higher daily milk yields. Mean actual and corrected milk yields in the minute of milking were greater in cows with higher daily milk yields, while the lowest mean corrected milk yield was recorded in cows in the first 40 days of lactation.

Milking rate in cows is a functional trait significant for the economics of raw milk production. The selection towards of an increase in milk yield, may have a positive effect on milking rate in cows.

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WPŁYW WYBRANYCH CZYNNIKÓW NA SZYBKOŚĆ ODDAWANIA MLEKA PRZEZ KROWY RASY POLSKIEJ HOLSZTYŃSKO-FRYZYJSKIEJ ODMIANY CZARNO-BIAŁEJ

Streszczenie. Celem pracy było zbadanie wpływu wybranych czynników fizjologicznych (wieku, stadium laktacji i dobowej wydajności mlecznej) na szybkość oddawania mleka przez krowy rasy polskiej holsztyńsko-fryzyjskiej odmiany czarno-białej. W badaniach określono czas trwania doju porannego, wieczornego oraz dobowego. Szybkość oddawania mleka przez krowy scharakteryzowano na podstawie średniego rzeczywistego i poprawionego udoju mleka w minucie doju. Przeprowadzona analiza statystyczna wykazała brak występowania zależności między grupą wiekową krów a czasem trwania doju oraz średnim udojem rzeczywistym i poprawionym. Stwierdzono skrócenie czasu trwania doju w miarę zaawansowania laktacji. Biorąc pod uwagę średni udój poprawiony, wykazano, że najmniejszą wartością tego parametru charakteryzowały się krowy będące w pierwszym okresie laktacji (≤40. dzień). Krowy o wyższej dobowej wydajności mleka, w stosunku do mniej wydajnych, charak-

teryzowały się dłuższym czasem doju oraz większym średnim udojem rzeczywistym i poprawionym. Szybkość oddawania mleka przez krowy jest cechą funkcjonalną istotną w ekonomice produkcji mleka surowego. Prowadzona selekcja w kierunku wzrostu wydajności mleka może wpłynąć pozytywnie na szybkość oddawania mleka przez krowy.

Słowa kluczowe: bydło rasy polskiej holsztyńsko-fryzyjskiej odmiany czarno-białej, cechy funkcjonalne, szybkość oddawania mleka.