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DETERMINANTS OF UDDER QUARTER MILK YIELD IN AUTOMATICALLY MILKED COWS

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ABSTRACT

The objective of this paper was to analyse udder quarter milk yield in automatically milked cows, taking into account the lactation number, lactation period and season, as well as to determine the share of individual quarters (front and rear quarters, left and right quarters) in total milk yield during a single milking. The analysis was conducted using data obtained from one cattle farm with 280 Polish Holstein-Friesian (PHF) cows, milked with 4 VMS milking robots. The analysed parameters included: milk yield during milking of front quarters (left and right), rear quarters (left and right), the ratio of front quarter to rear quarter and left to right quarter yields. In the oldest cows, an increase was observed in udder quarter milk yield in lactations 1–3, followed by a decrease in lactation 4 and then another increase. Cows in lactations ≥5 have better milk yield than cows in the 3rd lactation. An average milk yield of one quarter of the udder for all lactations was 3.81 kg. With higher lactation numbers, there was a decrease in milk yield for all udder quarters. The reduction in udder quarter milk yield of lactating cows ranged from 1.52 kg (rear right quarter) to 1.78 kg of milk (rear left quarter) and from 1.59 kg (front right quarter) to 1.70 kg of milk (front left quarter). No significant differences were observed in the milk yield of individual udder quarters in the spring, summer and autumn seasons. On the other hand, there was a marked increase in this parameter in the winter months. With successive lactations, the share of front quarters in total milk yield decreased – from 46.9% in primiparous cows to 41.2% in cows after ≥5 lactations. The share of rear quarters in milk yield in turn increased. With every successive lactation, the disproportion in the milk yield between the front quarters and rear quarters widened. When it comes to the left and right quarters of the udder, in terms of the factors considered, similar results were observed.

Key words: cows, milk, mammary gland, udder quarter, milk yield

INTRODUCTION

Milk production in Poland shows a sustained upward trend. In 2022, 12,381 million litres of raw milk were delivered to processing plants, which was 2.2% higher compared to the previous year. At the same time, the decline in the dairy cow population, observable since 2019, has been reversed. In December 2022, it amounted to 2,037,000 heads and was slightly (by 0.1%) higher than in 2021 [GUS 2023]. As a result of the concentration of breeding, the improvement of production technology and the improvement of dairy cattle genetics, milk yield is increasing. According to the Polish Federation of Cattle Breeders and Dairy Farmers [PFHBiPM 2022], in 2022 a statistical cow produced 7425 kg of milk (7015 kg the year before), with an average of 9037 kg of milk (8837kg the year before) obtained from cows under milk performance assessment, and 6324 kg of milk (5851 kg the year before) from cows not subject to the assessment [PFHBiPM 2022, PFHBiPM 2023]. The dairy farm model is also changing. with the number of farms declining, but average herd size increasing [GUS 2023].

The approach of dairy farmers to milk production has been changing over the last few decades, with the aim being to maximise milk yield and simultaneously minimise the required labour and financial resources. In order to optimise the milking process and reduce human labour input, the world's first milking robot was launched in the Netherlands in 1992, heralding an era of automatic milk-

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ing systems (AMS). Automatic milking systems are conducive to the welfare of the animals by allowing them to freely choose the time spent in the stall around the clock. The frequency of milking determines the amount of milk yield. Brzozowski et al. [2020] showed that when changing from traditional milking to automatic milking, milk yield from primiparous cows increased by 15%, while the subsequent lactation showed an increase in milk yield by a further 9%. AMSs allow monitoring such parameters as milk flow rate, number of milkings, somatic cell count in milk, oestrous activity or quarter milking [Carlström et al. 2013, Steeneveld et al. 2015, Tse et al. 2018, Solano et al. 2022].

The introduction of automatic milking systems has made it possible to focus on the milking performance of individual quarters, not just on performance at the level of individual animals. Milking parameters that are routinely measured at the quarter level during each milking with the use of AMS include milk yield, average milk flow rate and peak milk flow rate [Weaver and Hernandez 2016, Penry et al. 2018]. Quarter milking is undoubtedly an important factor for udder health, as it eliminates overmilking, adjusts milking parameters to the rate and amount of milk flow, as well as allows quick verification of the health of individual quarters [Sitkowska et al. 2016, Zucali et al. 2021].

The amount of milk produced is closely linked to the anatomical structure and functional characteristics of the individual quarters of the cow's udder [Atasever and Erdem 2009, Pritchard et al. 2010, Szencziová et al. 2013]. Appropriate udder conformation, in addition to having an impact on milk yield, including, above all, milking time, is also important in terms of ensuring animal health [Kumar et al. 2022]. Breeders who pay particular attention to that aspect aim to ensure that their herds consist of cows with evenly distributed yields from the individual quarters, which is desirable in the case of mechanical and automatic milking. Previous studies have also pointed out that differences in milk yield of more than 10–15% between the front quarters and rear quarters, as well as differences in milking time of more than 1 minute, have a negative impact on milk yield and animal health [Stankūnienė et al. 2008, Kuczaj 2010]. A detailed analysis of the milk yield of individual udder quarters of cows subject to automatic milking, taking into account the frequency of milking, was carried out in the study by Bogucki [2018]. It was found that during milking of primiparous and multiparous cows, the front quarters and rear quarters produced respectively: 45.8% and 54.2% and 41.8% and 58.2% of milk. Similar results were shown in an earlier study by Šlyžius et al. [2013], in which about 42% of the total milk yield was obtained from the front quarters and about 58% from the rear quarters. The relationship between the milk yield of individual quarters and susceptibility to mastitis was in turn indicated by Hammer et al. [2012], who observed an increase in mastitis cases in quarters characterised by the lowest productivity and milking frequency.

The objective of this paper was to analyse milk yield of individual udder quarters in automatically milked cows, taking into account the lactation number, lactation period and season, as well as to determine the share of individual quarters (front and rear quarters, left and right quarters) in total milk yield during a single milking.

MATERIAL AND METHODS

The analysis was conducted on the basis of data obtained from one of the dairy cattle farms in the Kujawsko-Pomorskie Province. The herd consisted of approximately 280 cows of the Polish Holstein-Friesian breed, of the black and white variety. The cows were under milk performance assessment (method A4) conducted by the Polish Federation of Cattle Breeders and Dairy Farmers. The average herd productivity in recent years has been around 11,000 kg of milk per lactating cow. The cows were kept in a free-stall, non-bedding barn with mats, equipped with 4 DeLaval VMS milking robots. The feed ration (PMR system, NRC feeding standards) consisted of maize silage, alfalfa silage, grass haylage, brewer's grains, soybean, rapeseed, maize and wheat middlings, mineral and vitamin supplements and pelleted feed available in the robots and in the feeding station (feeding cows with this type of feed depended on their current performance).

Data was assessed in terms of the following parameters (derived from 156,317 full milkings carried out in 2022 for all active quarters), extracted from the herd management system:

(A) Milk yield (kg) for:

- front left quarters (FL),
- front right quarters (FR),
- rear left quarters (RL),
- rear right quarters (RR),

(B) Milk yield ratio (%):

- front quarters to rear quarters,
- left to right quarters.

The following experimental factors were taken into account in the statistical analysis of the above mentioned parameters:

- lactation number (1, 2, 3, 4, $\geq$ 5),
- lactation period ($\leq$100, 101–200, 201–300, >300 days),
- season (spring – III, IV, V, summer – VI, VII, VIII, autumn – IX, X, XI, winter – XII, I, II).

Multivariate ANOVA (GLM procedure) was used in the statistical processing of the numerical data. Statistical

significance of differences between the means was tested using the Scheffe test [SAS 2022].

The following linear model was used:

$$y_{ijkl} = \mu + a_i + b_j + c_k + d_l + e_{ijkl}$$

where:

y_{ijkl} – $ijkl$-th milking,
μ – overall average,
a_i – fixed effect of i-th lactation number (1, 2, 3, 4, ≥5),
b_j – fixed effect of the j-th lactation period (≤100, 101–200, 201–300, >300 days),
c_k – fixed effect of the k-th season (spring, summer, autumn, winter),
d_l – fixed effect of the l-th quarter of the udder (FL, FR, RL, RR),
e_{ijkl} – random error of observations.

The share of individual udder quarters (front and rear quarters, left and right quarters) in the milk yield obtained during a single milking in terms of the above-mentioned parameters was also calculated.

RESULTS AND DISCUSSION

Analysing the milk yield obtained during the milking of individual quarters, an increase in the latter was observed in lactations 1–3, followed by a decrease in the 4th lactation and another increase in the oldest cows, in the 5th lactation and onwards (Table 1). In the case of the front quarters (left and right), there was an increase in the milk yield in the first three lactations from 2.89 to 3.54 and from 3.12 to 3.56 kg of milk, followed by a decrease to 3.09 and 3.30 kg of milk and an increase again to 3.28 and 3.63 kg of milk, respectively. The rear quarters (left and right) were characterised by milk yield of 3.40 to 4.82 and 3.39 to 4.74 kg of milk (lactations 1–3), 4.58 and 4.24 kg of milk (4th lactation) and 4.87 and 4.99 kg of milk (oldest cows), respectively. The difference in the performance of individual quarters in successive lactations was statistically significant ($P \leq 0.05$). It is worth noting that cows in lactations 5 and onwards produced more milk than cows in the 3rd lactation. This applied to all udder quarters except the front left quarter (FL). In the analysed herd, the proportion of cows in lactations 4 and 5 has been increasing in the age structure in recent years, which is a sign of the longevity of the cows, which can better realise their production potential. This is partly the result of the focus on animal welfare and health.

The lowest milk yields were observed in udder quarters of primiparous cows. Hopster et al. [2002] emphasise that the lower performance of primiparous cows is due to physiological reasons. At the same time, it should be emphasised that thanks to the automatic milking system, it is possible – due to the higher milking frequency in the case of this system – to achieve higher milk yield in these cows in subsequent lactations [Nogalski et al. 2011, Wright et al. 2013].

The author's own analyses showed better results than those obtained by Šlyžius et al. [2013]. In a study of a Lithuanian population of black and white cattle milked twice per day, it was shown that left and right rear quarters produced 3.42 and 3.47 kg of milk, respectively, while left and right front quarters – 2.63 and 2.71 kg of milk per milking.

The results presented in Table 1 show a significantly higher milk yield of rear quarters, compared to front quarters, which is in line with previous studies [Weiss et al. 2004, Tančin et al. 2006, Penry et al. 2017, Penry et al. 2018, Bogucki 2018, Inzaghi et al. 2021].

Considering all the analysed milkings of individual quarters (156,317), one quarter produced an average of 3.81 kg of milk per milking. Zucali et al. [2021], in a study conducted on dairy cattle farms in northern Italy, equipped with automatic milking systems of different brands, recorded an average quarter yield of 3.63 kg of milk per milking.

With higher lactation numbers, there was a significant ($P \leq 0.05$) decrease in milk yield for all udder quarters (Table 2). At the same time, it was shown to be at a fairly even level for all quarters. The reduction in udder quarter milk yield (comparing the beginning and end of lactation) ranged from 1.52 kg of milk (rear right quarters) to 1.78 kg of milk (rear left quarters). In contrast, for the front quarters, milk yields from both lactation periods decreased for the right quarters by 1.59 kg of milk and by 1.70 kg for the left quarters.

Comparing front and rear quarters, it was shown that the difference in milk yield between those two in successive lactation periods averaged between 1.6 kg milk (≤ 100 and >300 lactation days) and 2.0 kg milk (101–200 lactation days), and was higher for rear quarters.

In a study by Sitkowska et al. [2014], it was shown that the stage of lactation determined the performance of udder front quarters and rear quarters. The authors analysed individual quarter milkings and observed lower milk yield disproportion between front quarters and rear quarters, 0.31–0.46 kg (in primiparous cows) and 0.52–0.57 kg (in multiparous cows). The reason may be that the studied population of cows was characterised by an average production level during lactation – the average milk yield per cow for a single full milking ranged from 7 to 10 kg.

When it comes to differences between the seasons, no significant variation was observed in terms of milk yield for individual quarters in spring, summer and autumn. However, the mean values were statistically significantly different ($P \leq 0.05$). In these seasons, the milk yields of individual udder quarters were respec-

Table 1. Productivity of individual udder quarters in successive lactations, kg of milk

Number of lactation	Quarters	FL		FR		RL		RR	
	N	LSM	SE	LSM	SE	LSM	SE	LSM	SE
1	49192	2.89^{abcd}	1.15	3.12^{abcd}	1.21	3.40^{abcd}	1.35	3.39^{abcd}	1.48
2	49798	3.13^{aef}	1.50	3.36^{aefg}	1.52	4.26^{aefg}	1.85	4.07^{aefg}	1.83
3	29116	3.54^{begh}	1.65	3.56^{behi}	1.68	4.82^{beh}	2.17	4.74^{behi}	1.99
4	14572	3.09^{cgi}	1.64	3.30^{cfhj}	1.84	4.58^{cfhi}	2.21	4.24^{cfhj}	2.10
≥5	13639	3.28^{dfhi}	1.63	3.63^{dgij}	1.57	4.87^{dgi}	2.09	4.99^{dgij}	1.98

$^{a, b, c...}$ means in columns marked with the same letters differ significantly at $P \leq 0.05$.

Table 2. Productivity of individual udder quarters in successive lactations, kg of milk

Lactation period, days	Quarters	FL		FR		RL		RR	
	N	LSM	SE	LSM	SE	LSM	SE	LSM	SE
≤100	50712	3.66^{abc}	1.36	3.80^{ab}	1.42	4.60^{abc}	1.84	4.48^{abc}	1.83
101–200	40717	3.56^{ade}	1.38	3.78^{cd}	1.39	4.78^{ade}	1.80	4.59^{ade}	1.83
201–300	34725	2.90^{bdf}	1.34	3.14^{ace}	1.37	4.04^{bdf}	1.80	3.85^{bdf}	1.77
>300	30163	1.96^{cef}	1.16	2.21^{bde}	1.32	2.82^{cef}	1.67	2.96^{cef}	1.64

$^{a, b, c...}$ means in columns marked with the same letters differ significantly at $P \leq 0.05$.

Table 3. Productivity of individual udder quarters by season, kg of milk

Season	Quarters	FL		FR		RL		RR	
	N	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Spring	40265	3.08^{abc}	1.58	3.28^{ab}	1.57	4.06^{abc}	2.01	4.00^{a}	1.99
Summer	39578	3.05^{ade}	1.42	3.29^{bcd}	1.52	4.10^{ade}	1.88	4.01^{b}	1.83
Autumn	36980	3.12^{bdf}	1.39	3.32^{ace}	1.45	4.16^{bdf}	1.84	4.01^{c}	1.76
Winter	39494	3.31^{cef}	1.48	3.46^{bde}	1.49	4.38^{cef}	1.95	4.28^{abc}	1.93

$^{a, b, c...}$ means in columns marked with the same letters differ significantly at $P \leq 0.05$.

tively: 3.05–3.12 (FL), 3.28–3.32 (FR), 4.06–4.16 (RL) and 4.00–4.01 (RR) kg of milk (Table 3). On the other hand, there was a marked increase in this parameter in the winter months. In a single milking, an average yield from the front quarters was 3.31 (left) to 3.46 (right) kg of milk, and from the rear quarters – 4.28 (right) to 4.38 (left) kg of milk.

The milk yield of the cows depends to a significant extent on their nutrition. On farms feeding the cows summer or winter feed depending on the season, it is the main factor that differentiates animal productivity and the chemical composition of the milk. In herds, especially high-yield herds fed a homogeneous ration throughout the year, other factors, such as humidity and temperature in the barn may influence cow performance. Imrich et al. [2021] showed a statistically significant higher performance of cows in the winter period, compared to the summer period, despite ensuring welfare of the animals. A possible reason is that less favourable environmental conditions, with high temperatures during the summer months, reduce cow productivity, but also change the chemical composition of the milk and its cytological quality. The results of the studies cited above are in line with the results of the author's own analysis.

With successive lactations, the share of front quarters in total milk yield decreased – from 46.9% in primiparous cows to 41.2% in cows in lactation 5 and onwards (Table 4). The share of rear quarters in milk yield in turn increased from 53.1 to 58.8%. With every successive lactation, the disproportion in the milk yield between the front quarters and rear quarters widened – from 6.2 p.p. (primiparous cows) to 17.6 p.p. (5th and further lactations). In an earlier study by Bogucki [2018], among primiparous cows the share of the front quarters and rear quarters in daily milk yield was 45.8 and 54.2%, while in multiparous cows it was 41.8 and 58.2%. The results

Table 4. Share of individual udder quarters in milk yield in successive lactations, %

Number of lactation	Share of quarters			
	Front	Rear	Left	Right
1	46.9	53.1	49.1	50.9
2	43.8	56.2	49.9	50.1
3	42.6	57.4	50.2	49.8
4	42.0	58.0	50.4	49.6
≥5	41.2	58.8	49.6	50.4

Table 5. Share of individual udder quarters in milk yield in successive lactation periods, %

Lactation period (days)	Share of quarters			
	Front	Rear	Left	Right
≤100	45.1	54.9	49.9	50.1
101–200	43.9	56.1	49.9	50.1
201–300	43.3	56.7	49.8	50.2
>300	41.9	58.1	48.0	52.0

Table 6. Share of individual udder quarters in milk yield in individual seasons, %

Season	Share of quarters			
	Front	Rear	Left	Right
Spring	44.1	55.9	49.5	50.5
Summer	43.7	56.3	49.3	50.7
Autumn	44.1	55.9	49.8	50.2
Winter	43.9	56.1	50.2	49.8

of the author's own analysis also correspond to those obtained by Kuczaj et al. [2010] and Šlyžius et al. [2013].

Comparing the share of left and right quarters in milk yield, showed differences ranking from 0.2 to 1.8% (Table 4). A similar result – an average of 0.77% – was obtained in a study conducted on a Lithuanian dairy cattle farm [Šlyžius et al. 2014].

With higher lactation numbers, there was a decrease in the share of the front quarters in milk yield, from 45.1% to 41.9% (Table 5). The disproportion in milk yield between the front and rear quarters thus increased, from 9.8 to 16.2 percentage point. In the case of automatic milking systems, it is possible to achieve longer milking times, while conventional milking increases the risk of overmilking.

Comparing the share of left and right quarters in milk yield in the first three lactation periods showed minimal (up to 1.0 p.p.) variation in favour of the right quarters. A higher difference was found in cows at the end of lactation period, where the proportion of milk yield was 48.0 and 52.0% (for left and right quarters respectively).

In terms of individual seasons, the difference in milk yield between front and rear quarters ranged from 11.8 p.p. in spring and autumn, through 12.2 p.p. in winter, to 12.6 p.p. in summer (Table 6).

However, comparing the left and right halves of the udder showed similar performance. The most balanced values were observed in the autumn and winter months (0.4 p.p.), followed by spring (1.0 p.p.) and summer (1.4 p.p.).

CONCLUSIONS

In the oldest cows, an increase was observed in udder quarter milk yield in lactations 1–3, followed by a decrease in lactation 4 and then another increase. Cows in the 5th lactation onwards have better milk yield than cows in the 3rd lactation. An average milk yield of one quarter of the udder for all lactations was 3.81 kg. With higher lactation numbers, there was a decrease in milk yield for all udder quarters. The reduction in udder quarter milk yield of lactating cows ranged from 1.52 kg (rear right

quarters) to 1.78 kg of milk (rear left quarters) and from 1.59 kg (front right quarters) to 1.70 kg of milk (front left quarters). The milk yield of the individual udder quarters showed a clear increase only in the winter season, while there was little variation in the other seasons. With successive lactations, the share of front quarters in total milk yield decreased – from 46.9% in primiparous cows to 41.2% in cows in the 5th lactation onwards. The share of rear quarters in milk yield in turn increased. With every successive lactation, the disproportion in the milk yield between the front quarters and rear quarters widened. However, in terms of the parameters taken into account, no difference was found in the milk yield between the left and right halves of the udder.

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REFERENCES

Atasever, S., Erdem, H. (2009). Association between subclinical mastitis markers and body condition scores of Holstein cows in the Black Sea region, Turkey. J. Anim. Vet. Adv., 8, 476–480.

Bogucki, M. (2018). Effect of lactation stage and milking frequency on milk yield from udder quarters of primiparous and multiparous cows. S. Afr. J. Anim. Sci., 48, 636–642. DOI: 10.4314/sajas.v48i4.5.

Brzozowski, M., Piwczyński, D., Sitkowska, B., Boguck,i M., Sawa, A. (2020). The impact of introduction of an automatic milking system on production traits in Polish Holstein-Friesian cows. Anim. Sci. Pap. Rep., 38, 49–59. DOI: 10.1016/j.livsci.2020.104140.

Carlström, C., Pettersson, G., Johansson, K., Strandberg, E., Stålhammar, H., Philipsson, J. (2013). Feasibility of using automatic milking system data from commercial herds for genetic analysis of milkability. J. Dairy Sci., 96(8), 5324–5332. DOI: 10.3168/jds.2012-6221.

GUS (2023). Produkcja zwierzęca – Zwierzęta gospodarskie [Animal production – Livestock]. Główny Urząd Statystyczny, Warszawa. [In Polish]

Hammer, J., Morton, J., Kerrisk, K. (2012). Quarter milking quarter udder and lactation level risk factors and indicators for clinical mastitis during automatic milking system. Aust. Vet. J., 90, 167–174. DOI: 10.1111/j.1751-0813.2012.00917.x.

Hopster, H.R.M.B., Bruckmaier, R.M., Van der Werf, J.T.N., Korte, S.M., Macuhova, J., Korte-Bouws, G., Van Reenen, C.G. (2002). Stress responses during milking: Comparing conventional and automatic milking in primiparous dairy cows. J. Dairy Sci., 85, 3206–3216. DOI: 10. 3168/jds.S0022-0302(02)74409-3.

Imrich, I., Toman, R., Pšenková, M., Mlyneková, E., Kanka, T., Mlynek, J., Pontešová, B. (2021). Effect of temperature and relative humidity on the milk production of dairy cows. Sci. Tech. Innov., 12(1), 22–27. DOI: 10.5604/01.3001.0015.5609.

Inzaghi, V., Zucali, M., Thompson, P.D., Penry, J.F., Reinemann, D.J. (2021). Changes in milk and milk characteristics prior to clinical mastitis confirmation. Ital. J. Anim. Sci., 20, 1552–1559. DOI: 10.1080/1828051X.2021.1984852.

Kuczaj, M. (2010). Hodowla bydła, standardy unijne i krajowe [Cattle breeding, EU and national standards]. Wyd. UP Wrocław. [In Polish]

Kuczaj, M., Preś, J., Bodarski, R., Kupczyński, R., Stefaniak, T. Jawor, P. (2010). Performance of milk production and cows' health status as a function of milking frequency. Med. Wet., 66(1), 32–36.

Kumar, P., Dar, Y., Kumar, A. (2022). Functional anatomy of cow mammary glands with special reference to its defence mechanism. Int. J. Cow Sci., 6(1), 30–31. DOI: 10.18231/j.ijcs.2022.005.

Nogalski, Z., Czerpak, K., Pogorzelska, P. (2011). Effect of automatic and conventional milking on somatic cell count and lactation traits in primiparous cows. Ann. Anim. Sci., 11, 433–441.

Penry, J.F., Crump, P.M., Hernandez, L.L., Reiemann, D.J. (2018). Association of quarter milking measurements and cow-level factors in an automatic milking system. J. Dairy Sci., 10(8), 7551–7562. DOI: 10.3168/jds.2017-14153.

Penry, J.F., Crump, P.M., Ruegg, P.L., Reinemann, D.J. (2017). Cow and quarter-level milking indicators and their associations with clinical mastitis in an automatic milking system. J. Dairy Sci., 100, 9267–9272. DOI: 10.3168/jds.2017-12839.

PFHBiPM (2022). Ocena i hodowla bydła. Dane za rok 2021 [Cattle evaluation and breeding. 2021 data]. Polska Federacja Hodowców Bydła i Producentów Mleka. [In Polish]

PFHBiPM (2023). Ocena i hodowla bydła. Dane za rok 2022 [Cattle evaluation and breeding. 2022 data]. Polska Federacja Hodowców Bydła i Producentów Mleka. [In Polish]

Pritchard, T., Coffey, M., Mrode, R., Moore, K., Wall, E. (2010). Genetic Parameters of Udder Health Traits in Holstein Friesian UK Dairy Cattle. Conference: World Congress on Genetics Applied to Livestock Production At: Leipzig, Germany, Vol. 9 WCGALP.

SAS (2022). SAS/STAT® 9.4 User's guide. SAS Institute Inc., Cary, NC.

Sitkowska, B., Aerts, J., Piwczyński, D., Pejka, B., Mroczkowski, S. (2014). Wpływ wybranych czynników na wydajność mleczną krów w robotach udojowych Effect of selected factors on milk yield of cows in milking robots]. Rocz. Nauk. Zoot., 41, 41–49. [In Polish]

Sitkowska, B., Piwczyński, D., Brzozowski, M., Aerts, J. (2016). Dój ćwiartkowy w grupie krów pierwiastek i wieloródek [Quarter milking in a group of primiparous and multiparous cows]. Rocz. Nauk. PTZ, 12 (4), 35–48. [In Polish]. DOI: 10.5604/01.3001.0013.5397.

Solano, L., Halbach C., Bennett T.B., Cook N. B. (2022). Milking time behavior of dairy cows in a free-flow automated milking system. JDS Communications, 3, 426–430. DOI: 10.3168/jdsc.2022-0243.

Stankūnienė, V., Tacas, J., Mišeikienė, J. (2008). Dairy Farm Owner. In: Lithuanian Veterinary Academy. Milking Training Center, 32–39.

Steeneveld, W., Vernooij, J., Hogeveen, H. (2015). Effect of sensor systems for cow management on milk production, somatic cell count, and reproduction. J. Dairy Sci., 98, 3896–3905. DOI: 10.3168/jds.2014-9101.

Szencziová, I., Strapák, P., Stádník, L., Ducháček, J., Beran, J. (2013). Relationship of udder and teat morphology to milking characteristics and udder health determined by ultrasonographic examinations in dairy cows. Ann. Anim. Sci., 13, 783–795. DOI: 10.2478/aoas-2013-0053.

Šlyžius, E., Juozaitienė, V., Tušas, S., Juozaitis, A., Žymantienė, J. (2013). Relation of udder quarter development with daily milk yield¸ composition and somatic cell count. Vet. Med. Zoot., 63(85), 76–80.

Šlyžius, E., Juozaitienė, V., Tušas, S., Juozaitis, A., Žymantienė, J. (2014). Udder quarters morphological and milking traits risk factors influencing productivity and subclinical mastitis in dairy cows. Bulg. J. Agric. Sci., 20 (6), 1502–1507.

Tančin, V., Ipema, B., Hogewerf, P., Mačuhová, J. (2006). Sources of variation in milk flow characteristics at udder and quarter levels. J. Dairy Sci., 89, 978–988. DOI: 10.3168/jds.S0022-0302(06)72163-4.

Tse, C., Barkema, H.W., DeVries, T.J., Rushen, J., Pajor, E.A. (2018). Impact of automatic milking systems on dairy cattle producers' reports of milking labour management, milk production and milk quality. Animal, 12(12), 2649–2656. DOI: 10.1017/S1751731118000654.

Weaver, S.R., Hernandez, L.L. (2016). Autocrine-paracrine regulation of the mammary gland. J. Dairy Sci., 99, 842–853. DOI: 10.3168/jds.2015-9828.

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. DOI: 10.3168/jds.S0022-0302(04)73464-5.

Wright, J.B., Wall, E.H., McFadden, T.B. (2013). Effects of increased milking frequency during early lactation on milk yield and udder health of primiparous Holstein heifers. J. Anim. Sci., 91, 195–202. DOI: 10.2527/jas.2012-5692.

Zucali, M., Bava, L., Tamburini, A., Gislon, G., Sandrucci, A. (2021). Association between Udder and Quarter Level Indicators and Milk Somatic Cell Count in Automatic Milking Systems. Animals, 11, 3485. DOI: 10.3390/ani11123485.

Kuropatwińska, I., Bogucki, M. (2023). Determinants of udder quarter milk yield in automatically milked cows. Acta Sci. Pol. Zootechnica, 22(3), 65–72. DOI: 10.21005/asp.2023.22.3.08

UWARUNKOWANIA PRODUKCYJNOŚCI ĆWIARTEK WYMION KRÓW DOJONYCH AUTOMATYCZNIE

STRESZCZENIE

Celem pracy była analiza wydajności mlecznej ćwiartek gruczołu mlecznego krów dojonych automatycznie, z uwzględnieniem numeru laktacji, okresu laktacji i pory roku, jak również określenie udziału poszczególnych ćwiartek (przednich i tylnych, lewych i prawych) w produkcji mleka ogółem w czasie pojedynczego doju. Analizy przeprowadzono na podstawie danych pozyskanych z jednej z ferm bydła, w której utrzymywano 280 krów rasy PHF, dojonych 4 robotami VMS. Analizowano: wydajność w czasie doju ćwiartek przednich lewych i prawych, tylnych lewych i prawych, stosunek wydajności ćwiartek przednich do tylnych i lewych do prawych. Odnotowano wzrost produkcyjności ćwiartek wymion w laktacjach 1–3, następnie obniżenie w 4 i ponowny wzrost u krów najstarszych. Krowy będące w laktacjach $\geq$5 produkowały więcej mleka niż krowy w 3 laktacji. Biorąc pod uwagę wszystkie doje jedna ćwiartka produkowała średnio 3,81 kg mleka. Wraz z zaawansowaniem laktacji odnotowano spadek mleczności wszystkich ćwiartek wymienia. Obniżenie mleczności ćwiartek gruczołu mlecznego krów w laktacji wyniosło od 1,52 kg (tylne prawe) do 1,78 kg mleka (tylne lewe) i od 1,59 kg (przednie prawe) do 1,70 kg mleka (przednie lewe). Produkcyjność poszczególnych ćwiartek wiosną, latem i jesienią była mało zróżnicowana. W miesiącach zimowych odnotowano natomiast wyraźny jej wzrost. Wraz z kolejnymi laktacjami zmniejszał się udział ćwiartek przednich w całkowitej produkcji mleka - z 46,9% u pierwiastek do 41,2% u krów $\geq$5 laktacji. Udział ćwiartek tylnych w produkcji mleka tym samym wzrastał. Wraz z kolejną laktacją i jej zaawansowaniem pogłębiała się dysproporcja w produkcyjności ćwiartek przednich i tylnych. Porównując lewą i prawą połowę wymienia w obrębie uwzględnionych czynników wykazano podobne ich wydajności.

Słowa kluczowe: krowy, mleko, gruczoł mleczny, ćwiartka, produkcja mleka

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