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ANALYSIS OF PRODUCTION AND REPRODUCTION INDICATOR OF POLISH HOLSTEIN-FRIESIAN CATTLE OIN THREE CONSECUTIVE LACTATIONS

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Abstract. The aim of the research was to determine the productivity and reproduction indices of the Polish Holstein-Friesian Black-and-White variety cows in three consecutive lactations. The research was carried out in the Experimental Station of the National Research Institute Kołbacz on the Dębina farm. The herd of 1025 cows were kept in free-stall barns and fed with TMR system. The yield (kg) of milk, FCM milk, protein and fat was analyzed; content (%) of protein and fat and selected reproductive parameters such as age at the first calving, as well as inter-pregnancy periods and calving interval, period service, postpartum downtime in three consecutive 305-day lactations. The studies indicated that the average yield of milk, fat and protein showed an increasing tendency in the next three lactations. The average protein and fat content were similar. The highest results of these ingredients were obtained in cows in the second lactation. Lactation efficiency influenced the value of the analyzed fertility indices. With the increase in cows’ productivity, the calving interval and inter-pregnancy period, including period service and postpartum downtime, were significantly longer. The longest calving interval and inter-pregnancy period were observed in the third lactation, and the shortest in the first lactation of cows. With the extended of the calving period, the yield of milk, protein, and fat increased. The age at the first calving was the lowest in the 2nd and the highest in the 3rd lactation. The cows calving first for the first time had the highest milk fat content and the shortest calving period. The service period was the longest in the 2nd lactation and occurred in cows with the highest fat content. Postpartum downtime in the studied herd of cows was the longest in the third lactation. The resting period was extended with the increase in the yield of: milk, FCM milk, protein and fat.

Key words: Polish Holstein-Friesian cattle, cows productivity, fertility rates, fat, protein.

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INTRODUCTION

In Poland, over 90% of cows are the Polish Holstein-Friesian (PHF) breed in two varieties: Black-and-Red and White. This name was given by the Polish Federation of Cattle Breeders and Milk Producers in 2005. Cattle of this breed are characterized by an intensive metabolism and the utility type of the PHF cattle is milk. The chest is arched, the ribs are wide, and the udder is roomy, bowl-shaped with a wide base.

The selection of Polish Black-and-Red and White dairy cattle, which has been carried out for many years, and mating with purebred HF bulls, increased their milk yield. The constant supply of raw material stimulated the development and positive changes in the dairy industry. Milk producers have long been interested in factors influencing the increase of cows' productivity. These factors include reproductive rates. Fertility is a key element of effective milk production, and failure to obtain and/or not maintain pregnancy, the so-called sterility (lack of calving) is the main cause of production losses in dairy herds (Pinedo et al. 2020; Ghiasi et al. 2021).

The fertility traits are usually characterized by low heritability, and therefore is difficult to improve them by selection. Environmental factors such as nutrition, condition and animal welfare play a significant role in determining variability.

The aim of the study was to analyze the productivity of Polish Holstein-Friesian Black-and-White cows in subsequent lactations depending on the selected reproductive indicators.

MATERIAL AND METHODS

The research was carried out on 1025 Polish Holstein-Friesian Black-and-White variety cattle. The animals were selected randomly from the herd included in the utility value assessment (cows in 1 lactation of 305 days – 327 animals, 2 lactations 378 animals, and 3 lactations – 320 animals). The cows were kept in the Experimental Station of the National Research Institute Kołbacz on the Dębina farm in a free-stall barn and fed with the TMR (total mixed ration) system. The cows were milked three times in a side-by-side milking parlor equipped with the Afikim milking system and Afilab milking apparatuses for measuring milk.

Based on the source data obtained from the AFIFARM system, analyzes of individual parameters in the lactation system in individual research groups were carried out. In the research, the productivity of cows was analyzed including the yield (kg) of milk, FCM milk (fat corrected milk – milk with 4% fat content), protein and fat; protein and fat content (%) and selected reproductive parameters: age at the first calving, inter-pregnancy period, calving interval, service period, and postpartum downtime. The results for the next three 305-day lactations were analyzed. The results were statistically analyzed with the SAS® statistical program (2015). The significance of differences between the means was estimated using the Student's T-Test and Fisher's LSD (least significant difference) test, using the CORR Sas Enterprise Guide procedure (SAS/STAT 9.4, 2013). The results are summarized in the appropriate tables.

RESULTS

The highest milk yield (kg) in the examined herd of cows (Table 1) was obtained in the 3rd lactation (11 756 kg), the lower in the 2nd lactation (11 105 kg), and the lowest in the 1st lactation (9337 kg).

Table 1. Milk yield and FCM in the investigated herd of cows in the next 3 lactations [kg]

Traits	Lactation					
	1		2		3	
	mean	SD	mean	SD	mean	SD
Milk	9336[a]	2631	11 105[b]	3182	11 756[b]	2953
Milk FCM	3912[Ac]	2340	4617[d]	2701	5076[B]	2599

mean, SD – standard deviation; A, B – P ≤ 0,01; a, b, c, d – P ≤ 0,05.

Based on the obtained results, it can be concluded that the milk yield (kg) increased insubsequent lactations, which is also confirmed by the results of the research by Miciński (2007). A similar upward trend in subsequent lactations is indicated by the obtained results of milk yield corrected for the content of 4% fat (FCM, kg) (Table 1). The highest yield was achieved in cows in the third lactation (5076 kg), lower milk yield was recorded in cows in lactation 2 (4617 kg), and the lowest in the first lactation (3912 kg). There were statistically significant differences between the analyzed parameters (P ≤ 0.01; P ≤ 0.05). Antkowiak et al. (2007) also observed an increase in milk yield and FCM (kg) in subsequent lactations.

The authors state that proper nutrition of high-yield cows is very important because it affects the milk performance and its components, and affects the parameters of fertility, health, and longevity. Von Keyserlingk et al. (2009) argue that proper housing conditions for cattle are necessary to achieve specific production and reproductive parameters of cows. Sobotka et al. (2011) reported a beneficial effect of the TMR feeding system on the milk yield of cows (both daily and annual), the chemical composition of milk and its hygienic quality. According to Januś et al. (2013) the introduction of the TMR complete feeding system increases milk yield as well as its fat and protein content.

In the examined herd of dairy cows, both protein and fat (kg) yield (Table 2) were the lowest in the 1st lactation (129 kg for protein, 150 kg for fat), then higher in the 2nd lactation, and the highest in the 3rd lactation.

Table 2. The yield of protein and fat in cow's milk in the next 3 lactations [kg]

Traits	Lactation					
	1		2		3	
	mean	SD	mean	SD	mean	SD
Protein	129[A]	78,32	157[B]	96,33	176[C]	95,26
Fat	150	91,04	177	104,15	194	97,47

mean, SD – standard deviation; A, B, C – P ≤ 0,01.

Based on the obtained results, it can be concluded that the protein and fat yield (kg) increased in the subsequent lactations. Statistically significant differences (P ≤ 0.01) were recorded in the protein yield in milk. Gnyp (2012) observed in his research that the efficiency of fat and protein (kg) increases with the progress of subsequent lactations. Miciński (2007) obtained similar results in his research, which confirms the obtained results of his own research. Statistical analysis performed for the parameters presented in Table 1 and 2 showed significant

differences between the average yields (kg) of milk, FCM milk (with 4% fat content) and protein in subsequent lactations, while the average milk yield was significantly different in the first lactation, and in the second and third, the average milk yields did not differ significantly. The mean FCM milk and protein yields differed significantly in all analyzed lactations ($P \leq 0.01$; $P \leq 0.05$).

The content (%) of protein in milk of cows in the herd (Table 3) was the lowest in the 1st lactation (3.32), while in the 2nd and 3rd lactation was at the same level (3.39). In turn, the highest fat content was found in lactation 2 (3.84), and the lowest in lactation 3 (3.77).

Table 3. The content of protein and fat in cow's milk in the consecutive 3 lactations [%]

Traits	Lactation					
	1		2		3	
	mean	SD	mean	SD	mean	SD
Protein	3,32	0,35	3,39	0,38	3,39	0,36
Fat	3,78	0,57	3,84	0,61	3,77	0,57

SD – standard deviation.

According to Miciński (2007), along with the increase in milk yield, the protein content decreased, and the fat increased slightly. In his research, Gnyp (2012) showed a decrease in the percentage of protein and fat in milk in subsequent lactations. In turn, in their research, Januś et al. (2013) observed that with the increasing level of efficiency in subsequent lactations, the fat content was as follows: in the first lactation it was higher than in the second and third lactation, and the differences between the fat content in the 1st and 3rd lactations were not significant. The study also covered the protein content in the milk of PHF cows – the protein content was the highest in the 2nd lactation, lower in the 3rd and lowest in the 1st lactation, and the obtained results were significantly different. The obtained results of own research do not correlate with the research results obtained by the above-mentioned authors. It can be concluded that the studies showed no significant effect of milk yield on the percentage of protein and fat in milk.

According to the data for 2020 (PFHBiPM 2021a, b), in Polish Holstein-Friesian Black-and-White cows, the average milk yield in the first lactation was 8,411 kg, in the second lactation 9,254 kg and in the third lactation 9,492 kg. The protein yield in the first lactation was 281 kg, in the second lactation 312 kg and in the third lactation 314 kg. Data on milk fat yield were as follows: in the first lactation 332 kg, in the second lactation 367 kg and in the third lactation 377 kg. The average protein content in the first lactation was 3.34%, in the second lactation 3.37% and in the third lactation 3.31%, and the fat content was 3.95%, 3.96% and 3.97%, respectively.

The percentage of the basic components of milk depends on many factors. It is determined in 65% by the animal's genotype and in 35% by environmental factors (Januś et al. 2013). Guliński and Kłopotowska (2019) attempted to develop a method for determining the typical chemical composition of milk obtained from Polish Holstein-Friesian cows. In their study, indicated that changes in the composition of milk result mainly from the genetic assumptions of animals (their genotypes), which play an essential role in the hormonal regulation of the synthesis of milk components and the level of nutrients. Among all the components of milk, milk fat is the most susceptible to control through nutrition (Guliński et al. 2018). Guliński and Kłopotowska (2019) found that in the population of fully healthy and rationally fed PHF cows, the primary

factor leading to changes in the chemical composition of milk is its efficiency. This factor plays a crucial role in the composition of milk obtained in dairy herds, where rational balancing of rations takes place. Kuczaj et al. (2013), based on the conducted research, showed a significant impact of the cow housing system and milk production on the content (%) of fat and protein in milk – milk obtained from cows kept in a free-stall barns contained less fat and more protein than cows kept in a tie-stall housing system and alcove system. According to the research of Guliński and Socha (2021) the proportion of fat protein influences the characteristics of milk production. A decrease in the ratio from 1.1–1.4 : 1 to >1.7 : 1 meant a reduction in the daily milk yield and lactation milk yield in 305 days and a lower protein and lactose content. High daily loss of milk yield was associated with an increase in the fat-to-protein ratio in milk. It was shown that the ratio of fat to protein was genetically negatively correlated with milk yield for almost every day in milk in every lactation (Satoła and Ptak 2019).

The longest inter-pregnancy period in the analyzed herd of cows (Table 4) was observed in the third lactation (115 days), and the shortest in the first lactation (98 days).

Table 4. Cows between pregnancy and calving in the consecutive 3 lactations [days]

Traits	Lactation					
	1		2		3	
	mean	SD	mean	SD	mean	SD
IPI	98,25[a]	52,61	114,61[b]	64,82	115,49[b]	52,2
CI	–	–	379,47[a]	61,87	407,04[b]	79,06

N – count, mean, SD – standard deviation, a, b – $P \leq 0,05$; IPI – interpregnacy interval; CI – calving interval.

The inter-pregnancy period extended with subsequent lactations. A similar relationship occurred in the calving interval, which is closely related to the length of the inter-pregnancy period. The calving interval was extended in subsequent lactations. The statistical analysis of the conducted studies showed significant differences ($P \leq 0.05$) between the mean inter-pregnancy period in the first lactation and the mean inter-pregnancy periods in the second and third lactation. Significant differences ($P \leq 0.05$) were also noted for the mean calving interval in the 2nd and 3rd lactation. Sitkowska et al. (2009) showed in their research that with the extension of the calving interval, the percentage of milk fat increased, and the protein content decreased, while in their own research such a relationship does not occur. Observations on the effect of the length of the calving interal on the milk yield of cows in each lactation show that the highest average milk yield was obtained in cows in the second and third lactation (Sitkowska et al. 2009), which is confirmed by the results obtained in the analyzed herd. Miciński (2007) in his research, determining fertility based on the length of inter-pregnancy period and calving interval, found that it was related to the level of cows' productivity, deteriorating over the course of subsequent lactations, which corresponds to the results obtained from their own research. Extending the calving interval has a beneficial effect on the yield and chemical composition of milk, and improves reproductive parameters (Neja et al. 2013). According to the research conducted by Burgery et al. (2021) it is possible to extend the calving interval by extending the time until the first post-calving insemination, which may have a positive effect on fertility and health. Some cows may be better suited to the extended calving period than others because of differences in milk yield, lactation persistence or health status, justifying an adjustment of the calving period based on the individual characteristics of the cow.

The age of first calving (Table 5) was the lowest in the second lactation (743 days), higher in the first lactation (747 days) and highest in the third lactation (750 days).

Table 5. Selected breeding parameters in the next 3 consecutive of cows [days]

Traits	Lactation					
	1		2		3	
	mean	SD	mean	SD	mean	SD
AFC	747	85,56	743	70,96	750	88,73
SP	58^{A}	46,98	77^{B}	59,77	66^{C}	50,54
PD	63	21,12	64	20,29	64	18,28

N – count, mean, SD – standard deviation, A, B, C – P ≤ 0,01; AFC – age at the first calving; SP – service period; PD – postpartum downtime.

In the analyzed population of Black-and-White PHF cows, the age at the first calving was on average 799 days (26.2 months) (Chabuz et al. 2016). The estimated coefficients of Spearman's rank correlation between the age of the cows on the day of the first calving and the milk productivity in lactation were very low. A significant relationship was observed only between the age of the first calving and the percentage of fat in milk (Sitkowska et al. 2009). Gołębiewski and Brzozowski (2009), while analyzing the influence of the age at the first calving on reproductive indices, showed a significant influence of this factor on the pregnancy index and delay time, but did not find the influence of the age at the first calving on the average length of the period between insemination. Brzáková et al. (2019) found a positive genetic correlation between the age at the first calving and the period from first calving to re-calving in cows.

The service period (Table 5) was the longest in the second lactation, shorter in the third lactation and the shortest in the first lactation. Statistical analysis of the length of the service period showed significant differences between the average service periods in all tested lactations. According to the research by Bogucki et al. (2007) the shortest period of service is characteristic of cows with the lowest milk yield, and the longest period of service is characteristic for cows with higher milk yield, while in the examined herd of cows, this relationship is present only in the first and second lactation, in the third lactation, despite the increase in milk yield, the service period was shorter. The longest period of service was in the cows in the 2nd lactation, where the cows achieved the highest percentage of fat in milk.

Postpartum downtime, i.e. the mean period from calving to first insemination (Table 5), was the shortest in the 1st lactation, then longer in the 2nd lactation and the longest in the 3rd lactation. Juszczak and Hibner (2000) found in their research that the length of the postpartum downtime did not affect the amount of milk obtained in lactation, but in cows with a prolonged rest period there is an upward trend in lactation efficiency. This relationship has been confirmed in the authors'own research. On the other hand, Gołębiewski and Brzozowski (2009), analyzing the impact of subsequent lactation on the tested reproductive indicators, found that cows in the second lactation were characterized by the lowest values for the postpartum downtime period. The influence of the next lactation of cows on the development of other reproductive indicators was not confirmed.

Gołębiewski and Brzozowski (2009) showed in their research the influence of the housing system on the studied reproductive indicators. They observed more favorable values of the tested reproductive indicators in free-stall barns.

CONCLUSIONS

Based on the research, it was found that the average yield (kg) of milk, fat and protein showed an increasing tendency in the next 3 lactations.

It should be noted that the average content (%) of protein and fat were similar in 3 consecutive lactations. The highest results of these ingredients were obtained in cows in the second lactation. The mean protein content was the lowest in the first lactation and fat in the third lactation.

Lactation efficiency influenced the value of the analyzed fertility indices. With the increase in cows' productivity, the calving interval and inter-pregnancy periods, including postpartum service and downtime, were significantly longer.

The longest calving interval and inter-pregnancy period was observed in the third lactation, and the shortest in the first lactation of cows. With the lengthening of the calving interval, the yield of milk, protein, and fat increased.

The age at the first calving was lowest in the 2nd and highest in the 3rd lactation. The cows calving first for the first time had the highest milk fat content and the shortest calving period.

The service period was the longest in the 2nd lactation and occurred in cows with the highest fat content.

Postpartum downtime in the studied herd of cows was the longest in the third lactation. The resting period was extended with the increase in the yield of: milk, FCM milk, protein and fat.

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ANALIZA PRODUKCYJNOŚCI I WSKAŹNIKÓW ROZRODU KRÓW RASY POLSKIEJ HOLSZTYŃSKO-FRYZYJSKIEJ W TRZECH KOLEJNYCH LAKTACJACH

Streszczenie. Celem pracy była analiza produkcyjności i wskaźników rozrodu krów rasy polskiej holsztyńsko-fryzyjskiej odmiany czarno-białej w 3 kolejnych laktacjach. Badania przeprowadzono w Zakładzie Doświadczalnym PIB Kołbacz na fermie Dębina. Stado liczące 1025 krów utrzymywano w oborze wolnostanowiskowej i żywiono w systemie TMR. Analizie poddano wydajność (kg): mleka, mleka FCM, białka i tłuszczu; zawartość (%): białka i tłuszczu oraz wybrane parametry rozrodu: wiek pierwszego wycielenia, a także okresy: międzywycieleniowy, międzyciążowy, usługi, przestoju poporodowego w 3 kolejnych 305-dniowych laktacjach. W badaniach wykazano, że średnia wydajność mleka, tłuszczu i białka miała tendencję rosnącą w kolejnych 3 laktacjach. Średnia zawartość białka i tłuszczu były zbliżone. Najlepsze wyniki tych składników uzyskały krowy w drugiej laktacji. Wydajność laktacyjna miała wpływ na wartość analizowanych wskaźników płodności. Przy wzroście produkcyjności krów wyraźnie wydłużały się okresy: międzywycieleniowy i międzyciążowy, w tym usługi i przestoju poporodowego. Najdłuższy okres międzywycieleniowy i międzyciążowy zaobserwowano w trzeciej, natomiast najkrótszy w pierwszej laktacji krów. Wraz z wydłużaniem się okresu międzywycieleniowego wzrastała wydajność mleka, białka i tłuszczu. Wiek pierwszego wycielenia różnił się między drugą a trzecią laktacją – krowy cieliły się szybciej w drugiej laktacji. Krowy, które po raz pierwszy wycieliły się najwcześniej, charakteryzowały się najwyższą zawartością tłuszczu w mleku i najkrótszym okresem międzywycieleniowym. Okres usługi (od pierwszego unasienniania do dnia zacielenia) był najdłuższy w drugiej laktacji i występował u krów z największą zawartością tłuszczu. Przestój poporodowy w badanym stadzie krów był najdłuższy w trzeciej laktacji. Okres spoczynku ulegał wydłużeniu wraz ze wzrostem wydajności: mleka, mleka FCM, białka oraz tłuszczu.

Słowa kluczowe: bydło rasy polskiej holsztyńsko-fryzyjskiej, produktywność krów, parametry płodności, tłuszcz, białko.