MILK PRODUCTION AND REPRODUCTIVE PERFORMANCE IN PRIMIPAROUS COWS SIRED BY ELITE SIRES OF BULLS, PROVEN AI BULLS AND YOUNG UNPROVEN AI BULLS

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Abstract. The objective of this study was to analyse the effect of paternal origin – 3 groups of AI bulls: B_E-fathers bulls (elite sires), B_P-proven and B_{UP}-unproven (tested) young bulls, to characteristics of the production and reproduction of their daughters in the first lactation. The breeding values of elite sires of bulls and proven bulls were estimated by comparing their merit indices, including production, fertility, conformation and somatic cell score sub-indices. Daughters of elite bulls were characterized by significantly ($p \leq 0.05$) higher average yields of milk, fat and protein during 305-day lactation, compared with daughters of proven bulls and unproven bulls. Cows sired by elite bulls produced 9 429 kg milk during 305-day lactation, 784 kg milk more than daughters of AI proven bulls, and 1 044 kg milk more than daughters of AI unproven bulls during their significantly shorter lactations. Age at first calving was similar in all groups (778–803 days). ICI was longest (470 days) in daughters of sires of bulls, due to low insemination efficiency and very high milk production in the first lactation. Very high milk production was accompanied by long ICI resulting from low conception rates.

Keywords: milk production, components of milk, elite sires, proven and unproven of AI bulls, breeding value

Introduction. Cow's productivity is largely determined by the sire effect. Research results show that over 75 % of genetic progress is related to sire selection (Kacperska and Kawęcki, 1991, Kamieniecki et al., 1987). Van Tassel and Van Vleck (1991) estimated genetic trends in a dairy cattle population and found that the sires of bulls and sires of cows paths were responsible for 40 % and 30 % of genetic gain, respectively, whereas the dams of bulls and dams of cows paths for 20 % and 10 %, respectively. The role of bulls in herds has increased as they can sire many offspring (Kamieniecki et al., 1999). Appropriate sire selection and the effect of sires on the productivity of their daughters are among the most important considerations in dairy cattle breeding (Majewska et al., 2002).

Liberalization of international trade has facilitated access to the world's animal genetic resources (Strychalski et al., 2014). As a rule, bull mothers are inseminated with the semen of elite progeny-tested Holstein-Friesian sires, mostly from the US, Canada the Netherlands and France. Embryos and young breeding bulls are also imported each year for the purpose of insemination, which promotes genetic progress in the local dairy cattle population (Reklewski, 2011).

Top ranking sires are selected to achieve individual breeding goals in a given country. A number of traits in the categories of milk production and milk composition, including protein and fat yields, should be combined into a selection index to support making the right sire selection decisions (Trela and Choroszy, 2006). Selection indices reflect the genetic goals to be met in dairy cattle populations in a given country. Those goals may vary widely, and therefore selection indices used in each country are different, depending on economic and environmental conditions of milk production as well as the current trends in dairy farming and dairy cattle improvement (Osten-Sacken, 2005). Estimation of breeding value of bulls in Poland takes place through the following steps: selection of bulls to father bulls, cows to mothers of bulls, individual selection of bull's fathers and mothers (individual associations), rearing, individual assessment and selection of bulls, testing insemination, evaluation of breeding value of bulls in terms of the dairy features (milk performance evaluation results and assessment of type and construction of primiparous cows – daughters of the evaluated bull), selection of positively evaluated bulls and admission to the breeding. Breeding value of Polish Holstein-Friesian bulls is determined based on estimated breeding values for milk production features, conformation, fertility, and somatic cells count.

Calculated based on their will, in force since 2007, the breeding value index PF (Production and Functional traits) with sub-indices: comprises production (**PI_PROD**), conformation (**PI_POKR**), fertility (**PI_PŁOD**) and somatic cell score (**WH_KSOM**).

PF = 0.5* PI_PROD + 0.3 * PI_ POKR + 0.1 * PI_PŁOD + 0.1 * WH_ KSOM

The basis for the selection of fathers of breeder bulls evaluated in Poland, according to this index, is the highest breeding value for all the evaluated production and non-production characteristics. Test bulls are a part of the conventional method (insemination testing), as described above, but for the results of the assessment of their daughters they have to wait 3–4 years, after which it will be possible to calculate the PF index, making them priced bulls.

Due to rapid genetic progress and the young age of such sires, their daughters are not expected to produce less milk than daughters of proven AI bulls.

The aim. The aim of the study was to analyse the effect of paternal origin – 3 groups of AI bulls: fathers bulls (elite sires), proven and unproven (tested) young bulls, to characteristics of the production and reproduction of their daughters in the first lactation.

Materials and methods. The studies included cows in the first lactation and were conducted in selected 8 dairy herds enrolled in a milk-recording program. In each of the herds, fathers of primiparous cows were AI bulls: father bulls (elite sires), proven bulls and unproven (tested) young bulls. The breeding value of elite sires and proven AI bulls, is presented as breeding value index PF and the sub-indices. These values have been estimated by the Institute of National Research Institute of Animal Production in Balice (NRIAP 2013). TMR (total mixed ration) feeding system of similar composition was used in all the herds. The cows were milked twice daily using a mechanical milking system. Average annual milk yield per cow in the analyzed herds was 9 000 kg. Eighty six primiparous cows were divided into three groups: group 1 (B_E) - 18 cows sired by elite sires of bulls, group 2 (B_P) – 46 cows sired by proven AI bulls, group 3 (B_{UP}) - 22 cows sired by young unproven AI bulls.

The following indicators of productive performance a 100, 305-day and full lactation in 3 groups primiparous cows. They cover:

– the yields (kg) of milk, milk fat, milk protein, lactose and dry matter,

– the content (%) of milk fat, milk protein, lactose and dry matter during,

Reproductive performance was determined:

– age at first calving (days], insemination index [portions] I and II (first and second service conception rate), length of pregnancy [days], inter-pregnancy interval (IPI) and inter-calving interval (ICI) [days].

Due to differences in the number of cows sired by bulls of the analysed groups, the average advantages (within herds) in milk yield, the yields and content of milk fat, milk protein and dry matter during a 305-day lactation were determined for 3 groups of cows. The values of advantages were summed up to calculate the overall advantage for the progeny of sires of bulls (B_E) vs. the progeny of proven AI bulls (B_P), the progeny of sires of elite bulls (B_E) vs. the progeny of unproven AI bulls (B_{UP}), and the progeny of proven AI bulls (B_P) vs. the progeny of unproven AI bulls (B_{UP}) in each herd. The calculations were performed using the below equations:

$$\mathbf{P_{Be-Bp}} = [(x_{1Be} - x_{1Bp}) + (x_{2Be} - x_{2Bp}) + \\ + (x_{8Be} - x_{8Bp})]/8$$

$$\mathbf{P_{Be-Bup}} = [(x_{1Be} - x_{1Bup}) + (x_{2Be} - x_{2Bup}) + \\ + (x_{8Be} - x_{8Bup})]/8$$

$$\mathbf{P_{Bp-Bup}} = [(x_{1Bp} - x_{1Bup}) + (x_{2Bp} - x_{2Bup}) + \\ + (x_{8Bp} - x_{8Bup})]/8$$

where:

$\mathbf{X_{nBe}}$ - average value of the analyzed trait in daughters of sires of bulls in each (1,2…8) herd

$\mathbf{X_{nBp}}$ - average value of the analyzed trait in daughters of proven AI sires in each (1,2…8) herd

$\mathbf{X_{nBup}}$ - average value of the analyzed trait in daughters of unproven AI sires in each (1,2…8) herd

The yields of milk and major milk components were determined based on data supplied (final reports) by the Polish Federation of Cattle Breeders and Dairy Farmers (PFCBDF). The results were processed statistically, arithmetic means [$\overline{x}$], coefficients of variation [v] were calculated, and one-way non-orthogonal ANOVA was performed using the below model:

$$\mathbf{Y_{ij} = \mu + a_i + e_{ij}}$$

where:

Y_{ij} – value of analysed trait

μ – population mean

a_i – effect of the i-th group of sires

e_{ij} – random error

All calculations were performed in the SPSS ver.18.0 application. The significance of differences between means was estimated by Fisher's LSD test.

Results. The breeding values of elite sires of bulls and measured bulls, whose daughters were analysed in this study, are compared in Table 1. Elite sires of bulls were characterized by a higher selection index based on production and functional traits (PF), and a higher production sub-index ($p \leq 0.01$). The values of conformation sub-indices were similar. The somatic cell score breeding value sub-index was higher in proven AI bulls than in sires of bulls. It is expected that, the higher breeding value of elite sires of bulls be confirmed in higher productivity of their daughters.

The highest daily milk yield is achieved during the first 100 days of lactation. The data in Table 2 show that milk yield in a 100-day lactation exceeded 3 000 kg in all groups of cows, and the differences between groups were statistically non-significant. Daughters of sires of bulls were characterized by the highest milk production (3 209 kg). Daughters of unproven AI bulls produced only 32 kg of milk less. No significant differences were found between primiparous groups in the yields components of milk solids (fat, protein, and lactose).

Milk fat content was similar in all groups of cows (4.04–4.07 %). Significant differences were noted in milk protein content, which reached 3.27% in group B_T and 3.16% in the other two groups.

Table 1. **Breeding values of elite sires of bulls and measured bulls**

Sires AI bulls	Stat. measure.	Breeding values (indices/subindices)				
		PF	PI_PROD	PI_ POKR	PI_PŁOD	WH_ KSOM
fathers bulls (elite sires),	$\bar{x}$	105.2	108.5^A	106.6	102.0	90.5
	v	5.49	7.13	11.04	5.87	9.37
proven bulls	$\bar{x}$	102.6	103.4^B	106.1	99.9	95.4
	v	4.69	4.90	9.45	11.52	9.84
Mean values are significantly different at: A, B - P ≤ 0.01						

Table 2. **Milk production during a 100-day lactation in 3 group primiparous cows**

Specification	Groups of primiparous cows					
	B_E		B_P		B_{UP}	
	$\bar{x}$	v	$\bar{x}$	v	$\bar{x}$	v
Number of cows [N]	18		46		22	
Yield [kg]:						
milk	3209	20.21	3114	17.08	3177	22.11
fat	130	18.15	127	18.52	128	26.87
protein	101	17.78	98	17.65	104	22.60
lactose	159	21.53	155	18.18	158	21.72
dry matter	409	18.55	400	16.16	409	22.24
Content [%]						
fat	4.04	13.87	4.07	16.28	4.04	13.85
protein	3.16^a	0.22	3.16^a	6.77	3.27^b	8.81
lactose	4.94	2.63	4.97	3.23	4.98	3.61
dry matter	12.75	5.06	12.86	5.74	12.87	4.82
Mean values are significantly different at: a,b – P ≤ 0.05; B_E – daughters of AI sires bulls (elite bulls), B_P – daughters of proven AI bulls, B_{UP} – daughters of unproven AI bulls						

Daughters of sires bulls were characterized by significantly (P ≤ 0.05) higher average yields of milk and milk components during a 305-day lactation, compared with daughters of proven AI sires and unproven AI bulls (Table 3). The highest milk production (9 429 kg) was noted in group B_E, and it was 787 kg higher than in group B_P and 1 044 kg higher than in group B_{UP}. The lowest yields of milk and milk components were observed in daughters of young bulls in a progeny-testing program, but the differences relative to daughters of proven AI sires were statistically non-significant.

Table 3. **Milk production during a 305-day lactation in 3 group primiparous cows**

Specification	Groups of primiparous cows					
	B_E		B_P		B_{UP}	
	$\bar{x}$	v	$\bar{x}$	v	$\bar{x}$	v
Number of cows [N]	18		46		22	
Yield [kg]:						
milk	9429^a	20.92	8642^b	22.05	8385^b	22.05
fat	382^a	22.92	343^b	17.76	337^b	24.20
protein	316^a	19.63	287^b	18.61	283^b	21.31
lactose	463^a	22.49	426^b	20.79	415^b	21.93
dry matter	1212^a	20.99	1105^b	18.06	1083^b	21.76
Content [%]:						
fat	4.05	11.77	3.97	13.78	4.02	11.02
protein	3.35	5.59	3.32	6.28	3.38	6.43
lactose	4.91	2.72	4.93	3.58	4.95	3.30
dry matter	12.85	4.01	12.79	5.04	12.92	4.07
Mean values are significantly different at: a,b – P ≤ 0.05; Abbreviations as in the Table 2						

There were no significant differences between groups in the content of the analysed milk components (Table 3). Cows sired by proven AI bulls were characterized by the lowest content of fat, protein and dry matter in milk. Milk from cows by sires of bulls and young unproven AI bulls had a similar fat content (4.05 % and 4.02 %, respectively) and protein content (3.35 % and 3.38 %, respectively).

Milk production parameters during a full lactation in groups of cows are compared in Table 4. Significantly higher yields of milk and milk components were noted in group $B_{E,}$ in comparison with groups B_P ($p \leq 0.05$) and B_{UP} ($p \leq 0.01$). Such a high level of milk production in group B_E resulted not only from the highest breeding values of cows, but also from the length of full lactation, which was 39 days longer than in group B_P cows and 74 days longer than in group B_{UP} cows. During a 416-day lactation, daughters of sires of bulls produced 11 728 kg milk with the highest fat content (4.07 %) and the lowest protein content (3.31 %). High protein content (3.41 %) contained the milk of cows bulls from the other groups.

Table 4. **Milk production during a full lactation in 3 group primiparous cows**

Specification	Groups of primiparous cows					
	B_E		B_P		B_{UP}	
	$\bar{x}$	v	$\bar{x}$	v	$\bar{x}$	v
Number of cows [N]	18		46		22	
Lactation length [days]	416^{Aa}	21.11	377^{b}	20.24	342^{Bc}	15.84
Yield [kg]:						
milk	11728^{Aa}	24.14	10253^{b}	27.37	9160^{B}	21.27
fat	477^{Aa}	25.77	410^{b}	26.48	369^{B}	23.13
protein	388^{A}	23.94	350	26.44	312^{B}	19.49
lactose	574^{A}	25.37	506	25.92	453^{B}	20.48
dry matter	1517^{Aa}	24.49	1320^{b}	25.26	1186^{B}	20.96
Content [%]:						
fat	4.07	11.18	4.00	12.88	4.03	9.96
protein	3.31	5.91	3.41	6.75	3.41	5.82
lactose	4.89	2.77	4.93	3.54	4.95	3.16
dry matter	12.93	3.71	12.87	4.90	12.95	3.73
Mean values are significantly different at: a,b – $P \leq 0.05$; A, B - $P \leq 0.01$; Abbreviations as in the Table 2						

Average advantages in milk yield and the yields and content of milk components determined for groups of cows are presented in Table 5. An analysis performed within herds revealed high advantages in the yields of milk, fat, protein and dry matter during a 305-day lactation in daughters of sires of bulls, relative to advantages in daughters from other groups. The data given in Table 3 point to the absence of significant differences in milk production parameters between cows sired by proven AI bulls and unproven AI bulls, whereas the values of average advantages calculated for both groups within herds are different. Daughters of young bulls in a progeny-testing program ranked higher than daughters of proven AI sires in the yields of milk and milk components during a 305-day lactation. Daughters of young unproven AI sires ranked higher than daughters of proven AI sires and daughters of sires of bulls, and daughters of proven AI sires ranked higher than daughters of sires of bulls only in milk protein content. With respect to the dry matter content of milk, the analysed groups of cows were ranked as follows: daughters of proven AI sires, daughters of unproven AI sires, daughters of sires of bulls.

Table 5. **Average advantages within herds in milk yield and the yields and content of milk components during a 305-day lactation in 3 group primiparous cows**

Parameter	Average advantages		
	$B_E - B_P$	$B_E - B_{UP}$	$B_P - B_{UP}$
milk [kg]	830	569	- 261
fat [kg]	27	20	- 8
fat [%]	0.04	0.01	- 0.03
protein [kg]	19	8	- 10
protein [%]	- 0.060	- 0.084	- 0.024
fry matter [kg]	93	64	- 28
dry matter [%]	-0.099	- 0.046	0.053

Achieved advantage ranking suggests that breeding work in cattle herds, allowing to test and use the semen from bulls of 3 groups (fathers of bulls, priced bulls and tested bulls), indicates the positive impact of tested bulls on productivity of their daughters.

Age at first calving is an important reproductive parameter that affects milk production. Daughters of sires of bulls first calved at the youngest age (26 months); daughters of unproven AI sires and daughters of proven AI sires were 15 days and 25 days older, respectively, at first calving (Table 6). The number of services per conception is another key economic indicator. The data of Table 6 show that 1.5 semen doses were required per successful conception in daughters of proven AI sires, compared with 1.9 semen doses in daughters of sires of bulls and 2.1 semen doses in daughters of unproven AI sires. The differences noted between groups were not statistically significant due to high intra-group variation in the studied trait. The values of insemination index II were 3.6 in daughters of sires of bulls, 2.3 in daughters of proven AI sires and 2.0 in daughters of unproven AI bulls.

Low conception rates in cows sired by sires of bulls (Table 6) resulted in a prolonged IPI (189 days). In daughters of proven AI sires and unproven AI sires, IPI was 38 days and 71 days shorter, respectively (highly significant differences, $p \leq 0.01$). ICI was longest (470 days) in daughters of sires of bulls; in daughters of unproven AI sires, ICI was 72 days shorter (398 days), and the noted difference was statistically significant ($p \leq 0.01$).

Reduced conception rates in daughters of sires of bulls after the first calving could result from high milk production during both 100-day and 305-day lactations (Tables 1 and 2). In this group of cows (B_E), average daily milk yield exceeded 32 kg during the first 100 days of lactation, and it remained high (31 kg) over a 305-day lactation, which points to high lactation persistency. Cows sired by proven AI bulls and unproven AI bulls were characterized by a lower daily milk yield during a 305-day lactation, at 28 kg and 27 kg, respectively.

Table 6. **Reproductive performance of in 3 groups primiparous cows**

Specification	Groups of primiparous cows					
	B_E		B_P		B_{UP}	
	$\bar{x}$	v	$\bar{x}$	v	$\bar{x}$	v
Number of cows [N]	18		46		22	
Age at first calving [days]	778	6.71	803	9.11	793	9.68
Insemination index I (first service conception rate) [portions]	1.9	67.67	1.5	70.59	2.1	58.10
Insemination index II (second service conception rate) [portions]	3.6^A	55.60	2.3^B	58.89	2.0^B	53.85
Inter-pregnancy interval (IPI) [days]	189^A	50.22	151	50.64	118^B	35.51
Length of pregnancy [days]	279	3.31	280	2.07	278	1.70
Inter-calving interval (ICI) [days]	470^A	20.23	431	17.95	398^B	9.85

Mean values are significantly different at: A, B - $P \leq 0.01$
Abbreviations as in the Table 2

Discussion

Properly implemented breeding program allows for achieving breeders of a higher breeding value, which gives a greater genetic progress in the next generation. This is confirmed by the results obtained during the work. The highest protein content in milk of cows after tested bulls can indicate that in the current country program the content of protein in milk was of great importance. Milk of daughters of those bulls in the 305-day lactation contained 3.38 % of protein. Similar protein content (3.39 %) was obtained from Holstein-Friesian (HF) cows in Løvendahl and Chagunda (2011) research.

High milk yield and its chemical composition depends not only on the genetic value of bulls used for breeding, but also on rational nutrition (Sobotka et al., 2011) and optimum welfare of cows. Generally, the analysed groups of heifers were characterized by a higher milk yield in the 305-day lactation than that given by other researchers. In Kuczaj et al., (2008) studies, 8843 kg of milk, with 4.26 % of fat and 3.25 % of protein content, in the 305 days lactation was obtained from Polish Holstein-Friesian cows fed in the TMR (total mixed ration) system. Muir et al., (2004) have achieved Canadian HF heifers' milk production of 7690 kg. In our study, milk yield of heifers exceeded these values significantly. The highest efficiency was achieved in cows after the elite bulls (B_E).

In an era of increased cows productivity, an evaluation of breeding values of bulls, in terms of functional features (Gnyp, 2008, Krychowski, 2006, Konsowicz et al., 2013), is of significant importance. Heifers after the elite bulls were calving earliest. A similar age of cows at the day of the 1st calving, i.e. approximately 778 days, was obtained by Guliński's (2002) research. In the research by In Sobek et al., (2005) conducted on a large population of cows (3457 pcs.), the first calving took place much later. The average age of the 1st calving of Polish Holstein-Friesian heifers, under the milk performance evaluation in 2012, was 829 days (PFCBDF 2013). Løvendahl and Chagunda (2011) reported that age of 1st calving of Canadian Holstein cows was 802 days. Miciński (2009) indicated a good efficiency of a high productivity cows fertilization (1.75–2.50 procedures). Norman et al., (2009) by analysing the breeding parameters of Holstein cows raised in the United States, reported usage of 2.3–2.7 portions of semen/1 successful fertilization.

In our study, the length of 1st pregnancy ranged from 278 to 280 days, therefore it was comparable to the one reported by Blöttner et al., (2011) for a Holstein-Friesian race (280 days). The length of first calving interval in the analysed groups of cows ranged from 398 to 470 days. The delay of the first insemination in high efficiency cows is connected with a longer duration of energy reserves recovery after calving. This has an effect on lengthening of the calving interval. Muir et al., (2004) reported that calving interval of the Canadian population was 395 days, and in Haile-Mariam et al., (2008) research it was lengthened to 415 days.

Acknowledgments. Daughters of sires elite bulls were characterized by significantly ($p \leq 0.05$) higher average yields of milk, fat and protein during a 305-day lactation, compared with daughters of proven and AI unproven sires. Cows sired by elite bulls produced 9 429 kg milk during a 305-day lactation, 784 kg milk more than daughters of AI proven bulls and 1 044 kg milk more than daughters of AI unproven bulls during their significantly shorter lactations. Age at first calving was similar in all groups (778-803 days). ICI was longest (470 days) in daughters of sires of bulls, due to low insemination efficiency and very high milk production in the first lactation. Very high milk production was accompanied by long ICI resulting from low conception rates.

The achieved results indicate that the implemented breeding program is correct in the part concerning the selection and matchmaking of the fathers and mothers of bulls. It is confirmed by sorted advantages of productivity of daughters of individual groups of bulls.

References

1. Blöttner S, Heins B. J, Wensch-Dorendorf M, Hansen L. B, Swalve H. H. Brown Swiss × Holstein crossbreds compared with pure Holsteins for calving traits, body weight, backfat thickness, fertility, and body measurements. J Dairy Sci. 2011. 94(2). P. 1058–1068.

2. Gnyp J. Lifetime dairy production efficiency of cows descending from bulls from various countries. Rocz Nauk PTZ 2008. 4(4). P. 23–30. [in Polish]

3. Guliński P. Production and breeding characteristics of cattle sheds participating in the Polish-Canadian Milk Programme. Part. III. Zesz Nauk AP w Siedlcach. 2002. 61. P. 87–95. [in Polish]

4. Haile-Mariam M., Carrick M. J., Goddard M. E. Genotype by Environment Interaction for Fertility, Survival, and Milk Production Traits in Australian Dairy Cattle. J Dairy Sci. 2008. 91. P. 4840–4853.

5. Kacperska M., Kawęcki A. The age of first calving and milkiness of F1 hybrids after Polish Black-and-White cows and Holstein-Friesian bulls. Rocz Nauk Rol. 1991. 107(4). P. 137. [in Polish]

6. Kamieniecki H., Wójcik J., Czerniawska-Piątkowska E., Szarkowski K. Breeding value of bulls used in SHIUZ Szczecinek depending on the genotype and evaluation order. Zesz Nauk Przegl Hod. 1999. 47. P. 95–103. [in Polish]

7. Kamieniecki K., Stenzel R., Zalewski W. Progeny evaluation of the Polish Black-and-White and Holstein-Friesian bulls in terms of efficiency, milking ability and habit. Zesz Probl Post Nauk Rol. 1987. 332. P. 105. [in Polish]

8. Konsowicz K., Pogorzelska J., Miciński J., Sobotka W., Zwierzchowski G. Relationships between sire effect, milk production in young cows their productive longevity. Med Wet. 2013. 69(10). P. 557–640.

9. Krychowski T. Trends in dairy cattle breeding in the Western Europe – the prospect of a next decade. Przegl Hod. 2006. 5. P. 1–5. [in Polish]

10. Kuczaj M., Kupczyński R., Zielak A., Blicharski P. Klucznik J. Changes in the level of production traits in Polish Holstein-Friesian cows of Black- or Red-and-White variety. . Rocz. Nauk PTZ. 2008. 4(2): 9–17. [in Polish]

11. Løvendahl P., Chagunda M. G. Covariance among milking frequency, milk yield, and milk composition from automatically milked cows. J Dairy Sci. 2011. 94. P. 5381–5392.

12. Majewska A., Czaja H., Wójcik P. Impact of father on the age of first calving and subsequent milk productivity of the Polish Black-and-White first-calf heifers. Zesz Nauk Przegl Hod. 2002. 62. P. 155–159. [in Polish]

13. Miciński J. Milk performance traits and reproduction parameters of high yielding cows during a normal and extended production cycle. Rozprawy i monografie, Wyd. UWM Olsztyn. 2009. 147 P. 1–101. [in Polish]

14. Muir B. L., Fatehi J., Schaeffer L. R. Genetic Relationships Between Persistency and Reproductive Performance in First-Lactation Canadian Holsteins. J. Dairy Sci 2004. 87. P. 3029–3037.

15. National Research Institute of Animal Production (NRIAP). The evaluation of dairy cows use value. Results in 2012. Warszawa 2013. [In Polish].

16. Norman H. D., Wright J. R., Hubbard S. M., Miller R. H., Hutchison J. L. Reproductive status of Holstein and Jersey cows in the United States. J Dairy Sci. 2009. 92(7). P. 3517–3528.

17. Osten-Sacken A. Selection indexes in dairy cattle breeding. Przegl. Hod 2005. 5. P. 9-12.

18. Polish Federation of Cattle Breeders and Dairy Farmers. The evaluation of dairy cows use value. Value - 2012 year. Warszawa 2013. [in Polish]

19. Reklewski Z. The future of dairy cattle breeding in Poland. Zesz Nauk Przegl Hod. 2011. 59. P. 11–28. [in

Polish]

20. Sobotka W., Miciński J., Wróblewski P., Zwierzchowski G. The effect of conventional and TMR feeding systems on feed intake, cow productivity, milk composition and hygienic quality. Rocz Nauk PTZ. 2011. 7(4). P. 87–96. [in Polish]

21. Strychalski J., Gugołek A., Daszkiewicz T., Konstantynowicz M., Kędzior I., Zwoliński C. A. Comparison of selected performance indicators, nutrient digestibility and nitrogen balance parameters in Californian and Flemish Giant rabbits. J Appl Anim Res. 2014. DOI:10.1080/09712119. 2013.875905.

22. Trela J., Choroszy B. Work of the national research institute of animal production on the improvement of dairy cattle breeding in Poland. Wiad Zoot. 2006. XLIV(2). P. 3–10. [in Polish]

23. Van Tassel C. P., Van Vleck L. D. Estimates of genetic selection differentials and generation intervals for four paths of selection. J Dairy Sci. 1991. 74. P. 1078–1086.

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