Relationship between primiparas first 100-days lactation and their lifetime milk production in Polish Holstein-Friesian Cattle

Zależność między wynikami pierwszej 100-dniowej laktacji pierwiastek a wydajnością życiową w stadzie krów holsztyńsko-fryzyjskich

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Abstract

The aim of this study was to identify the relationship between the lifetime performance of cows and their performance during the first 100 days of lactation. The studied material consisted of breeding documentation for 2,347 Holstein-Friesian cows, that were used for milk production between 1995 and 2010, in the Pedigree Breeding Centre in Osięciny. Such parameters as milk yield, fat (kg, %) and protein content (kg, %) were taken into consideration while analysing the results for the first 100 days of lactation and the lifetime milk performance. The study included only animals that had already been culled. Results indicate that the factors affecting the primiparas milk production during the 100-day lactation are as follows: herd, year and season of first calving as well as the age at first calving. It was proven that the sources of variation in the lifetime performance, in terms of the milk yield, fat and protein content, were: herd, year of first calving, age at first calving and the level of milk yield during the first 100 days of primiparas lactation. It was observed that the season of first calving did not significantly affect milk performance traits throughout the cows productive life. The calculated correlation coefficients, mainly of weak relationship between levels of the lifetime performance and the 100-day performance, showed a moderate positive correlation between the percentage content of fat and protein in milk in both periods.

Keywords: age at first calving, lifetime performance, predicting, primiparas

Streszczenie

Celem badań było określenie związku między poziomem wydajności życiowej krów oraz ich wynikami w ciągu pierwszych 100 dni laktacji. Badanie przeprowadzono na podstawie dokumentacji hodowlanej dotyczącej 2,347 krów holsztyńsko-fryzyjskich, które były użytkowane mlecznie w latach 1995 - 2010, w Ośrodku Hodowli Zarodowej w Osięcinach. Zebrano informacje dotyczące produkcyjności mleka, tłuszczu (kg,%) i białka (kg,%). Wzięto pod uwagę wyniki z pierwszych 100-dni laktacji i wydajności życia. Do badania włączono tylko zwierzęta, które zostały już wybrakowane ze stada. Analizy wykazały, że czynnikami wpływającymi na poziom cech mleczności pierwiastek, podczas laktacji 100-dniowej, były: stado, rok pierwszego wycielenia, sezon pierwszego wycielenia oraz wiek pierwszego wycielenia krów. Udowodniono, że źródłem zmienności użytkowości życiowej w zakresie wydajności mleka, tłuszczu i białka były stado i rok pierwszego wycielenia, wiek pierwszego wycielenia oraz poziom wydajności mlecznej podczas pierwszych 100-dni laktacji pierwiastek. Stwierdzono, że sezon pierwszego wycielenia nie wpłynął znacząco na poziom cech mleczności w całym okresie produkcyjnym krów. Obliczone współczynniki korelacji, na ogół o słabych zależnościach między poziomem wydajności 100-dniowych i życiowych, wykazały umiarkowane dodatnie zależności między procentową zawartością tłuszczu i białka w mleku w obu badanych okresach.

Słowa kluczowe: pierwiastki, przewidywanie, wiek pierwszego wycielenia, wydajność życiowa

Detailed abstract

W przedstawionej pracy analizowano długość użytkowania krów w czołowych wysokoprodukcyjnych stadach bydła mlecznego Polski w ciągu 15 lat. Celem prowadzonych badań była próba ustalenia zależności między wynikami ich wydajności w pierwszej 100-dniowej laktacji a poziomem życiowej wydajności krów. W związku z tym obliczono współczynnik korelacji Pearsona pomiędzy powyższymi wydajnościami. W następnym kroku zbudowano modele regresji wielorakiej służące do prognozowania wydajności życiowych na podstawie wyników pierwszych 100-dni laktacji pierwiastek. W modelu opisującym zmienność wydajności życiowej mleka brano pod uwagę wiek pierwszego wycielenia (dni), poziom wydajności mleka w 100-pierwszych dniach laktacji pierwiastek. W modelowaniu cech składu mleka uwzględniano ponadto analogiczną cechę odnoszącą się do wydajności z początkowej laktacji pierwiastek.

W badanym okresie 1995-2010 zaobserwowano skrócenie wieku pierwszego wycielenia krów z 900 dni do 800 dni. Zdecydowanie krótszy wiek pierwszego wycielenia krów stwierdzono już po 2001 roku, utrzymywał się on na poziomie 800 dni do 2009 roku, kiedy przekroczył 820 dni (wyk. 1). Najwyższą wydajność mleczną podczas 100-dniowej laktacji pierwiastek zaobserwowano w grupie krów, których sezon wycielenia przypadał na miesiące wiosenne. Najniższą wydajnością mleka charakteryzowała się grupa zwierząt cielących się po raz pierwszy w miesiącach letnich. Różnice między grupami okazały się wysoko istotne (tab. 2). Czynnik wiek pierwszego wycielenia różnicował istotnie badane zwierzęta pod względem

wydajności mleka, tłuszczu i białka oraz zawartości tłuszczu w mleku (tab. 2). Najwyższy poziom badanych cech stwierdzono w grupie najstarszych pierwiastek, które w momencie pierwszego wycielenia były w wieku powyżej 28 miesięcy życia. Odpowiednio najniższe poziomy tych cech zaobserwowano w grupie pierwiastek o przeszło 100 dni młodszych. Grupa najlepszych pierwiastek, mlecznic w okresie 100-dniowej laktacji osiągała również najwyższe wydajności mleka, tłuszczu i białka za cały okres użytkowania. Różnice w wydajności mleka przekraczały 10 000 kg (tab. 3). Przeprowadzone badania wykazały, że czynnikami warunkującymi poziom cech użytkowości mlecznej pierwiastek w 100-dniowej laktacji były: stado-rok pierwszego wycielenia, sezon pierwszego wycielenia oraz wiek pierwszego wycielenia krów.

Udowodniono, że źródłem zmienności użytkowości życiowej w zakresie wydajności mleka, tłuszczu i białka były stado i rok pierwszego wycielenia, wiek pierwszego wycielenia oraz poziom wydajności mlecznej podczas pierwszych 100-dni laktacji pierwiastek. Zaobserwowano, że sezon pierwszego wycielenia nie wpłynął istotnie na poziom życiowych cech mleczności. Obliczone współczynniki korelacji, na ogół o słabych zależnościach między poziomem wydajności 100-dniowych i życiowych, wykazały umiarkowane dodatnie zależności między procentową zawartością tłuszczu i białka w mleku w obu badanych okresach. Jakość skonstruowanych modeli regresji wielorakiej dowodzi, że przewidywanie życiowej wydajności mleka, tłuszczu i białka, zawartości (%) tłuszczu i białka na podstawie wyników pierwszych 100 dniach laktacji pierwiastek jest ograniczone.

Introduction

The lifetime milk performance of cows is dependent on many factors (Heinrichs and Heinrichs, 2011; Sawa and Krężel-Czopek, 2009), inter alia, on the initial phase of the use of animals and the age at first calving (Bach, 2011; Berry and Cromie, 2009; Cozler, et al., 2008; Ettema and Santos, 2004; Januś and Borkowska, 2012; Nilforooshan and Edriss, 2004; Sitkowska and Mroczkowski, 2005). The early age at first mating, course of pregnancy and beginning of milking, have a huge impact on the animal's body and its future efficiency (Berry and Cromie, 2009; Cozler, et al., 2008). Cows are usually culled from herds too early and as a result the productive life, that is too short, does not allow cows to show their full productive potential and does not guarantee the reimbursement of costs (Brivkell and Wathes, 2011; Cozler, et al., 2008; Januś and Borkowska 2012; Sitkowska and Mroczkowski, 2005). What is more, over the last twenty years, animal's genetics has changed as well (Cozler, et al., 2008).

The primiparas milk yield depends on many factors, but primarily on the age at first calving (AFC). The difference between populations of Holstein dairy cattle in different countries is called AFC median. The age at first calving in Holstein dairy cattle may be country specific , and for instance, in Ireland the average AFC is 25 months (Berry and Cromie, 2009), in England - 26 months (Brickell and Wathes, 2011), in the US and in Iran - about 27 months (Hare, et al., 2006; Nilforooshan and Edriss, 2004). A higher AFC may be found in Italy where it reaches 28 months (Pirlo, et al., 2000).

In the present study the time in which the cow was used in one of the Polish leading highly productive dairy cattle herds, during 15 years, has been analyzed. The aim of this study was to identify the relationship between the level of the lifetime milk performance of cows and their performance during the first 100 days of lactation.

Material and methods

The study was conducted on the basis of the breeding documentation concerning 2,347 Holstein-Friesian cows, used for milk production between 1995 and 2010, in Pedigree Breeding Centre in Osięciny. Such parameters as milk yield, fat (kg, %) and protein content (kg, %) were taken into consideration while analysing the results for the first 100 days of lactation and the lifetime performance The study included only animals that had already been culled.

In order to identify the factors affecting primiparas and multiparas milk performance, the multivariate analysis of variance was applied. In the case of the first age group, such factors were included into the linear model: herd, year of first calving, calving season (spring - March, April, May; summer - June, July, August; autumn - September, October, November; winter - December, January, February), and age at first calving (AFC) (<761; 761-810; 811-860 days). For variance analysis of the primiparas milk performance the linear following model was used (Model 1):

$$y_{ijkm} = \mu + HY_i + S_j + A_k + e_{ijkm},$$

where:

y_{ijkm} – record of mth cow for controlled traits, μ – mean for the whole population, HY_i – i^{th} effect of the herd-year of calving, S_j – j^{th} effect of the season of calving, A_k – k^{th} effect of the age at first calving, e_{ijkm} – random error.

Furthermore, as the source of the variability of multiparas milk performance such factors were included into the model: herd, year of first calving, calving season, age at first calving, and the level of milk yield during the first 100 days of primiparas lactation (<2,900; 2,900-3,299; 3,300-3,750; >3,750). For variance analysis of the multiparas lifetime milk performance the following linear model was used (Model 2):

$$y_{ijklm} = \mu + HY_i + S_j + A_k + C_l + e_{ijklm},$$

where:

C_l – l^{th} category of 100-day milk performance, other abbreviations as in Model 1.

The significance of the differences between means of different groups was tested using the Scheffé test (SAS, 2011).

In order to determine the relationship between 100-day primiparas milk yield and their lifetime performances, the Pearson's correlation coefficients and their significance were calculated. In the next step, multiple regression models were built for predicting the lifetime performance based on the results of the first 100 days of primiparas lactation. The model describing the variation in the lifetime milk yield included age at first calving (days) and level of milk yield, fat and protein content in the first 100 days of primiparas lactation. In the model the features of the milk composition, the parallel trait, concerning the yield of initial period of primiparas lactation, were taken into account. Calculations were made using SAS package (SAS, 2011).

Results and discussion

In this study, the attempt to predict the lifetime performance of cows, based on the results from the first 100 days of their first lactation, was made. The results of the initial period of milk performance were as follows: milk yield - 3,322.7 kg, fat - 126.8 kg, protein - 101.6   kg, fat content - 3.85%, protein content - 3.07%.

During the period between 1995 and 2010 year the reduction of the AFC from 900 days to 800 days was observed. AFC was significantly shorter after 2001, and remained at the level of 800 days till 2009, when it exceeded 820 days (Figure 1). In other countries, in the same period, similar trends were observed, for instance, in the Netherlands and Spain it was shown that AFC decreased over the time (Hare, et al., 2006).
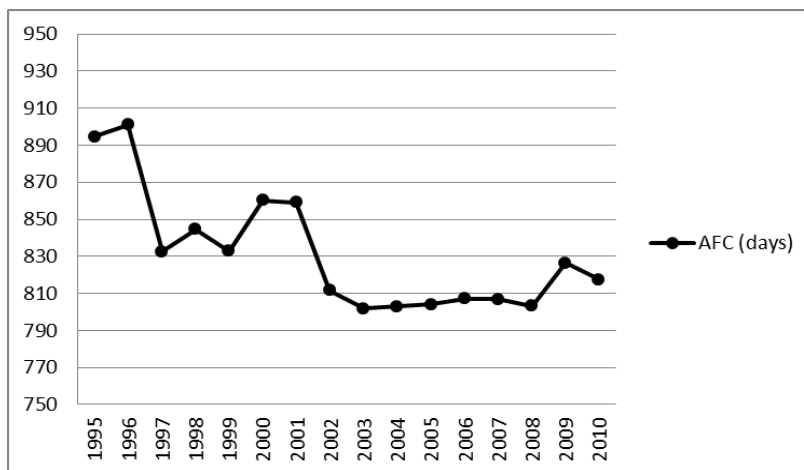

Figure 1. The average age at first calving (days) recorded for primiparas in the estimated period of time

During the examined period it was noted that during the primiparas 100-day lactation, the milk yield increased from 2,500 kg to over 3,500 kg. Until 2007, the primiparas 100-day milk yield did not exceed 3,500 kg, but after that year yield was significantly higher (Figure 2).
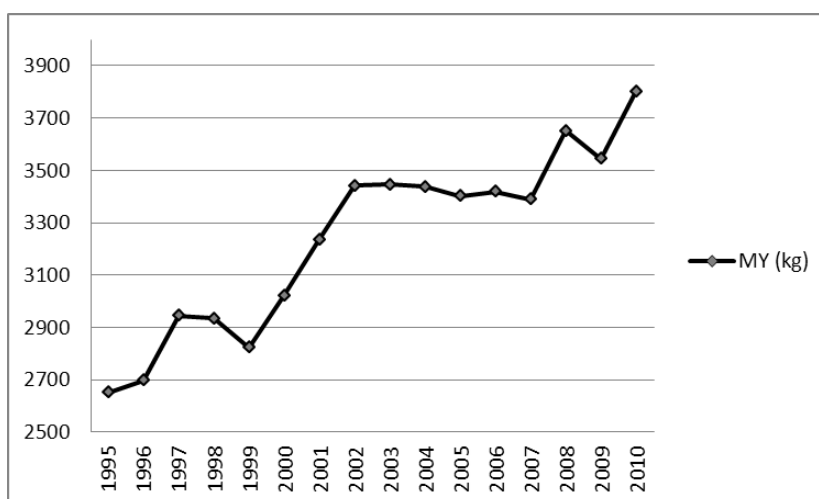

Figure 2. The average milk yield (kg) recorded for primiparas in the estimated period of time

During many years the yield of both protein and fat increased. After the year 2000, during the primiparas 100-day lactation, fat yield exceeded 120 kg, and the protein yield exceeded 95 kg (Figure 3).
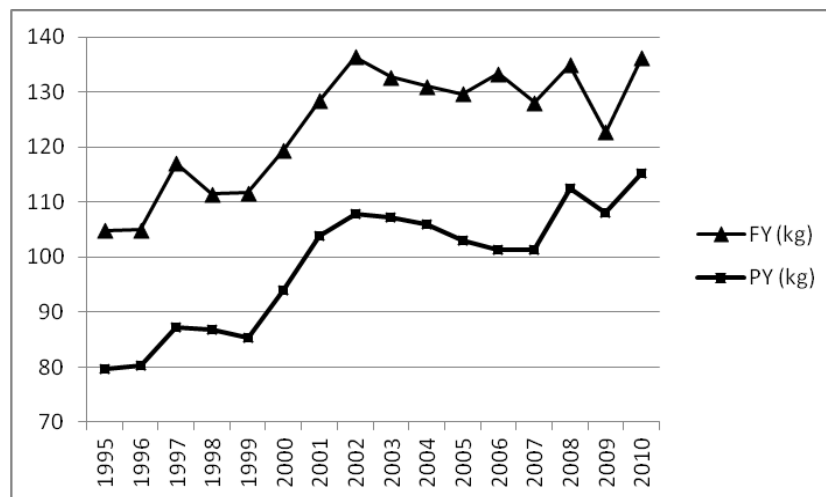

Figure 3. The average fat and protein yield in milk (kg) recorded for primiparas in their first 100-day lactation in the estimated period of time

The fat content (%) in the primiparas 100-day lactation in 2009 ranged from 4% to 3.5%, and the protein content (%) ranged from 3.2% in 2001 to 2.95% in 2006. The percentage of the protein content in milk was characterized by a greater variability (Figure 4).
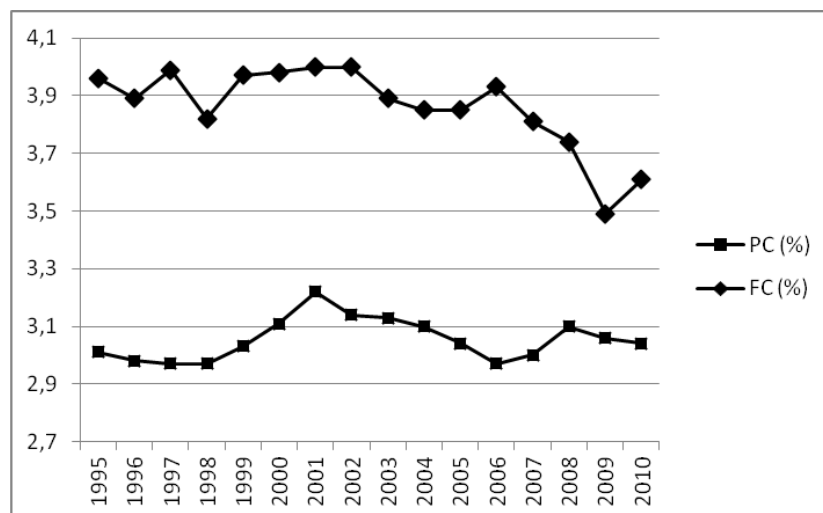

Figure 4. The average fat and protein content in milk recorded for primiparas in the estimated period of time

In the case of milk performance characteristics for primiparas 100-day lactation, such factors were taken into account: herd, year of first calving, season of first calving and AFC. Levels of traits concerning the lifetime milk performance were dependant on:

herd, year of first calving, season of first calving, AFC and the level of milk yield during the first 100 days of primiparas lactation.

All examined factors (herd, year and season of calving and AFC) affected the cow's milk yield during the primiparas 100-day lactation (Table 1). During the cows productive life, herd, year and AFC as well as the level of milk yield in the primiparas 100-day lactation had an influence on the traits connected to the milk yield and milk components. According to Ettema and Santos (2004) and Heinrichs and Heinrichs (2011), AFC has a significant effect on the production of milk during the first lactation. They described a negative effect on milk during the first lactation and on fat and protein content in the first lactation. Nilforooshan and Edriss (2004) reported the association between AFC and the first lactation milk yield in Iranian Holsteins, with the highest yield achieved in the case of heifers that calved at the age of 24 months. The figures describing milk components, especially fat content, were reduced when AFC decreased (Ettema and Santos, 2004).

Table 1. The F_{emp} value and the significance of the estimated factors impact on the milk composition and yield

	100-day performance of primiparas				
Estimated factors	MY100	FY100	FC100	PY100	PC100
Herd-Year	16.20**	10.96**	5.19**	20.18**	6.50**
Calving season	20.47**	34.13**	50.33**	15.73**	58.20**
AFC	8,92**	19.97**	7.47**	9.82**	0.65
	Lifetime performance of cows				
Estimated factors	LMY	LFY	LFC	LPY	LPC
Herd-Year	9.00**	9.25**	5.03**	9.06**	3.94**
Calving season	1.34	1.22	0.97	1.23	0.25
AFC	7.89**	6.95**	2.69*	7.29**	5.49**
Category of 100-day milk performance	55.87**	29.54**	90.15**	45.95**	50.34**

Symbols for tables 1-5 and figures 1-4

MY100 – primiparas 100-day milk yield (kg)

FY100 – 100-day fat yield in the primiparas milk (kg)

FC100 – 100-day fat yield in the primiparas milk (%)

PY100 – 100-day protein yield in the primiparas milk (kg)

PC100 – 100-day protein yield in the primiparas milk (%)

LMY –lifetime milk yield (kg)

LFY – lifetime milk fat yield (kg)

LFC – lifetime milk fat yield (%)

AA(aa) – means marked with the large (small) letters are

significantly at P≤0.01 (P≤0.05)

LPY – lifetime milk protein yield (kg)

LPC – lifetime milk protein yield (%)

AFC – Age at first calving (days)

N – number

AN –autumn

SG – spring

SR – summer

WR – winter

** (*) – highly significant effect (significant))

The highest milk yield during the primiparas 100-day lactation was observed in the group of cows that calved during the spring season. The group of animals calving for the first time during the summer months, was characterized by the lowest milk yield. The differences between groups were highly significant (Table 2). In the research of Svensson and Hultgren (2008), it was shown that cows that calved in summer produced more milk than those calving during other months. In the case of fat and protein productivity and its content in milk during the primiparas 100-day lactation ,

the highest values were noted in the group that was calving during autumn months. The lowest fat and protein yield was recorded in the group of primiparas that started their lactation in the summer season. The lowest content of these components was detected in the milk from cows calving during the spring season. The differences between the levels of the described traits were found to be highly significant (Table 2).

Table 2. Primiparas 100-day milk performance (LSMEAN)

			100-day performance				
		N	MY100	FY100	FC100	PY100	PC100
Calving season	AN	947	3,090.99[AB]	124.25[AB]	4.03[ABC]	96.36[A]	3.11[ABC]
	SG	937	3,198.48[AC]	117.70[ACD]	3.72[ADE]	95.29[B]	2.98[AD]
	SR	832	3,000.30[BCD]	113.97[BCE]	3.83[BDF]	91.77[ABC]	3.06[B]
	WR	1,048	3,131.99[D]	121.78[DE]	3.92[CEF]	96.20[C]	3.07[CD]
AFC	<761	813	3,030.67 [Aab]	115.35[AB]	3.84[a]	92.56[Aab]	3.06
	761-810	1,142	3,111.47 [a]	117.93[C]	3.83[bc]	94.89[a]	3.06
	811-860	861	3,108.99 [b]	120.68[Aa]	3.92[b]	95.36[b]	3.07
	>860	948	3,170.63 [A]	123.75[BCa]	3.93[ac]	96.80[A]	3.06

 The AFC factor significantly differentiated the tested animals in terms of milk, fat and protein yield and fat content in milk (Table 1). The highest levels of traits were noted in the group of the oldest primiparas, which during the first calving were older that 26 months (860 days), while the lowest levels of these traits were observed in the group of primiparas that were more that 100 days younger (Table 2). There are many publications (Berry and Cromie, 2009; Cozler, et al. 2008; Ettema and Santos, 2004; Gardner, et al., 1988; Heinrichs and Heinrichs, 2011) investigating the effect of AFC on the performance throughout the cow's productive life. According to Svensson and Hultgren (2008) and Ettema and Santos (2004), a higher age at calving was associated with a higher milk production. Pirlo et al. (2000) documented an increase in milk yield in the Italian Holsteins (20 - 36 months of age), during the first calving. Age at first calving was also shown to influence calving performance, fertility (Ettema and Santos, 2004) and longevity (Dürr, et al., 1999; Ojango, et al., 2005). In research of Ettema and Santos (2004) as well as Heinrichs and Heinrichs (2011) the age at calving showed negative effects on first-lactation milk, fat and protein content in the first lactation. Extending AFC beyond 750 days did not improve lactation or primiparas health (Ettema and Santos, 2004)

On the basis of the results of cows lifetime milk production, it was found that higher milk, fat and protein yields were observed for animals, which had their first calving season during the summer and autumn and lower levels were observed for cows that started their lactation in spring months (Table 3). Cows that calved during summer and winter, survived slightly longer than those from other groups. In the study of Bach (2011), it was noted that heifers which calved in winter or spring had greater odds of finishing the first lactation than those calving in summer and autumn.

The highest milk, fat and protein yield was found in the milk of cows, which age at first calving was in the range between 761 and 810 days. The level of these traits differed significantly compared to the oldest group of cows (calving after 860 days of age) (Table 3). The oldest primiparas were briefly used for milk production, which influenced their lifetime performance. Age at first calving determines the beginning of the cow's productive life and influences it's lifetime productivity (Ojango and Pollott, 2001). Ojango and Pollott (2001) and Ruiz-Sánchez et al. (2007) indicated that early-maturing heifers were better milk producers. According to Hoffman (1997) calving at less than 22 month of age had a negative influence on milk yield. Nilforooshan and Edriss (2004) found that the optimal age at first calving was between 23 and 24 months. Ettema and Santos (2004) concluded that both too early and too late calving ages had negative effects on cow's productivity.

Table 3. Lifetime milk performance (LSMEAN)

Factors		N	Traits				
			LMY	LFY	LFC	LPY	LPC
Season	AN	591	30,611.49	1,214.46	4.01	997.61	3.25
	SG	585	29,355.20	1,168.02	4.00	956.59	3.25
	SR	497	30,979.25	1,236.35	4.02	1,007.51	3.25
	WR	666	30,681.96	1,212.58	3.98	996.43	3.24
AFC	<761	481	31,074.87[A]	1,218.90	3.96	1,003.61[a]	3.23[Aa]
	761-810	716	31,631.76[B]	1,252.79[A]	3.99	1,028.10[A]	3.24
	811-860	558	31,098.25[C]	1,249.58[B]	4.03	1,016.76[B]	3.27[A]
	>860	584	27,823.02[ABC]	1,110.14[AB]	4.03	909.67[ABa]	3.26[a]
Category of 100-day performance	>2,900	613	24,147.03[ABC]	1,008.56[ABC]	4.20[ABC]	800.51[ABC]	3.31[ABC]
	2,900-3,300	593	28,606.92[ADE]	1,169.21[ADE]	4.10[ADE]	941.19[ADE]	3.28[ADa]
	3,301-3,750	608	32,586.19[BDF]	1,301.67[BD]	3.99[BDF]	1,061.45[BDa]	3.24[BEa]
	>3,750	525	36,287.76[CEF]	1,351.98[CE]	3.72[CEF]	1,155.01[CEa]	3.17[CDE]

The group of the best primiparas and dairy cows, during the whole productive life, reached the highest milk, fat and protein yield in the period of the 100-day lactation. Differences in the milk yield exceeded 10,000 kg (Table 3).

The correlation coefficients between milk, fat and protein yields in the first 100 days of lactation, and the corresponding lifetime performances, indicated the low dependency between these characteristics, respectively: 0.178; 0.186; 0.179 (Table 4). In the study of Sawa and Krężel-Czopek (2009) coefficient of correlation between the first lactation milk yield and lifetime milk yield was 0.452, which was significantly higher than the one reported in or study. Highly significant relationships were shown for the percentage of fat (0.622) and protein (0.570) content (Table 4). The phenotypic correlations between AFC and milk yield were very small and negative (−0.05). It is in accordance with other studies in which AFC and milk yield were

estimated as small and negative (−0.20 to −0.09) (Ruiz-Sánchez et al., 2007; Ojango and Pollott, 2001; Nilforooshan and Edriss, 2004). However, Teke and Murat (2013) reported the moderate positive correlation between AFC and milk yield (r = 0.32; P<0.001).

Table 4. Pearson correlation coefficients between the 100-day and lifetime yields

Traits	AFC	MY100	FY100	FC100	PY100	PC100
LMY	-0.052*	0.177**	0.120**	-0.063**	0.174**	-0.019
LFY	-0.039	0.098**	0.185**	0.107**	0.125**	0.052**
LFC	0.035	-0.248**	0.263**	0.622**	-0.135**	0.270**
LPY	-0.040	0.154**	0.134**	-0.018	0.178**	0.049*
LPC	0.096**	-0.208**	0.084**	0.355**	0.025	0.570**

** (*) – highly significant correlation coefficient (significant)

The regression models, constructed in order to predict the milk, fat and protein yield, were characterized by a poor predictive ability - the adjusted coefficient of determination ranged from 0.031 to 0.037.

Table 5. Assessment of the parameters in regression model and their significance

Variable	LMY	LFY	LFC	LPY	LPC
Intercept	26,662.0000**	1,159.5731**	1.4867**	833.7680**	1.5742**
AFC	-9.2512*	-0.3865*	-0.0001	-0.2423	0.0001**
MY100	3.2076*	-0.1797**	-0.0001*	-0.0695	-0.0001**
FY100/ FC100	0.6527	5.6839**	0.5410**	0.7204	0.0658**
PY100/C100	63.9049	4.9157*	0.2360**	6.7773**	0.4388**
Assessment of the entire model	**	**	**	**	**
Adjusted coefficient of determination	0.0325	0.0380	0.3979	0.0327	0,372

** (P≤0.01), * (P≤0.05) – significance of the model parameter and the full model

Significantly better results in predicting outcome were obtained for fat and protein content, respectively - adjusted coefficient of determination: 0.398 and 0.367. Taking into account the fact that the maximum value of this coefficient is "1", it may be assumed that the possibility of predicting the lifetime milk performance on the basis of the first 100 days of primiparas lactation is very limited.

Conclusions

The study showed that the factors affecting the level of traits of the primiparas milk production, during the 100-day lactation, were: herd, year of first calving and season of first calving as well as AFC.

It was proven that the sources of variation in the lifetime performance, in terms of the milk, fat and protein yield, were: herd, year of first calving, AFC and the level of the milk yield during the first 100 days of primiparas lactation. It was observed that the season of first calving did not affect significantly the level of milk performance traits throughout the cows productive life.

The calculated correlation coefficients, mainly of weak relationship between levels of the lifetime performance and the 100-day performance, showed a moderate positive correlation between the percentage of fat and protein content in milk in both periods.

The quality of the constructed multiple regression models shows that the possibility of predicting the lifetime milk, fat and protein yields as well as fat and protein content (%), on the basis of the first 100 days of primiparas lactation, is limited.

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