ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol., Zootechnica 10 (3) 2011, 55–64*

THE EFFECT OF DAIRY CATTLE MANAGEMENT SYSTEMS ON MILK YIELD, COMPOSITION AND SOMATIC CELL COUNT

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Abstract. The study was conducted on two family farms (herds A and B). The experimental materials comprised Polish Holstein-Friesian cattle raised in 2006–2009. The objective of this study was to compare SCC, the yield and composition of milk from Holstein-Friesian Black-and-White cows kept in the tie-stall and free-stall system for four years. The analysis indicates that cows housed in a tie-stall barn (herd A) were characterized by higher milk performance than cows kept in a free-stall barn (herd B). Milk yield was correlated with SCC in milk in both herds. Yield increase in the A herd was connected with the SCC decrease. Such dependence has not been found in the herd B.

Keywords: cell count, dairy cattle, dry matter, fat, milk yield, protein, somatic milk composition, urea

INTRODUCTION

Recent years have witnessed considerable changes in Polish dairy farms, including in cattle management systems and nutritional regimes, accompanied by genetic improvement of the local dairy cattle. The above changes resulted in a rapid increase in cow productivity and milk production levels, both in herds entered into the Performance Testing Scheme and in the remaining part of the population. Concentration in the dairy industry and an increase in herd size are observed despite a decrease in cattle population.

The ultimate goal of dairy cattle breeding and raising is to produce the largest possible amount of high-quality milk. The value of raw milk is determined by its organoleptic, biochemical and technological properties, as well as cytological and toxicological parameters. The quality of raw milk is evaluated based on fat and protein content, total microbial counts, somatic cell counts (SCC), the presence of undesirable substance, and adulteration [Kroll et al. 1996]. Among the above quality determinants, an important role is played by SCC being a diagnostic criterion of udder health state.

Macrophages and lymphocytes (100–150 000 cells per ml) are the dominant cell types in normal milk from a healthy udder. Elevated somatic cell levels are usually indicative

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of an inflammation of the udder known as mastitis. Cell counts increase substantially in mastitic mammary secretions, and their proportions change, with neutrophilic granulocytes accounting for 95% of the total cell population [Glazer 2000]. Apart from mastitis, somatic cell counts in milk are also affected by the cow's age, breed, lactation stage, milk performance, season, stress, nutritional and housing standards, and the method of milking [Mroczkowski et al. 1999, Ludwiczuk et al. 2001, Malinowski 2001, Stenzel et al. 2001, Giersz and Litwińczuk 2002]. It is estimated that in Poland over 50% of the dairy cattle population suffers of the mammary gland, most of which are asymptomatic (subclinical) [Pytlewski et al. 2002]. Since 1998, SCC has been used as a criterion for raw milk classification at dairy plants, and since 1999 it has been recorded monthly in herds tested for milk performance. Since 2007, somatic cell score has been one of the traits in the Selection Index.

The objective of this study was to compare SCC, the yield and composition of milk from Holstein-Friesian Black-and-White cows kept in the tie-stall and free-stall system for four years.

MATERIAL AND METHODS

The analysis was conducted on two family farms (herds A and B). The materials comprised Polish Holstein-Friesian cattle raised in 2006–2009.

Farm A had an area of 56 ha arable land. Throughout the year, the cows stayed in a tie-stall barn built in 1949, which has been modernized several times since then. There were 69 stalls in the barn, including 57 deep litter stalls and 12 stalls without litter, equipped with rubber mats. Dry cows, heifers and calves were kept in group pens, on deep litter. Herd A was entered into the Performance Testing Scheme in 1998 (A_4 method). Cows and heifers were inseminated with the semen of foreign and Polish Holstein-Friesian bulls (including test bulls). The animals were fed grass-hay silage (in traditional feeding), maize silage, hay (as a supplement), ensiled brewer's spent grain and a concentrate. Diet composition was as follows: maize silage (30 kg), grass-hay silage (ad libitum), brewer's spent grain (4 kg) and concentrated feed offered according to individual needs, based on milk production levels. The cows were milked twice daily using a pipe milking machine. Milk was cooled in a 26 00 l container.

On farm B, covering an area of 52.5 ha arable land, cows were housed in a free-stall barn constructed in 2003, with a roof ridge skylight. The maximum stocking density was 65 animals. The floor of lying boxes was covered with straw, and manure was removed daily. Herd B was entered into the Performance Testing Scheme in 1996 (AT_4 method). Cows and heifers were inseminated with the semen of foreign and Polish Holstein-Friesian bulls (including test bulls). The animals were fed a partially mixed ration (PMR). Both in the summer and in the winter, diet composition was as follows: grass-hay silage, maize silage, dried maize pulp, a farm-made concentrate and commercially available complete pelleted feed. The basal ration, sufficient to produce 20 kg milk, was composed of maize silage (29 kg), grass-hay silage (15 kg), concentrate (2.0 kg) and dried maize pulp (0.1 kg). Cows with a higher daily milk yield were given pelleted concentrated feed from feeding stations, in the amount of 1 kg per extra 2 kg of milk. PMR was administered once daily

in the winter, and twice daily in the summer. The cows were milked twice a day in a 2 x 4 herringbone parlor.

Data concerning properties of dairy usability were taken from the results of utility value evaluation (reports) made for Polish Federation of Cattle Breeders and Dairy Farmers during the period 2006–2009 as well as breeding documentation from the farms.

Milk performance records (in the form of reports) for 2006–2009, provided by the Polish Federation of Cattle Breeders and Dairy Farmers, cow/heifer records and breeding records kept on the investigated farms were analyzed in the study. Milk yield and composition in both cattle herds were determined subject to year, lactation, and SCC. The results were verified and presented in the tables.

RESULTS AND DISCUSSION

Tables 1 and 2 present the number of cows and milk production levels on both farms. In farm A, the herd consisted of 62 dairy cows, while in farm B, the herd comprised 63 animals.

In farm A, an increase in the milk performance of cows observed until 2008 was followed by a decrease. In the first year of the study (2006), average yield per cow was 8 809 kg milk, 364 kg fat (4.13%) and 288 kg protein (3.26%). In 2008, it increased to 9 547 kg milk, 403 kg fat (4.22%) and 318 kg protein (3.33%), which resulted in an increment in milk, fat and protein yield of 738 kg, 39 kg and 30 kg, respectively. Similar yield has been noticed in the last year of analysis. In farm B, milk yield per cow increased from 7 970 kg in 2006 to 8 298 kg in 2007, then it decreased to 7 482 kg in 2008, to reach 8 060 kg in 2009. Feeding was probably crucial factor for yield decrease in every cow lactation group.

A comparison of milk production in both herds showed that cows housed in a tie-stall barn were characterized by higher milk performance. Winnicki et al. [2007] studied the effect of management system on cow productivity and found that average daily milk yield and milk yield per standard-length lactation were higher in the tie-stall system than in the free-stall system. A similar trend was observed by Ziemiński and Ćwikła [2006].

The analyzed herds differed also with regard to milk composition (Tables 1 and 2). An increase in milk yield, observed in successive lactations, was accompanied by an increase in the yield of fat and protein. In herd A, the average fat content of milk ranged from 4.13–4.29%, and the average protein content of milk was in the range of 3.26–3.38%. The above results are highly satisfactory, particularly in view of the high milk performance of cows. The average productivity of cows tested in Poland in 2009 reached 6 935 kg milk, 4.17% fat content and 3.33% protein content [Polish Federation of Cattle Breeders and Dairy Farmers 2010].

Throughout the experimental period, a higher milk yield was noted in cows kept in the free-stall system (herd B), compared with those housed in a tie-stall barn (herd A). Herd B cows had a high average protein content of milk (3.35–3.41%). Dorynek et al. [2002] also noted a higher protein content of milk from cows kept in a free-stall barn with lower yield.

Milk produced on both farms was supplied to the same dairy plant, and it was classified as prime quality milk (Table 3). The allowable limits for the hygienic quality of prime class milk are set at 100 000 bacteria (microorganisms) and 400 000 somatic cells per milliliter [PN–81/A–86002].

Table 1. Milk yield and composition in successive lactations in herd A (tie-stall system)
Tabela 1. Wydajność i skład mleka krów w kolejnych laktacjach w stadzie A (obora uwięziowa)

Parameter Cechy	Year Rok	Lactation – Laktacje				
		first pierwsza	second druga	third trzecia	fourth and subsequent czwarta i dalsze	total razem
Number of cows, head Liczebność krów, szt.	2006	30	18	14	11	73
	2007	20	15	14	8	57
	2008	22	15	12	10	59
	2009	21	16	13	10	60
Milk yield, kg Wydajność mleka, kg	2006	8 014	10 046	9 238	9 200	8 809
	2007	8 511	8 996	10 098	9 260	9 041
	2008	9 122	9 691	9 812	9 746	9 547
	2009	8 609	9 943	10 144	9 217	9 466
Fat, kg Tłuszcz, kg	2006	332	408	383	385	364
	2007	360	389	428	390	386
	2008	362	423	427	417	403
	2009	363	420	443	402	406
Fat, % Tłuszcz, %	2006	4.15	4.06	4.14	4.18	4.13
	2007	4.23	4.33	4.24	4.21	4.26
	2008	3.97	4.46	4.35	4.28	4.22
	2009	4.21	4.22	4.37	4.36	4.29
Protein, kg Białko, kg	2006	265	316	309	301	288
	2007	298	300	335	312	306
	2008	299	332	321	333	318
	2009	276	331	333	301	310
Protein, % Białko, %	2006	3.3	3.15	3.35	3.27	3.26
	2007	3.5	3.34	3.31	3.37	3.38
	2008	3.27	3.43	3.27	3.41	3.33
	2009	3.2	3.32	3.28	3.26	3.26

The average SCC in milk was below 400 000 per ml in herd A, and it ranged from 243 000 to 308 000 per ml in herd B. This suggests that the analyzed milk was obtained from healthy cows or cows with undiagnosed subclinical infections. According to Kamieniecki et al. [2004], SCC in healthy cows should not be higher than 100 000 per cm^3 milk. A free-stall housing system could have contributed to the lower SCC in milk from herd B cows, which is consistent with the findings of other authors. Borkowska and Januś [2002], Dorynek et al. [2002], noted lower SCC in milk from cows kept in free stalls, in comparison with cows housed in a tie-stall barn. Winnicki et al. [2007] reported no differences between the above management systems with respect to SCC in milk.

Table 2. Milk yield and composition in successive lactations in herd B (free-stall system)
Tabela 2. Wydajność i skład mleka krów w kolejnych laktacjach w stadzie B (obora wolno stanowiskowa)

Parameters Cechy	Year Rok	Lactations – Laktacje				
		first pierwsza	second druga	third trzecia	fourth and subsequent czwarta i dalsze	total razem
Number of cows, head Liczebność, osob.	2006	21	17	13	9	60
	2007	20	20	14	10	64
	2008	19	19	15	11	64
	2009	22	17	14	13	66
Milk yield, kg Wydajność mleka, kg	2006	6 825	8 717	8 783	8 261	7 970
	2007	7 658	8 361	8 828	8 747	8 289
	2008	7 367	8 074	7 272	6 915	7 482
	2009	7 263	8 897	8 290	8 524	8 060
Fat, kg Tłuszcz, kg	2006	277	366	369	358	332
	2007	313	339	384	358	343
	2008	294	345	293	310	312
	2009	316	357	370	336	339
Fat, % Tłuszcz, %	2006	4.06	4.19	4.2	4.33	4.16
	2007	4.09	4.05	4.35	4.09	4.13
	2008	4.00	4.28	4.03	4.78	4.17
	2009	4.34	4.01	4.46	3.94	4.21
Protein, kg Białko, kg	2006	229	300	289	274	267
	2007	262	278	305	279	279
	2008	244	279	242	246	255
	2009	249	297	289	273	272
Protein, % Białko, %	2006	3.36	3.44	3.28	3.31	3.35
	2007	3.42	3.33	3.46	3.19	3.36
	2008	3.32	3.46	3.33	3.56	3.41
	2009	3.42	3.33	3.48	3.20	3.37

According to Litwińczuk et. al. [2003], the urea content of milk should be 150–300 mg · l^{-1} at a protein level of 3.2–3.6%. Urea concentrations in the analyzed milk remained in the normal range (Table 3).

The crossing of Polish Black-and-White cattle with Holstein-Friesians resulted in an increase in the height, body weight and productivity of cows, and an improvement in udder shape and udder capacity. Normal udder structure reduces the incidence of udder diseases [Słoniewski 2007]. As demonstrated by Rosochowicz et. al. [2002], a higher proportion of HF genes in cattle improves milk yield but increases disease susceptibility, thus elevating SCC in milk. Stenzel et al. [2001] studied Black-and-White cattle with various percentages of HF genes and found that SCC ranged from 288 000 to 786 000 per ml milk.

Table 3. Milk composition and parameters
Tabela 3. Skład i inne parametry mleka

Parameter Cechy	erd tado	Year – Rok			
		2006	2007	2008	2009
Fat, kg Tłuszcz, kg		364	386	403	406
	B	332	343	312	339
Fat, % Tłuszcz, %		4.13	4.26	4.22	4.29
	B	4.16	4.13	4.17	4.21
Protein, kg Białko, kg		288	306	318	310
	B	267	279	255	272
Protein, % Białko, %		3.26	3.38	3.33	3.26
	B	3.35	3.36	3.4	3.37
CC, ths per ml L , tys. na ml		392	385	390	364
	B	308	243	261	275
rea, mg per l Mocznik, mg na l		258	261	245	231
	B	237	202	169	165
Protein Fat, kg Białko Tłuszcz, kg		652	692	721	716
	B	599	622	567	611
Milk quality class lasa mleka		prime ekstra	prime ekstra	prime ekstra	prime ekstra
	B	prime ekstra	prime ekstra	prime ekstra	prime ekstra

The correlations between SCC in milk, milk yield and milk composition in cattle herds kept in a free-stall barn and a tie-stall barn are shown in Tables 4 and 5. In herd A, an increase in milk yield was correlated with a decrease in SCC. Such a relationship was not observed in herd B. In both herds, SCC had no effect on the content of fat, protein and dry matter in milk, which is consistent with the findings of Borkowska and Januś [2002]. Giersz et al. [2004] studied the correlation between cow genotype and SCC in milk. The cited authors noted the lowest SCC (300 000 per ml) in cows with the lowest proportion of HF genes (1–50%), whereas SCC in milk from Holstein-Friesian cows was by 63% higher (477 000 per ml). The above was most probably due to the high susceptibility of high-yielding cattle to various diseases, including mastitis. In a study by Bogucki and Sawa [2002], the decrease in SCC which accompanied an increase in daily milk yield was more pronounced in cows with a higher percentage of HF genes. These data are indicative of a negative dependence between milk yield and SCC.

Table 4. Correlation between SCC and milk yield and composition in the tie-stall system
Tabela 4. Zależność między LKS a wydajnością i składem mleka krów utrzymywanych uwięziowo

Parameter Cechy		tatistical measure Miary stat.	CC, ths per ml – L , tys. na ml			
			0–100	101–200	201–400	400
Milk yield Wydajność mleka	kg		10 308	9 940	9 319	8 592
		s	2 197	1 148	1 236	2 275
Fat Tłuszcz	kg		441	437	405	398
		s	75	95	53	61
	%		4.31	4.31	4.35	4.26
		s	0.44	0.32	0.24	0.35
Protein Białko	kg		342	322	324	299
		s	65	41	45	39
	%		3.33	3.16	3.48	3.29
		s	0.08	0.18	0.24	0.19
ry matter ucha masa	kg		1 358	1 249	1 254	1 118
		s	249	144	173	327
	%		13.23	13.02	13.45	13.09
		s	0.50	0.50	0.59	0.50

Table 5. Correlation between SCC and milk yield and composition in the free-stall system
Tabela 5. Zależność między LKS a wydajnością i składem mleka krów utrzymywanych wolno stanowiskowo

Parameter Cechy		tatistical measure Miary stat.	CC, ths per ml – L , tys. na ml			
			0–100	101–200	201–400	400
Milk yield Wydajność mleka	kg		7 444	8 416	7 286	7 777
		s	2 717	1 206	1 547	701
Fat Tłuszcz	kg		342	340	322	339
		s	67	38	85	35
	%		4.25	4.07	4.39	4.36
		s	0.60	0.45	0.40	0.26
Protein Białko	kg		296	280	254	256
		s	62	38	62	19
	%		3.37	3.33	3.48	3.30
		s	0.23	0.18	0.21	0.10
ry matter ucha masa	kg		1 102	1 091	982	1 020
		s	196	137	226	85
	%		13.21	12.99	13.43	13.14
		s	0.74	0.50	0.47	0.26

The data presented in Table 6 show that the free-stall system supported the production of prime quality milk in successive lactation. A considerable effect of cow age on SCC in milk was observed by Bogucki and Sawa [2002] who also noted a decrease in milk yield related to an increase in SCC. Ludwiczuk et al. [2001], Stenzel et al. [2001], Sawa and

Piwczyński [2002] arrived at similar conclusions. Dorynek and Kliks [1998] noted the lowest SCC in milk during the first lactation. The recorded value was highly significantly different from the average SCC in the other lactations. SCC increased with cow age, and it reached the highest level in the fourth lactation. In a study by Pytlewski et al. [2002], SCC was highest in the third lactation, and lowest in milk from primiparous cows.

Table 6. Correlation between SCC and successive lactations
Tabela 6. Zależność między liczbą komórek somatycznych a kolejną laktacją

	erd tada	tatistical measure Miary stat.	uccessi e lactations – olejne laktacje						
			first pierwsza	second druga	third trzecia	fourth czwarta	fifth pi ta	si th szósta	se enth siódma
CC L		n	51	38	25	18	13	7	1
			632	557	347	618	553	221	127
		s	797	549	275	606	542	153	–
		n	42	33	28	13	4	–	–
	B		234	185	343	330	692	–	–
		s	204	150	416	272	828	–	–

CONCLUSIONS

The analysis indicates that cows housed in a tie-stall barn (herd A) were characterized by higher milk performance than cows kept in a free-stall barn (herd B). Milk yield was correlated with SCC in milk in both herds. Yield increase in the A herd was connected with the SCC decrease. Such dependence has not been found in the herd B.

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WPŁYW SYSTEMÓW UTRZYMANIA KRÓW NA WYDAJNOŚĆ, SKŁAD ORAZ LICZBĘ KOMÓREK SOMATYCZNYCH W MLEKU

Streszczenie. Analizę przeprowadzono w dwóch gospodarstwach rodzinnych (stado A i B). Materiał badawczy stanowiły krowy rasy polskiej holsztyńsko-fryzyjskiej użytkowane w latach 2006–2009. Celem pracy była analiza porównawcza wydajności i składu mleka oraz liczby komórek somatycznych w mleku krów holsztyńsko-fryzyjskich odmiany czarno-białej w okresie ich 4-letniego użytkowania, utrzymywanych w oborze uwięziowej i wolno stanowiskowej. Przeprowadzona analiza wskazuje, że krowy utrzymywane w systemie uwięziowym (stado A) charakteryzowały się wyższą produkcyjnością w porównaniu z krowami utrzymywanymi w oborze wolno stanowiskowej (stado B). Wystąpiła odmienna zależność między wydajnością mleka a liczbą komórek somatycznych w mleku krów w obydwu stadach. Wolno stanowiskowe utrzymanie krów wpłynęło na pozyskanie mleka wyższej jakości.

Słowa kluczowe: białko, bydło mleczne, liczba komórek somatycznych, mocznik, skład mleka, sucha masa, tłuszcz, wydajność mleka

Accepted for print – Zaakceptowano do druku: 1.08.2011