Archiv Tierzucht 54 (2011) 3, 249-256, ISSN 0003-9438

Effect of housing system and milk yield on cow fertility

Anna Sawa and Mariusz Bogucki

Department of Cattle Breeding, University of Technology and Life Sciences in Bydgoszcz, Faculty of Animal Breeding and Biology, Bydgoszcz, Poland

Abstract

The effect of housing system (tethered vs. loose) and milk yield of 10 358 cows on their fertility was analysed in 1 721 farms from the Pomerania and Kujawy regions of Poland. The GLM, FREQ and CORR procedures of the SAS package were used for statistical calculations. The housing system significantly affected cow fertility, which also depended, both in the first reproductive cycle and over the cows' lifetime, on milk production level after the first calving. A stronger relationship (unfavourable for breeders) between milk production and fertility was found for tethered cows compared to their loose-housed contemporaries. Regardless of the milk production level of first calvers, loose-housed cows showed better fertility

Keywords: cow, housing system, milk yield, fertility

Zusammenfassung

Auswirkung von Haltung und Milchleistung auf die Fertilität

Die Auswirkung der Haltung (angekettet gegenüber frei) und der Milchleistung auf die Fertilität von 10 358 Kühnen wurde in 1 721 Bauernhöfen in den Regionen Pommern und Kujawien in Polen ausgewertet. Für die statistischen Berechnungen wurden die GLM-, FREQ- und CORR-Routinen des SAS-Pakets verwendet. Die Haltung hatte einen signifikanten Einfluss auf die Fertilität der Kühe, die sowohl im ersten Reproduktionszyklus als auch über die gesamte Lebensdauer der Kühe auch vom Milchproduktionsniveau nach dem ersten Kalben abhing. Eine stärkere Beziehung (für Züchter nicht von Vorteil) zwischen Milchproduktion und Fertilität wurde für angekettete Kühe im Vergleich zu ihren freien Artgenossen festgestellt. Frei gehaltene Kühe zeigten unabhängig vom Niveau der Milchproduktion der Erstkalbenden eine bessere Fertilität.

Schlüsselwörter: Kuh, Haltung, Milchleistung, Fertilität

Introduction

Reproduction is not only essential for species survival but also affects the course of breeding and selection and determines the cows' dairy performance. It is also of economic importance because reproductive diseases are the main threat to the economic performance of intensively managed dairy cows (Krzyżewski *et al.* 2004, Studer 1998). Performance test results of cows (PFHBIPM 2009) and research findings (Nebel & McGillard 1993, Sawa & Krężel-Czopek 2009,

Seeland & Henze 2003) indicate that fertility of (especially high-yielding) cows deteriorates, while culling due to infertility and reproductive dysfunction become the main reason for removal of cows from the herd (Dymnicki *et al.* 1985).

Housing systems vary the most in the breeding of cattle, especially cows. In terms of freedom of movement, cows are housed in tie-stall barns (kept in stanchions) or loose-housing barns (freedom of movement in group pen). The tie-stall system is dominant in Poland, accounting for over 98.8 % of all cowsheds according to a 2002 survey (Nawrocki 2009). However, there is a clear tendency towards the loose-housing system. About 80 % of Polish cowsheds use the tie-stall system (Fiedorowicz 2008). Each has its advantages and limitations, and may differentially affect milk quantity and quality, as reported by many authors (Skrzypek 2002). When summarizing the findings of other authors who compared the effect of tethered vs. loose housing on cows' milk performance, health, fertility and behaviour. Zdziarski *et al.* (2002) concluded that none of the systems was clearly superior, although the loose system had some advantage. According to Dorynek *et al.* (2006), the advantages of loose barns include freedom of movement, hoof wear, better milking hygiene (milking takes place in dedicated milking parlours), greater scope for mechanization and automatization of production, easier work for attendants, especially during milking, and the possibility of handling more cows by a single employee. However, compared to the tethered system, the lack of close contact between humans and animals may leave the attendants unaware of the animal's specific characteristics or the first signs of disease, thus resulting in longer treatment or even premature culling. According to Stevenson (2000), the loose housing system reduces individual feed intake control, and feeding errors are known to be the main factor in metabolic diseases and poorer reproductive parameters of the cows.

The aim of the study was to evaluate the effect of housing system and milk yield in first-calf heifers on the level of some fertility traits of cows in their first reproductive cycle and during a cow's lifetime, based on large body of data collected as part of performance testing, concerning fertility of cows in the Kujawsko-Pomorskie province (about 10 % of the Polish population of performance-tested cows).

Material and methods

The study was conducted in the Pomerania and Kujawy regions on 1 721 farms that had at least 10 cows. Data on the housing system (tethered or loose) were provided by breeders using the questionnaire method in 2001. Fertility data were obtained from the Symlek system for 10 358 cows that first calved in 2001 and were used or culled by the end of 2008. Cow fertility in the first reproductive cycle and over the cows' lifetime was described based on:

- calving interval (CI) – number of days between calving and conception.
- rest period (RP) – number of days between calving and first insemination,
- service period (SP) – number of days between first and successful insemination,
- insemination index (II) – number of services per conception.

In the statistical analysis, two-way analysis of variance and the following linear model were used (SAS 2004):

$$Y = \mu + a_i + b_j + (ab)_{ij} + e_{ijk} \quad (1)$$

where μ is the overall mean, a_i is the effect of i-th housing system (tethered or loose), b_j is the effect of j-th milk yield of first calvers (≤5 000, 5 001-6 000, 6 001-7 000, 7 001-8 000 and >8 000 kg), $(ab)_{ij}$ is the housing system × milk yield interaction and e_{jjk} is the random error of observations.

Significant differences were analysed using the Scheffe test.

Frequency of cows culled due to infertility and reproductive disorders was analysed according to the housing system and milk yield of first calvers using Chi-square test of independence (SAS 2004). In addition, correlation coefficients were calculated between the milk yield of first calvers and individual fertility traits of the tethered and loose-housed cows.

Results and discussion

Of the 10 358 investigated and performance tested cows, 8 732 were housed in tie-stall barns and 1 626 in loose-housing barns (Table 4). On most Polish farms, cows are kept in tie stalls (Grodzki *et al.* 2002). According to Fiedorowicz (2008), 80 % of Polish cowsheds currently use the tie-stall system.

The present study was conducted in 1 679 farms with tethered cows and in 42 farms with loose-housed cows. The loose housing system was used in just 2.4 % of the barns, similarly to milk recorded herds in the Mazowieckie province (Reklewski & Dymnicki 2001).

Regardless of the housing system, reproductive parameters were poor, in particular the long CI and low conception rate. Housing system caused statistically significant differences in most fertility traits, with cow fertility in both the first reproductive cycle and over the cows' lifetime also depending on milk production level after the first calving (Table 1). Düring (1987) investigated a high significant effect of the housing system on different fertility parameters.

Table 1
Effect of housing system and milk yield of first calvers on fertility

Parameters	Factors		
	Housing system	Yield	Interaction
Calving interval (CI), first	*	*	*
Calving interval (CI), mean	*	*	*
Rest period (RP), first	-	*	-
Rest period (RP), mean	-	*	-
Service period (SP), first	*	*	*
Service period (SP), mean	*	*	*
Insemination index (II), first	*	*	*
Insemination index (II), mean	*	*	*
Mean number of CI	*	*	*

*significant at $P \leq 0.01$

Loose-housed cows were characterized by better fertility, as reflected in parameters such as CI, SP and II, while RP (its minimum duration is determined by breeders who select cows for insemination) was similar regardless of the housing system at 88 days in the first reproductive cycle and at 90 days on average over the cows' lifetime (Table 2 and 3). The beneficial effect of the loose housing system was more pronounced in the first reproductive cycle (CI shorter by 29 days, SP shorter by 28 days, II lower by 0.55) than over the cows' lifetime (CI shorter by

24 days, SP shorter by 22 days, II lower by 0.43). Nogalski (2006) observed that loose-housed cows had better fertility (CI, SP, II) compared to tethered cows, although the differences were not significant. Kowalski *et al.* (2003) showed that in a loose barn CI was 16 days longer but first service conception rate was 7 % better than for a tethered barn. The percentage of cows treated for reproductive diseases was much lower for those from the loose system. According to Majewska (2006), the first and second CI of loose-housed cows was shorter than for the tethered system, with a lower number of semen doses needed for conception. Likewise, Ernst & Streit (1990) demonstrated that the calving interval of loose-housed cows was significantly shorter than for tethered cows.

Table 2
Effect of housing system and milk yield of first calvers on fertility in the first reproductive cycle

Milk yield, kg	Number of cows		Calving interval, days		Rest period, days		Service period, days		Insemination index	
	Tethered	Loose	Tethered	Loose	Tethered	Loose	Tethered	Loose	Tethered	Loose
≤5 000	2 366	150	378	366	75.3	67.8	24.2	17.9	1.63	1.44
5 001-6 000	1 549	221	401	382	82.6	82.2	36.9	21.3	1.88	1.57
6 001-7 000	1 273	251	426[a]	399[a]	88.6	87.9[C]	53.4[C]	29.5	2.16[F]	1.70[F]
7 001-8 000	805	235	460[A]	422[A]	90.8	94.3[D]	84.6[D]	44.6	2.74[G]	2.00[G]
>8 000	1 156	427	517[B]	467[B]	100.7	105.7[E]	129.9[E]	75.1	3.44[H]	2.39[H]
In general	-	-	436	407	87.6	87.6	65.8	37.7	2.37	1.82

[a]means within lines followed by the same letters differ significantly at $P \leq 0.05$, [A, B, C, D, E, F, G, H]means within lines followed by the same letters differ significantly at $P \leq 0.01$.

Table 3
Effect of housing system and milk yield of first calvers on lifetime fertility

Milk yield, kg	Calving interval, days		Rest period, days		Service period, days		Insemination index		No of calving interval	
	Tethered	Loose	Tethered	Loose	Tethered	Loose	Tethered	Loose	Tethered	Loose
≤5 000	393	380	81.9	77.4	31.0	27.5	1.72	1.62	2.13[K]	1.25[K]
5 001-6 000	410	394	86.8	84.5	40.7	28.0	1.91	1.70	2.65	2.32
6 001-7 000	427[A]	404[A]	88.9	91.3	54.2[D]	32.5[D]	2.18[G]	1.73[G]	2.43	2.12
7 001-8 000	453[B]	418[B]	92.5	92.4	77.2[E]	44.2[E]	2.61[H]	1.96[H]	2.17	2.16
>8 000	492[C]	457[C]	98.8	102.2	108.6[F]	69.3[F]	3.09[I]	2.34[I]	1.90	1.99
In general	435	411	89.8	89.6	62.3	40.3	2.30	1.87	2.26	1.97

[A, B, C, D, E, F, G, H, I]means within lines followed by the same letters differ significantly at $P \leq 0.01$

It was found that the increasing milk yield of first calvers (from ≤5 000 kg to >8 000 kg) had a negative effect on their fertility in the first reproductive cycle (Table 2), especially when the animals were kept in tethered barns. Their CI increased from 378 to 517 days, SP lengthened from 24 to 130 days, and II increased from 1.63 to 3.44. Fertility of loose-housed cows also deteriorated with the increasing milk yield of first calvers, but to a considerably smaller extent. Differences between the values of these parameters in tethered and loose-housed cows increased with the milk production level of first calvers (e.g. for CI from 12 days for the lowest milk production level of first calvers to 50 days for the highest milk production level of first calvers, for SP from 6 to 55 days, and for II from 0.19 to 1.05, respectively). The results

obtained indicate that similarly to Nogalski (2006), loose-housed cows responded more smoothly to the increasing milk yield compared to tethered cows. In our study, the increased milk production level of first calvers was paralleled by the increased RP, more so in loose-housed cows than in their contemporaries from tethered barns. Probably, the energy deficit period was longer in higher yielding cows. As a result of a negative energy balance, cows may remain anoestrous for 40-97 days (Stevenson *et al.* 1997). The first ovulation after calving occurs about 10-15 days after the greatest energy deficit, usually with no concurrent signs of oestrus (Żurek *et al.* 1995). The onset of oestrous cycle after calving is highly correlated after calving with the reinitiation of LH impulses that concur with the cow's biological rhythm, while the onset of LH release is associated with the time of energy deficit after parturition (Canfield & Butler 1990).

The negative effect of the increasing milk yield on cow fertility, shown in the present study, is consistent with the findings of other authors. According to Reklewski *et al.* (2003), it may be due to the fact that daily lactation yield peaks during the period when cows are more likely to conceive, i.e. between 60 and 90 days after calving. The principal reason for reproductive disturbances is the aggravation of the negative energy balance, which leads to intense mobilization of body fat reserves, thus increasing the incidence of metabolic and hormonal disorders and lengthening the period between calving and first oestrus after calving (Reklewski *et al.* 2003). Garnsworthy (2004) and Gong *et al.* (2002) did not observe differences in ovarian activity and signs of oestrus between cows with low and high production potential, but the conception rate of cows with high production potential was lower. This suggests that these cows had normal ovulation, which is evidence of normal gonadotropin secretion, while fertility disturbances could be due to low oocyte quality and disturbances in early embryo development.

The milk yield of first calvers also differentiated fertility over the cows' lifetime (Table 4), but this effect was also smaller than during the first reproductive cycle. Different studies also indicated an antagonistic relationship between higher milk yield and reproductive performance (Bielefeld *et al.* 2004, Nebel & McGillard 1993, Sölkner *et al.* 2000). In addition, fertility and udder health problems are one of the most significant problems affecting commercial milk production (Hinrichs *et al.* 2006).

Table 4
Proportion of cows culled due to infertility and reproductive diseases depending on housing system and milk yield of first calvers

Milk yield, kg	Total number of cows		Cows culled due to infertility and reproductive diseases X^2=401.20**			
			Tethered		Loose	
	Tethered	Loose	Number	%	Number	%
≤5 000	3 262	346	936	28.8	58	16.8
5 001-6 000	1 707	242	588	34.5	58	24.0
6 001-7 000	1 427	280	498	34.9	75	26.8
7 001-8 000	924	264	334	36.2	72	27.7
>8 000	1 412	494	588	41.6	166	33.6
In general	8 732	1 626	2 944	33.8	429	26.4

**$P \leq 0.01$

Nogalski (2006) concluded that in tethered barns an increase in milk yield was paralleled by a decrease in fertility parameters, and in loose barns there was no significant correlation between milk yield and fertility. The same author holds that the loose housing system somewhat weakened the negative effect of high milk yield on reproductive function of the cows.

The results given in Table 5 indicate that the relationship between the cows' milk yield and fertility is higher in tethered barns compared to loose barns. For tethered cows, Nogalski (2006) showed a significant effect of milk yield on fertility parameters, but the correlations for loose-housed cows were not significant. Castillo-Juarez *et al.* (2000) demonstrated that improved housing conditions inhibit the negative effect of high milk yield on cow fertility and health.

The described relationships between milk yield and fertility parameters are confirmed by highly significant correlation coefficients (Table 5) whose values are higher for the first reproductive cycle compared to average lifetime fertility. The results obtained are in agreement with the findings of other authors, who showed that slightly less favourable fertility parameters in cows from the groups with extended CI are compensated by high milk yields, as evidenced by the correlation coefficients ranging from 0.21 to 0.52 (Krzyżewski *et al.* 2004). The unfavourable relationship between milk yield and fertility is attributed to the fact that the highest daily milk yield period takes place during the time intended for cow fertilization, while the high milk yield is paralleled by an increase in reproductive dysfunction (Pösö & Mäntysaari 1996). Nebel & McGillard (1993) showed that selection of cows for milk yield increases the concentrations of somatotropin and prolactin, which stimulate milk secretion, but on the other hand it reduces the concentration of insulin, which acts antagonistically to the above hormones but has a stimulatory effect on the development of ovarian follicles. As a result, higher yielding cows are inseminated later and require a greater number of inseminations per conception (Ouweltjes *et al.* 1996). Our results (Table 2 and 3) support the above statements. According to Swanson (1989), the mammary gland of high-yielding cows has priority over the reproductive system.

Table 5
Coefficient of correlation (r) between milk yield of first calvers and fertility of cows depending on housing system

Parameters	Housing system	
	Tethered	Loose
Calving interval (CI), first	0.56**	0.50**
Calving interval (CI), mean	0.49**	0.49**
Rest period (RP), first	0.21**	0.25**
Rest period (RP), mean	0.16**	0.21**
Service period (SP), first	0.50**	0.42**
Service period (SP), mean	0.46**	0.40**
Insemination index (II), first	0.46**	0.34**
Insemination index (II), mean	0.43**	0.34**
Mean number of CI	0.26**	0.18**

**$P \leq 0.01$

The present findings show a significantly better fertility in cows from the loose housing system. Freedom of movement in the group pen allows animals to freely express their natural instincts and behaviours, which is of particular importance for oestrus control. The better fertility of loose-housed cows is supported by the lower rate of culling due to infertility and reproductive diseases compared to tethered barns (26 % vs. 36 %) (Table 4). Likewise, Majewska (2006) reported that the percentage of cows culled because of infertility was lower in the loose system (41.2 %) compared to the tethered system (56.7 %). It was also shown that the increase in the production level of first calvers caused 2-fold and 1.4-fold increases in culling rate due to infertility in loose and tethered barns, respectively.

In conclusion, regardless of the milk production level of first calvers, loose-housed cows showed better fertility. A stronger relationship (unfavourable for breeders) between milk production and fertility was found for tethered cows compared to their loose-housed contemporaries.

References

Bielefeld JCH, Badertscher R, Tolle K, Krieter J (2004) Influence of systematic effects on fertility traits in Swiss Brown cows. Arch Tierz 47, 537-549

Canfield RW, Butler WR (1990) Energy balance and pulsatile luteinzing hormone secretion in early postpartum dairy cows. Domest Anim Endocrinol 7, 323-330

Castillo-Juarez H, Oltenacu PA, Blake RW, McCulloch CE, Cienfiegos-Rivas EG (2000) Effect of herd environment on the genetic and phenotypic relationships among milk yield, conception rate, and somatic cell score. J Dairy Sci 83, 807-814

Dorynek Z, Pytlewski J, Antkowiak I (2006) Productive life and lifetime productivity of black-and-white cows kept in the loose barn system. Acta Sci Pol Zoot 5, 13-24 [in Polish]

Düring F (1987) Studies on the health situation in Schleswig-Holstein dairy cattle herds. Schriftenreihe des Institutes für Tierzucht und Tierhaltung der Christian-Albrechts-Universität zu Kiel, Heft 35 [in German]

Dymnicki E, Osińska M, Sobczyńska M, Jasiorowski T (1985) Influence of some factors on calving interwal and reasons of culling cows. Zesz Probl Post Nauk Rol 300, 257-262 [in Polish]

Ernst E, Streit P (1990) Calf losses and their causes. Die Michpraxis 28, 208-212 [in German]

Garnsworthy PC (2004) The environmental impact of fertility in dairy cows: a modeling approach to predict methane and ammonia emissions. Anim Feed Sci Tech 112 (1-4), 211-223

Fiedorowicz G (2008) Technology in cattle husbandry including elements of animal production. IBMER Warszawa, 290 [in Polish]

Gong JG, Armstrong DG, Baxter G, Hogg CO, Garnsworthy PC, Webb R (2002) The effect of increased dietary intake on superovulatory response to FSH in heifers. Theriogenology 57, 1591-1602

Grodzki H, Nałęcz-Tarwacka T, Slósarz J, Przysucha T (2002) Changes in cattle number, milk production and quality during the recent years in Polish. Zesz Nauk Prz Hod 60, 221-231 [in Polish]

Hinrichs D, Stamer E, Junge W, Kalm E (2006) Genetic Analysis of Several Disease Categories Using Test Day Threshold Models in German Holstein Cows. Arch Tierz 49, 3-16

Kowalski ZM, Lach Z, Fastyn T (2003) Effect of a housing system on body condition, health and reproduction in dairy cows. Rocz Nauk Zoot, Supl 17, 731-734 [in Polish]

Krzyżewski J, Strzałkowska N, Reklewski Z, Dymnicki E, Ryniewicz Z (2004) Influence of calving interval length in HF cows on milk yield, its composition and some reproduction traits. Med Wet 60, 76-79 [in Polish]

Majewska A (2006) Effect of management system on the calving type and milk yield of holstein-friesians cows. Folia Univ. Agricult Stetinensis, Zoot 250, 127-138 [in Polish]

Nebel RL, McGilliard ML (1993) Interactions of high milk yield and reproductive performance in dairy cows. J Dairy Sci 76, 3257-3268

Nawrocki L (2009) Technology and welfare of cattle. Oficyna Wyd. Politechniki Opolskiej, 222 [in Polish]

Nogalski Z (2006) Effect of milk productivity on fertility in tied and loose-housed cows. Acta Sci Pol Zoot 5, 97-106 [in Polish]

Ouweltjes W, Smolders EAA, Eldik P, Elving L, Schukken YH (1996) Herd fertility parameters in relation to milk production in dairy cattle. Livest Prod Sci 46, 221-227

PFHBIPM - Polska Federacja Hodowców Bydła i Producentów Mleka (2009) The results of milk recording in Poland in 2008 year [in Polish]

Pösö J, Mäntysaari EA (1996) Genetic relationships between reproductive disorders operational days open and milk yield. Livest Prod Sci 46, 41-48

Reklewski Z, Dymnicki E (2001) State of milk production in milk recorded herds in the Mazovian voivodship. Zesz Nauk Prz Hod 55, 81-99 [in Polish]

Reklewski Z, Dymnicki E, Oprządek J, Oprządek A, Krzyżewski J (2003) Relationship between calving interval and insemination coefficient and milk capacity of cows in 305-days lactation. Ann of Warsaw Agricult Univ SGGW 39, 58-65 [in Polish]

SAS (2004) SAS/STAT 9.1 User's Guide, SAS Institute Inc., Cary, NC, USA

Sawa A, Krężel-Czopek S (2009) Effect of first lactation milk yield on efficiency of cows in herds with different production levels. Arch Tierz 52 (1), 7-14

Seeland G, Henze C (2003) Relations between milk yield and fertility after strong increased milk yield. Arch Tierz 46, 103-112 [in German]

Skrzypek R (2002) Somatic cell count in bulk tank milk in relation to management and technological factors. Med Wet 58, 632-635 [in Polish]

Sölkner J, Miesenberger J, Willam A, Fuerst C, Baumung R (2000) Total merit indices in dual purpose cattle. Arch Tierz 43, 597-608

Stevenson JS (2000) Reproductive management of dairy cows in high milk-producing herds. J Dairy Sci 84, 128-143

Stevenson JS, Lamb GC, Hoffman DP, Minton JE (1997) Interrelationhips of lactation and postpartum anovulation in suckled and milked cows. Livest Prod Sci 50, 57-74

Swanson LV (1989) Interaction of nutrition and reproduction. J Dairy Sci 72, 805-814

Studer R (1998) A veterinary perspective of on-farm evaluation of nutrition and reproduction. J Dairy Sci 81, 872-876

Zdziarski K, Grodzki H, Nałęcz-Tarwacka T, Brzozowski P, Przysucha T (2002) The influence of housing system and genotype of cows on the lenght of use and their life time milk performance. Zesz Nauk Prz Hod 62, 29-35 [in Polish]

Żurek E, Foxcroft GR, Kenneyly IJ (1995) Metabolic status and interval to first ovulation in postpartum cows. J Dairy Sci 78, 1909-1920

Received 2 November 2009, accepted 22 March 2011.

Corresponding author:

Anna Sawa
email: sawa@utp.edu.pl

Department of Cattle Breeding, Faculty of Animal Breeding and Biology, University of Technology and Life Sciences in Bydgoszcz, Mazowiecka 28, 85-084 Bydgoszcz, Poland