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THE INFLUENCE OF INBREEDING DEPRESSION ON REPRODUCTION TRAITS - AGE AT FIRST CALVING IN DAIRY COWS

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Abstract

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The aim of this study was to evaluate the effect of inbreeding depression on age at first calving in Holstein and Czech Fleckvieh cows. Only cows with a complete pedigree to the fifth generation were used. Data were collected from 34 farms in the Czech Republic. For proper comparison, each inbred cow (n=1046) was assigned to at least one noninbred equal (n=1046). Inbred and noninbred pairs were matched on characteristics such as identical father, first calving interval occurring at the same farm and calves born in the same year and month (± 2 months). The PROC GLM of SAS® with five fixed effects was applied to all data. Inbred Holstein and Czech Fleckvieh cows and their matched noninbred equals were then divided according to inbreeding coefficient into four (event. five) groups. For Holstein inbred groups: F_X=1.25; F_X=3.125; F_X=6.0-12.0; F_X=25.0; F_X>25; respectively all animals, the following extension of age at first calving was found: +2.7; +6.9; +9.5; +18.5; +26.8; +9.6 days, respectively. While for Czech Fleckvieh inbred groups: F_X=1.25; F_X=3.125; F_X=6.0-12.0; F_X=25.0; respectively all animals, the prolongation of age at first calving was detected on the level +2.3; +3.9; +9.8; +21.3; +9.8 days, respectively. This study showed the negative effect of inbreeding on prolongation of age at first calving. Deterioration in this reproduction trait occurred even at low levels of the coefficient F_X. At higher levels the differences between inbred and noninbred cows were significant (P<0.05-0.01).

Key words: inbreeding, age at first calving, reproduction, Czech Fleckvieh, Holstein

Introduction

Reproduction is a typical quantitative trait of major significance for cattle breeding, not only due to its close relationship to economics but to safeguard general cattle breeding as well. For this reason, considerable attention is given to improving reproductive performance (Stádník et al., 2002). The sire-father's effect has significant importance for reproduction and other traits such as milk production (Stádník and Louda, 1999), exterior (Šafus et al., 2005), and health (Vacek et al., 2007).

One very significant factor that influences these quantitative traits is the level of inbreeding which is the result of combining sire-father and dam-mother and their mutual coefficient of relationship. Inbreeding depression has been evaluated and confirmed not only in groups of numerically smaller breeds (Biedermann et al., 2004; Biedermann et al., 2005; Kallweit and Baulain, 2001; Vries et al., 2006; Kehr et al., 2010), but also in breeds with worldwide large numerical distribution including Holstein cows. Inbreeding is studied as a general problem of breeding (Freyer et al., 2005; Pirchner 2004) and its negative effect has been confirmed chiefly in terms of milk production, a significant economic factor (Parland et al., 2007; Casanova et al., 1992; Miglior 1992, Miglior 1995a, 1995b; Bezdíček et al., 2008). In relation to reproductive traits, the influence of inbreeding depression has been detected mainly on length of service period (Cassell et al., 2003; Hermas et al., 1987; Wall et al., 2005; Hoeschele, 1991; Bezdíček et al., 2007), as well as on number of services and

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conception rate (Hermas et al., 1987), and first calving interval (Smith et al., 1998). Age at first calving is also a important quantitative reproductive trait influenced by the individual's genetics and environment as well.

Smith et al. (1998) studied inbreeding depression in Holstein cowsclassified by the Holstein Association (Brattleboro, VT) from 1983 to 1993. Mixed model estimates of depression per 1% increase in inbreeding were, +0.55 day for age at first calving. Specifically, extension of age at first calving of 5.0 days was found in cows with values of inbreeding F_X = 12.5%.

Ahmad et al. (1973) analysed the pedigree and performance records of 967 pure bred Sahiwal cows and 68 bulls. The coefficient of inbreeding in 325 inbred cows ranged from 0.2 to 33.3% with an average of 6.9 ± 0.3. The average age at first calving showed a decreasing trend with increased inbreeding. The regression of age at first calving on inbreeding was -1.2 ± 2.7 days, however, statistically insignificant.

Thompson et al. (2000a) processed data for calculating inbreeding depression in Holstein cows and found that inbreeding above 10% were clearly associated with higher ages at calving. However, low to moderate levels of inbreeding (<7%) appeared to be associated with the lowest ages at calving, about 3 to 5 days less than noninbred animals. Inbred Holstein cows with F_X > 10% showed increasing age at calving by 26 days.

Similar monitoring was carried out by Thompson et al. (2000b) to evaluate inbreeding effect on production and reproduction traits in Jersey Cattle. Levels of inbreeding >0.10 caused an increase in age at calving. These high levels of inbreeding were associated with 8 to 25 additional days of age at calving, depending on inbreeding class and lactation.

Parland et al. (2007) studied the inbreeding effect on fertility traits in Irish Holstein-Friesians as well. Mean age at first calving was 763 days. The research found a deleterious effect on production and fertility traits. In 12.5% inbred animals there was an increase in age at first calving of 2.5 days. Age at first calving is considered as a significant reproductive trait (Teke and Murat, 2013) and reflects not only an individual's genetic inheritance from sire-father and dam-mother, but also the influence of the environment and specific breeding programme on the farm.

The aim of the present study was to evaluate the impact of inbreeding level on age at first calving in Holstein and Czech Fleckvieh cows. Cow pairs (inbred and noninbred ones) the most similar from the standpoint of genetics and breeding environment were observed and evaluated.

Materials and Methods

Evaluation of the relations between inbreeding level and age at first calving (day) was done separately for Holstein cows (a dairy breed) and Czech Fleckvieh (a breed with dual-purpose meat-milk production) and for both breeds together as well. The study included only cows with a complete pedigree to the fifth generation and year of calving 1996 – 2010. Data were collected from 34 farms in the Czech Republic between years 2000 - 2010. Also, the database of cows of the corporation CRV Czech Republic was used. The confirmation of pedigree (sire-side) was based on conformation of optimal gestation length.

For appropriate comparison, each inbred cow (n=1.046) was assigned to at least one outbreed equal (n=1.046). Inbred cows were matched with their outbreed equals on characteristics such as (1) identical father, (2) first calving interval occurring at the same farm and (3) calves born in the same year and month (± 2 months). Inbred Holstein and Czech Fleckvieh cows and their matched noninbred equals were then divided according to the inbreeding coefficient of inbred cows into four groups (F_X = 1.5-2.3%, F_X = 3.0-5.0%, F_X = 8.0-12.5%, F_X = 25.0%). For Holstein cows there was also a group with the value F_X 25.01- 28.125%. The occurrence of higher F_X coefficients in the Czech Republic is very exceptional. These are random errors occurred in the population.

The level of inbreeding – inbreeding coefficient F_X was calculated as follows (Wright, 1922).

$F_X = \Sigma\, 0.5^{n+\acute{n}+1}(1+F_a)$

Σ = sum over all paths through to common ancestor

n = the number of generations from the sire to the common ancestor

n′ = the number of generations from the dam to the common ancestor

F_a = the inbreeding coefficient of the common ancestor

Data were analysed using PROC GLM of SAS®. The effects of inbreeding and other factors were estimated from the model as follows:

$$Y_{ijkl} = \mu + BREED_i + YEAR_j + INBREEDING_k + BVS_{ijkl} + BVM_{ijkl} + e_{ijkl}$$

where :

Y_{ijkl} = corrected value of age at first calving

μ = mean value

$BREED_i$ = Holstein; Czech Fleckvieh

$YEAR_j$ = year of birth

$INBREEDING_k$ = level of inbreeding (F_X=1.125 - 28.125)

BVS_{ijkl} = breeding value of the sire-father for milk production

BVM_{ijkl} = breeding value of the dam-mother for milk production

e_{ijkl} = residual error.

Differences between estimated variables were tested at the levels of significance P < 0.05 (+), P < 0.01 (++), and P < 0.001 (+++).

Calculations were processed for inbred cows and outbreed equals separately, based on breed (Holstein, Czech Fleckvieh and all animals as well) and also separately in terms of different inbreeding groups F_X = 1.5-2.3%, F_X = 3.0-5.0%, F_X = 8.0-12.5%, F_X = 25.0%; in Holstein also F_X = 25.01-28.125%). Including breeding values in the calculation was to express the quality of the sire and dam. Processing of breeding value data and monitoring of reproduction traits were completed toward December 2010. In this study were excluded sires in natural service.

Results

The impact of inbreeding level on age at first calving was evaluated in Holstein and Czech Fleckvieh cows by comparing this reproductive character in inbred and noninbred cows. Table 1 shows basic statistics for Holstein cows and Table 2 the values for Czech Fleckvieh cows. These show clearly the minimum and maximum values, variability (s_x) and average. The results are presented separately for each inbreeding group. In comparison to variability, there was a higher s_x value for inbred animals. This greater variability can be observed for all inbred groups and in both breeds. The highest variability was found for inbred animals with higher levels of F_X. For example, for the Holstein breed there were s_x values for inbred cows F_X=1.25% (s_x=78.54); 25% (s_x=85.16) and 25% and more (s_x=90.45). A similar tendency was found for Czech Fleckvieh where the variability was F_X=1.25% (s_x=81.81) and in 25% (s_x=90.07).

The Holstein as a breed specialised for milk production is considered generally breed with early maturity. On the other hand, Czech Fleckvieh, a breed with dual-purpose meat-milk production, is a breed with a moderate maturity. Average age at first calving corresponds with this fact and they are shown in Table 3. Noninbred animals of the Holstein breed reached an average of 813.2 days, while for Czech Fleckvieh cows the average age at first calving was 832.4 days.

The age at first calving is a reproductive trait that is significantly affected by inbreeding depression. This is evident in this study in Holstein and Czech Fleckvieh cows as well. The influence of inbreeding depression as extension of age

Table 1
Basic statistical parameters of Holstein cows

F_X	Trait	n	Inbred cows				Noninbred cows			
			min.	max.	s_x	avg.	min.	max.	s_x	avg.
1.25	F_X	167	1.25	1.562	0.0665	1.27				
	AFC	167	654.3	1009.3	78.54	812.3	698.2	1026	62.03	809.5
	BVS	167	-226	2022	432.3	655.8	-226	2022	432.3	655.8
	BVM	167	-560	1816	338.4	92.2	-490.8	1235	286.5	88.7
3.125	F_X	201	2.5	3.125	0.0121	3.12				
	AFC	201	653.6	1149.1	71.51	801.41	687	977.9	55.94	794.5
	BVS	201	-609	2022	463.49	784.34	-609	2022	463.49	784.34
	BVM	201	-705	948	303.26	67.02	-518	950	274.9	67.12
6-12	F_X	67	4	12.5	1.8151	6.5				
	AFC	67	705.28	1009.3	69.39	808.59	687	1017	65.36	799.2
	BVS	67	-222	1648	425.83	663.66	-222	1648	425.83	663.66
	BVM	67	-895	1064	329.63	193.58	-541.5	902	324.5	189.2
25	F_X	119	25	25	0	25				
	AFC	119	638.3	1064	85.16	820.34	628	1034	82.55	804.3
	BVS	119	-333	1740	442.87	115.85	-333	1740	442.87	115.85
	BVM	119	-1020	1020	324.3	-15.52	-744	760	276.58	22.42
25.1-28.125	F_X	39	25.78	28.125	0.7580	26.42				
	AFC	39	673.9	1044.3	90.45	825.33	684.8	1002	76.63	799.22
	BVS	39	-168	1343	525.75	510.15	-168	1343	525.75	510.15
	BVM	39	-583	724	339.71	103.33	-530	903	321.58	124.85

AFC=Age at first calving (in months); BVS=Breeding value of sire (kg Milk); BVM=Breeding value of mother (kg Milk) at first calving is shown in Table 3 according to breed and tab. IV for all monitored animals.

These show the trend to deterioration of this trait with increase in inbreeding. Within the comparison of the individual inbred Holstein groups (F_X=1.25; F_X=3.125; F_X=6.0-12.0; F_X=25.0; F_X>25; all animals) and the noninbred ones, the following extension of age at first calving in inbred cows was found: +2.7; +6.9; +9.5; +18.5; +26.8; +9.6 days. For Czech Fleckvieh inbred groups (F_X=1.25; F_X=3.125; F_X=6.0-12.0; F_X=25.0; all animals) compared to noninbred contemporaries

Table 2
Basic statistical parameters of Czech Fleckvieh cows

F_X	Trait	n	Inbred cows				Noninbred cows			
			min.	max.	s_x	avg.	min.	max.	s_x	avg.
1.25	F_X	37	1.25	1.56	0.0848	1.28				
	AFC	37	693.12	1003.2	81.81	828.28	743.3	933.3	45.72	826.4
	BVS	37	-74	1351	378.01	601.24	-74	1351	378.01	601.24
	BVM	37	-313	601	-265.64	62.08	-369	560	249.9	56.12
3.125	F_X	226	3.125	3.215	0.0084	3.126				
	AFC	226	608	1076.2	81.34	823.21	659.7	1137	64.78	819
	BVS	226	-731	1508	426.14	564.51	-731	1508	426.14	564.51
	BVM	226	-651	881	253.38	67.99	-720	972	238.5	76.5
6-12	F_X	43	4	12.5	2.8550	6.21				
	AFC	43	732.64	1070.1	80.83	809.47	753.9	986.5	57.53	800.9
	BVS	43	-264	1351	464.46	684.76	-264	1351	464.46	684.76
	BVM	43	-367	693	183.38	198.35	-300	506	160.9	199.1
25	F_X	147	25	25	0	25				
	AFC	147	695.6	1184.7	90.07	830.87	694.6	1038	66.5	803.6
	BVS	147	-1520	1314	486.20	64.19	-1520	1314	486.20	64.19
	BVM	147	-1200	1020	327.83	-28.55	-712	1020	249.21	11.43

AFC=Age at first calving (in months); BVS=Breeding value of sire (kg Milk); BVM=Breeding value of mother (kg Milk)

Table 3
Inbreeding depression on age at first calving (in days) in Holstein and Czech Fleckvieh cows

			Holstein				Czech Fleckvieh			
			Inbreeding		Difference	P	Inbreeding		Difference	P
			YES	NO			YES	NO		
F_X	1.25	n	167	167	2.7	NS	37	37	2.3	NS
		LSM	827.8	825.1			837.5	835.2		
	3.125	n	201	201	6.9	NS	226	226	3.9	NS
		LSM	801.2	794.3			833.2	829.3		
	6.0 - 12.0	n	67	67	9.5	NS	43	43	9.8	NS
		LSM	817.3	807.8			870.0	860.2		
	25.0	n	119	119	18.5	NS	147	147	21.3	*
		LSM	834.9	816.4			843.7	822.4		
	25.01-28.125	n	39	39	26.8	NS				
		LSM	806.9	780.1						
Σ		n	593	593	9.6	*	453	453	9.8	*
		LSM	822.8	813.2			842.2	832.4		

NS = non significant; P < 0.05 (*)

the extension of age at first calving in days was: +2.3; +3.9; +9.8; +21.3; +9.8. The significant differences (P<0.05) were detected between inbred and noninbred groups consisted of both breed animals. . This is depicted graphically as inbreeding depression for separate breeds (Figure 1).

The total representation of inbreeding depression for all animals (n= 1046; Holstein = 593; Czech Fleckvieh = 453) is shown in Table 4. Extension of age at first calving for individual inbred groups F_X=1.25; F_X=3.125; F_X=6.0-12.0; F_X=25.0; F_X>25; respectively all animals was: +2.7; +5.4; +9.3; +20.1; +26.8; respectively 9.6 days. The differences between inbred and noninbred cows of both breeds at the level of inbreeding F_X = 25 % were statistically significant (P<0.01).

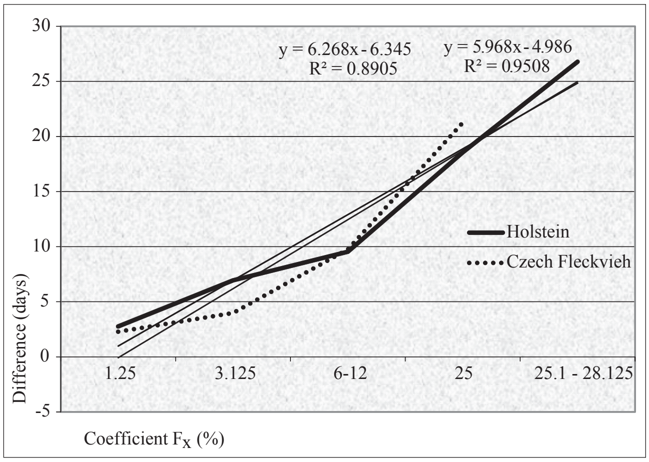

Fig. 1. Graphic evaluation of inbreeding depression in age at first calving in Holstein and Czech Fleckvieh cows

Statistical significance of individual effects applied in mathematic models evaluating effect on age at first calving is shown in Table 5. Coefficients of determination expressing the proportion of explainable variance, varied in terms of separate inbred groups at intervals 0.1086 to 0.3194. For inbred groups F_X 1.25 to 12.0% the difference was highly significant (P<0.0001), for the group with F_X = 25.0 it was also highly significant P<0.0012 as it was for the group with the highest inbreeding F_X =25.01 to 28.125, P<0.0139.

Discussion

Extension of age at first calving for inbred cows of different breeds has also been described by other authors (Ahmad et al., 1973; Thompson et al., 2000 a, b; Smith et al., 1998; Parland et al., 2007). For example Smith et al. (1998) reported an extension of age at first calving in Holstein inbred cows (F_X =12.5%) of 5 days. Thompson et al. (2000a) found in Holsteins that inbred cows with F_X > 10% showed increased age at calving of 26 days. Similarly in Jersey cows, Thompson et al. (2000b) found that a level of inbreeding greater than 0.10 was clearly associated with higher age at calving (increase of up to 25 days). Parland et al. (2007) also confirmed the negative influence of inbreeding on fertility traits in Irish Holstein-Friesians. In 12.5% of inbred animals increase in age at first calving was 2.5 days. Despite the obvious negative influence of inbreeding on age at first calving, some authors have pointed to the statistical insignificance of results (Ahmad et al., 1973), especially at

Table 4
Effect of inbreeding and its level on age at the first calving (in days) of all cows observed

			Inbreeding		Difference	P
			YES	NO		
F_X	1.25	n	204	204	2.7	NS
		LSM	830.2	827.5		
	3.125	n	427	427	5.4	NS
		LSM	815.1	809.7		
	6.0 - 12.0	n	110	110	9.3	NS
		LSM	845.6	836.3		
	25.0	n	266	266	20.1	**
		LSM	844.7	824.6		
	25.01-28.125	n	39	39	26.8	NS
		LSM	806.9	780.1		
Σ		n	1046	1046	9.6	**
		LSM	829.5	819.8		

NS = non significant; P < 0.01 (**)

Table 5
Statistical significance of effects used in the models on age of cows at first calving according to different level of inbreeding

		F_X=1.25	F_X=3.125	F_X=6.0-12.0	F_X=25.0	F_X=25.1-28.125
Model	P	<.0001	<.0001	<.0001	<.0012	<.0139
	r^2	0.2052	0.1007	0.3061	0.1086	0.3194
Inbreeding	P	0.6786	0.2430	0.2840	0.0040	0.1309
	F-test	0.17	1.36	1.15	8.38	2.34
Breed	P	0.4837	<.0001	0.0004	0.0029	
	F-test	0.49	21.36	13.09	8.94	
Year	P	<.0001	<.0001	0.0062	0.0156	0.0184
	F-test	3.81	2.80	2.13	1.72	2.38
Breeding value sire	P	0.1238	0.0558	0.7789	0.1200	0.2631
	F-test	2.38	3.67	0.08	2.43	1.27
Breeding value dam	P	0.0017	0.1182	0.0054	0.2383	0.3301
	F-test	10.01	2.45	7.9	1.39	0.96

lower levels of the coefficient F_X. It is therefore important to be aware of the level of coefficient of determination and statistical significance of mathematic model.

Conclusion

This study showed the detected negative effect of inbreeding on age at first calving in Holstein as well as Czech Fleckvieh cows. Deterioration in this reproduction trait occurred even at lower levels of the coefficient F_X. At higher levels the differences between inbred and noninbred cows were more significant. In inbred animals there was more variability represented by the s_x value.

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