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RELATIONSHIP BETWEEN INBREEDING AND DAILY MILK PRODUCTION IN HOLSTEIN COWS

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ABSTRACT

The aim of this study was to evaluate the effect of inbreeding on milk production in Holstein cows (milk in kg; fat and protein content in %) during the first five daily milk controls (first lactation). This period is very important because is associated with a large increase in milk production and with total milk production at lactation. Daily production of inbred cows (F_x = 3.125 − 25 %) and their non-inbred half-sisters (F_x = 0) was compared. The non-inbred half-sisters had the same sire, the calving was carried out on the same farm, in the same year (± 2 months) and the dam reached a similar breeding value for kg of milk (± 5 %). The degree of inbreeding was evaluated to the fifth generation. Statistical evaluation was carried out using paired tests and ANOVA (GLM) − in a program Statistica®. The following fixed effects were included in the calculation: degree of inbreeding, somatic cell count, relative breeding value of sire and dam. The results showed a trend to the negative impact of inbreeding on daily milk production at the first and second controls. There is also an obvious tendency to lower milk production in the case of a higher somatic cell count.

Key words: inbreeding; daily milk production; dairy cattle

INTRODUCTION

The first and second daily milk control is very important in monitoring cattle milk production. This period is associated with a large increase in milk production, which has a major impact on total milk production during the lactation (305 days). For this reason, attention must be paid to the beginning of lactation, nutrition and health in particular. In addition to external factors, genetic factors also play an important role. From the genetic viewpoint, milk production is a typical quantitative trait. Thus, consideration should be given to population genetic factors, such as heterosis effects and its counterbalance − inbreeding depression. A number of studies have shown that milk production during lactation is significantly affected by inbreeding level. However, there are fewer published studies of the relationship between inbreeding and daily milk production.

The aim of this study was to evaluate the effect of inbreeding within the first five daily milk controls (from 30 to 150 days after calving; milk recording in the Czech Republic uses the method A4 = interval between controls is 4 weeks) and to determine differences in milk yield between inbred and non-inbred animals.

The effect of inbreeding on milk production has been proven in a number of studies. The relationship has been studied from different viewpoints, such as the effect of incomplete pedigree (Cassell *et al*., 2003; Lutaaya *et al*., 1999), study of expression of recessive genes (Van Raden and Miller, 2006), studies of SNP markers (Bjelland *et al*., 2013) and in terms

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of inbreeding depression in large populations (the Holstein breed − Miglior *et al*., 1995a; 1995b; Rokouei *et al*., 2010) as well in small cattle populations (the German Gelbvieh and Braunvieh breeds − Krogmeier *et al*., 1997; Swiss Braunvieh − Casanova *et al*., 1992).

The effect of inbreeding on milk production has been studied in different populations and breeds. In general, there is inbreeding depression in milk production (in kg), but conclusions concerning its effect on the fat and protein content (in %) are often inconsistent. One extensive study of inbreeding depression in Holstein (Miglior *et al*., 1995a) and Jersey cattle (Miglior *et al*., 1995b) was carried out in Canada. In both studies, a negative effect of inbreeding was found for milk, fat and protein production (in kg) and positive correlation to the percentage of fat and protein. Croquet *et al*. (2006) studied inbreeding depression in a Holstein cow population in Belgium. The results are described separately for the first, second and third lactation and totally for all lactations. A negative effect of inbreeding was found for milk production (in kg), fat and protein content (in %) and a positive relationship between inbreeding and somatic cell count.

Bezdíček *et al*. (2008) compared milk production per lactation (305 days) between inbred and non-inbred equals (half-sisters). The results showed a decrease in milk production in inbred cows by up to 472 kg of milk per lactation compared to non-inbred contour lines. The regression coefficient for milk yield was b_{yx} = -59.75 kg, for fat and protein content (in %) the regression coefficient was b_{yx} = +0,010112 a +0,0030 % / 1 % F_x.

Dezetter *et al*. (2015) studied the effect of inbreeding depression in a French population of Holstein, Montbeliarde and Normande breeds. The authors found an inbreeding depression on milk production (in kg) in all three breeds. Specifically, when the F_x coefficient was increased by one percent, they found the following effect of inbreeding in Holstein cattle: milk production (-41 kg in kg), fat content (0.0003 %), fat yield (-1.7 kg), protein content (-0.0002 %), protein yield (-1.3 kg) and somatic cell count (0.006). A similar trend was found in the Montbeliarde (-35 kg; -0.00004 %; -1.4 kg; 0.0002 %; -1.1 kg; 0.006) and in Normande breeds as well (-32 kg; -0.001 %; -1.4 kg; -0.0001 %; -1.3 kg; 0.001).

Thompson *et al*. (2000a; 2000b) studied inbreeding effects on milk production in the Holstein and Jersey cows (USA population). In both studies, the authors reported negative effect of inbreeding on milk, fat and protein yield (in kg), but no effect of inbreeding in terms of somatic cell count.

Similarly, inbreeding depression in milk production has been found in other large Holstein populations, such as an Italian population of cows (*e.g.* Biffani *et al*., 2002) and also in small cattle populations, such as in the German Gelbvieh, Braunvieh and in Swiss Braunvieh breeds (Krogmeier *et al*., 1997; Casanova *et al*. 1992).

The aim of this study was to evaluate the effect of inbreeding on milk production in Holstein cows (milk in kg; fat and protein content in %) during the first five daily milk controls (first lactation).

MATERIAL AND METHODS

Milk recording is carried out in the Czech Republic by method A4 (the intervals between controls are 4 weeks). Evaluation of the effect of inbreeding was carried out during the five daily control of milk production (A4 system = control after cca 4 weeks; cca from 30 to 150 days after calving).

The data included monitoring in 15 farms (own monitored data and from a database provided by CRV Czech Republic). The database was created of inbred (and non-inbred) Holstein cows in the first lactation with a complete pedigree to the fifth generation. The inbreeding coefficient was calculated using the B-calc software. The inbreeding coefficient ranged from F_x = 3.125 − 25 %.

Milk production is significantly influenced by a number of genetic and non-genetic factors such as sire, dam and farm. Therefore, each inbred cow was assigned to at least one outbred equal − half-sister. Inbred and outbred equals were similar for characteristics such as (1) the same sire, (2) first calving took place at the same farm and year (± 2 months) and (3) dam had reached a similar breeding value for kg of milk (± 5 %).

Data were analyzed using ANOVA (GLM analysis) by means of a Statistica® software. In the first step, we carried out a basic statistical analysis and pair test for evaluation of differences in milk production (in kg) and fat and protein content (in %) between inbred animals and their non-inbred half-sisters. We then carried out an evaluation (GLM analysis) taking into account inbreeding coefficient, number of somatic cells, breeding value of the sire and breeding value of the dam.

The effects of milk production were estimated from the model as follows:

$$Y_{ijkl} = \mu + Inbreeding_i + SCC_j + RBVS_k + RBVD_l + e_{ijkl}$$

where :

Y_{ijkl} = corrected value (depended variable) represented the milk production (kg), fat content (in %), protein content (in %)

μ = mean value

$Inbreeding_i$ = coefficient of inbreeding 1 (F_x = 3.125 %); 2 (F_x = 5 – 25 %)

SCC_j = somatic cell count; 1 (< 300 ths.); 2 (≥ 300 hs.); 3 (not found)

$RBVS_k$ = relative breeding value of sire 1 (RBVS < 105); 2 (RBVS ≥ 105)

$RBVD_l$ = relative breeding value of dam 1 (RBVD < 105); 2 (RBVD ≥ 105)

e_{ijkl} = residual error

A test of homogeneity (Cochran-Hartley-Bartlett test) was carried out in the case of the ANOVA (GLM) test and following Tukey HSD test. Differences between the estimated variables were tested at the level of significance P < 0.05 or P < 0.01.

The relative breeding value presented genetic value of an animal for the trait "milk production". The number of somatic cells was used as a possible factor related to the milk production and content of milk components. However, this was a particular value at a specific time. Therefore, it is not clear whether it is the start, ongoing or end of udder inflammation. For this reason, the number of somatic cells was not related to the inbreeding coefficient, but only to the daily milk yield (in kg) and milk components content (fat and protein in %).

RESULTS

Table 1 shows the basic statistical values (average; s_x; maximal value; minimal value; number of records) of milk production in kilograms for inbred cows (F_x = 3.125 – 25 %) and their non-inbred half-sisters. Similarly, Tables 2 and 3 present the fat and protein content (%). From the tables, there is an obvious tendency to lower milk production in inbred animals compared to their non-inbred half-sisters, from the first to the fourth control. In the first milk control, there was a decrease in yield in inbred animals of -0.62 kg (p = 0.4916), in the second control the decrease was -1.65 kg (p = 0.0513). At the third, fourth and fifth control there was a reduced daily milk production in inbred animals by -0.81; -1.12 and -0.02 kg. At the fifth control, the daily milk production in inbred and non-inbred animals was comparable (Figure 1). These results also correspond to the regression coefficients in first and second control -0.1171 and -0.1890 kg milk / 1 % F_x.

A similar tendency was found using ANOVA (GLM) (Table 4). In this case, the following factors were taken into consideration: inbreeding; somatic cell count and relative breeding value of sire and dam.

Table 1. Comparison of milk production (in kg) between inbred and non-inbred cows at the first to fifth daily milk controls (Holstein; 1st lactation)

Sequence of milk control	Milk production of inbred cows[a]		Milk production of non-inbred half-sisters		Differences in kg (p value)
	mean; s_x (kg)	max.; min.; N (kg)	mean; s_x (kg)	max.; min. (kg)	
1. control	32.73 ± 7.59	48.4; 18.4; 101	33.35 ± 7.78	61.5; 16.0	-0.62 (p = 0.4916)
2. control	33.16 ± 7.66	53.5; 18.8; 101	34.81 ± 7.06	62.7; 15.8	-1.65 (p = 0.0513)
3. control	31.90 ± 7.06	55.0; 15.9; 101	32.71 ± 6.81	54.6; 15.4	-0.81 (p = 0.3149)
4. control	29.70 ± 6.89	50.1; 16.2; 101	30.19 ± 6.80	53.9; 16.2	-1.12 (p = 0.1420)
5. control	27.37 ± 6.34	51.0; 10.1; 101	27.39 ± 6.70	51.0; 10.1	-0.02 (p = 0.9942)

a = F_x (3.124 – 25 %)

Table 2. Comparison of fat percentage in milk between inbred and non-inbred cows at the first to fifth daily milk controls (Holstein; 1st lactation)

Sequence of milk control	Fat (%) in milk in inbred cows[a]		Non-inbred half-sisters		Differences in kg (p value)
	mean; s_x (kg)	max.; min.; N (kg)	mean; s_x (kg)	max.; min. (kg)	
1. control	4.03 ± 0.75	7.0; 2.68; 101	4.07 ± 0.92	6.68; 2.13	-0.04 (p = 0.7163)
2. control	3.75 ± 0.61	4.95; 2.05; 101	3.60 ± 0.72	6.55; 2.19	0.15 (p = 0.0652)
3. control	3.75 ± 0.72	6.1; 2.3; 100	3.68 ± 0.61	5.14; 2.27	0.07 (p = 0.4060)
4. control	3.80 ± 0.60	5.17; 2.24; 100	3.71 ± 0.62	5.27; 2.24	0.09 (p = 0.3109)
5. control	3.84 ± 0.74	5.64; 2.03; 98	3.77 ± 0.67	5.65; 2.01	0.07 (p = 0.4353)

a = F_x (3.124 – 25 %)

Table 3. Comparison of protein percentage in milk between inbred and non-inbred cows at the first to fifth daily milk controls (Holstein; 1st lactation)

Sequence of milk control	Protein (%) in milk in inbred cows[a]		Non-inbred half-sisters		Differences in kg (p value)
	mean; s_x (kg)	max.; min.; N (kg)	mean; s_x (kg)	max.; min. (kg)	
1. control	3.08 ± 0.32	3.9; 2.54; 101	2.97 ± 0.31	3.64; 2.97	0.11 (p = 0.0111)
2. control	3.09 ± 0.36	3.91; 2.36; 101	3.04 ± 0.43	5.08; 2.33	0.05 (p = 0.3014)
3. control	3.18 ± 0.34	4.0; 2.43; 100	3.14 ± 0.30	4.21; 2.46	0.04 (p = 0.4162)
4. control	3.28 ± 0.45	4.25; 2.58; 100	3.25 ± 0.30	4.14; 2.39	0.03 (p = 0.4682)
5. control	3.39 ± 0.32	4.47; 2.71; 99	3.32 ± 0.33	4.30; 2.70	0.07 (p = 0.0416)

a = F_x (3.124 – 25 %)

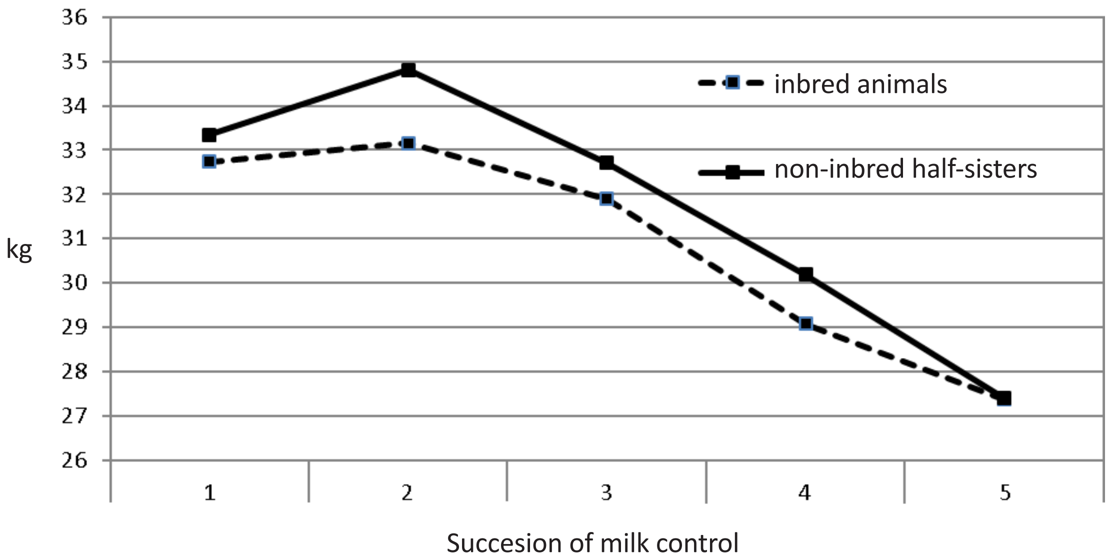

Figure 1. LSM of daily milk production (in kg) in inbred and non-inbred cows at the first to fifth milk controls

Table 4. GLM analysis of selected factors affecting milk production (in kg) at the first to fifth milk controls (Holstein; 1st lactation)

		1. milk control	2. milk control	3. milk control	4. milk control	5. milk control	No. of animals
F_x	F_x = 3.125 %	33.77^A	33.28	31.29	28.12	26.91	84/84/84/84/84
	F_x = 5 – 25 %	29.84^A	31.06	31.79	28.77	25.98	27/27/27/27/27
Somatic cell count	≤ 300 ths.	32.32	33.76	32.25	29.94	27.43	65/57/57/53/54
	≥ 301 ths.	30.94	29.99	32.,72	28.08	26.63	14/22/23/30/28
	not found	32.17	32.77	29.67	27.32	25.29	32/32/31/28/29
RBV sire	≤ 99	32.66	32.67	30.87	27.4	25.28	31/31/31/31/31
	≥ 100	30.95	31.68	32.23	29.5	27.62	80/80/80/80/80
RBV dam	≤ 99	31.53	31.76	30.98	27.94	25.64	64/64/64/64/64
	≥ 100	32.09	32.58	32.12	28.96	27.26	47/47/47/47/47

RBV – relative breeding value; A = (p = 0.0662)

The results also show the negative effects of inbreeding on milk production. Cows with a higher coefficient of inbreeding (F_x = 5 – 25 %) had lower milk production (on the margin of significance) than cows with a lower coefficient of inbreeding (F_x = 3.125 %). Specifically, in the first milk control there was a difference between inbred groups 3.93 kg (F_x lower vs. F_x higher; 33.77 vs. 29.84 kg) and during the second control the difference was 2.22 kg (33.28 vs. 31.06 kg of milk). At the third, fourth and fifth controls the difference between inbred animals was minimal. Table 4 also shows the relationship between somatic cell count and milk production in the first to fifth control. These results reveal higher milk production in the case of a low somatic cell count. Although the differences were not statistically significant, the trend is evident, which is related to udder health. There was no statistical relationship between somatic cell count and milk components (fat, protein in %).

In general, the results disclose lower daily milk production in cows with a higher F_x coefficient, especially during the first and second milk control (i.e. about 60 days after birth). In the next controls (from the third to the fifth) the differences between low inbred and high inbred animals were very small. In evaluating milk components (% of fat and protein) the results showed no significant differences between inbred animals and their non-inbred half-sisters or between different inbred groups. This is evident from the differences (Tables 2, 3, 5 and 6) as well as from the regression coefficients, which were very low with both positive and negative values. For example in the first control the regression coefficients between milk components (fat; protein in %) and inbreeding coefficient were: -0.0052 and + 0.0154 / 1 % F_x, respectively. There is no apparent effect of inbreeding depression on milk components (in %). From this point of view, it is more reasonable to assume a negative relationship between decreased milk production and increased content of milk components. This relationship has been confirmed in many publications.

DISCUSSION

The conclusions of this study agree with other authors, although many studies evaluated the impact of inbreeding over the whole of lactation with fewer focused on daily milk production. The conclusion in this study is in concert with Thompson *et al*. (2000a; 2000b), who reported the effect of inbreeding on milk production (per lactation) for milk, fat and protein: in Holstein -327.6; -12.27 and -8.67 kg; in Jersey -163.7; -8.99 and -8.16 kg. They also studied the effect of inbreeding on daily milk production. In particular, for Jersey cows, they found an effect of inbreeding mainly at the beginning of lactation. After the peak of milk production the effect of inbreeding for animals with F < 7 % was small (in Holstein F < 6; Thompson *et al*., 2000a; 2000b). The negative effect of inbreeding on milk

Table 5. GLM analysis of selected factors affecting fat content (in %) at the first to fifth milk controls (Holstein; 1st lactation)

		1. milk control	2. milk control	3. milk control	4. milk control	5. milk control	No. of animals
F_x	F_x = 3.125 %	4.10	3.79	3.89	3.86	3.81	84/84/83/83/82
	F_x = 5 – 25 %	3.94	3.53	3.67	3.72	3.99	27/27/27/27/27
Somatic cell count	≤ 300 ths.	4.07	3.65	3.64	3.69	3.88	65/57/57/53/54
	≥ 301 ths.	4.02	3.66	4.00	3.82	4.03	14/22/23/30/28
	not found	3.96	3.67	3.70	3.85	3.78	32/32/30/27/27
RBV sire	≤ 99	4.09	3.62	3.88	3.83	3.89	31/31/31/31/31
	≥ 100	3.94	3.7	3.68	3.75	3.91	80/80/79/79/78
RBV dam	≤ 99	3.91	3.61	3.89	3.85	3.94	64/64/63/63/62
	≥ 100	4.12	3.71	3.67	3.72	3.86	47/47/47/47/47

RBV – relative breeding value

Table 6. GLM analysis of selected factors affecting protein content (in %) at the first to fifth milk controls (Holstein; 1st lactation)

		1. milk control	2. milk control	3. milk control	4. milk control	5. milk control	No. of animals
F_x	F_x = 3.125 %	3.08	3.10	3.25	3.32	3.44	84/83/83/83/82
	F_x = 5 – 25 %	3.20	3.14	3.18	3.28	3.34	27/27/ 27/27/27
Somatic cell count	≤ 300 ths.	3.12	3.09	3.12	3.25	3.37	65/57/57/53/54
	≥ 301 ths.	3.15	3.13	3.33	3.31	3.42	14/22/23/30/28
	not found	3.16	3.13	3.19	3.35	3.37	32/32/30/27/27
RBV sire	≤ 99	3.16	3.13	3.24	3.32	3.42	31/31/31/31/31
	≥ 100	3.13	3.11	3.19	3.29	3.36	80/80/79/79/78
RBV dam	≤ 99	3.14	3.14	3.22	3.30	3.38	64/64/63/63/62
	≥ 100	3.14	3.10	3.20	3.30	3.40	47/47/47/47/47

RBV – relative breeding value

production was reported also by Miglior *et al*. (1995a; 1995b). The authors (Miglior *et al*., 1995b) have found an inbreeding depression per 1 % of F_x in milk, fat and protein yield (in kg) of Holstein cows as follows: -25.0; -0.9 and -0.8 kg (fat and protein percent regression were +0.05 %). For somatic cell score, the regression coefficient was r = 0.012 per 1 % increase of inbreeding (Miglior *et al*., 1995a). These authors (Miglior *et al*., 1992) have found a similar relationship between F_x and milk production also in Jersey cattle: milk -9.84 kg; fat yield -0.55 kg; fat percentage -0.0011 %.

Bezdíček *et al*. (2008) also showed that inbred cows have lower dairy production per lactation (305 days). The decrease in milk production was associated with increase in the content of milk components. Particularly, for fat and protein the regression was: b_{yx} = +0.010112 a +0.0030 % / 1 % F_x.

Similar results were reported by Croquet *et al*. (2006), who studied a Holstein cattle population in Belgium and found inbreeding depression for milk (in kg), fat and protein content (in %) as follows: -18.81 kg; -0.91 %; -0.65 %. They also described the relationship between inbreeding and number of somatic cells. Increase in the coefficient of inbreeding by 1 % was associated with the increase in a somatic cell score by 0.005 (Croquet *et al*., 2007).

The negative effect of inbreeding on milk production was also observed in other breeds. Dezetter *et al*. (2015) studied inbred depression in a French population of dairy cows of Holstein, Montbeliarde and Normande breeds. The authors report similar conclusions that the rise of inbreeding was associated with a reduction of milk production (-41, -35 and -32 kg) and, at the same time, with an increase or decrease in fat (0.0003; -0.00004; -0.001 %) and protein (-0.0002; 0.0002; -0.0001 %) content.

In general, many authors noted the negative impact of inbreeding on milk production during lactation. Only few studies analyzed daily milk production in relation to the inbreeding coefficient. In the fat and protein content (in %) the results presented by the various authors are not uniform, but in general there is a slight effect of inbreeding depression in both positive and negative direction.

CONCLUSION

Although most of the results in this study are not statistically significant, there is an obvious tendency of negative effect of inbreeding on daily milk production at the beginning of lactation, mainly during the first two controls (about 60 days after calving). In the middle of lactation (after maximal daily milk production) the effect of inbreeding was weak. There is also an obvious tendency to decreased milk production in the case of a higher somatic cell count.

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