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Genetic relationship between lactation persistency and conformation traits in Polish Holstein-Friesian cow population

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ABSTRACT: The objective of this study was to find genetic relationships between lactation persistency and conformation traits of Polish Holstein-Friesian cows. The data were derived from SYMLEK – the Polish National Database. The analysis used 22 conformation traits and 3 persistency measures of 18 216 first lactation cows. Persistency was defined as milk yield in the second 100 days in milk (DIM) divided by the yield in the first 100 DIM, milk yield in the third 100 DIM divided by the yield in the first 100 DIM, and milk yield at 280 DIM divided by milk yield at 60 DIM. The lactation curve was modelled with fourth-order Legendre polynomials using a multiple-trait prediction method. The multiple-trait REML method was applied for (co)variance component estimation. The linear model for persistency included fixed effects of herd-year-season of calving, age of calving class, and random animal effect; the linear model for type traits included fixed effects of herd-year-season of calving-classifier, age of calving class, lactation stage, and random animal effect. Stature and composite type traits (except type and conformation) were moderately or strongly genetically correlated with each of the three persistency measures. Genetic correlations of lactation persistency with overall feet and leg score and overall udder score were high and positive, whereas the correlations with stature and size were high but negative. All linearly scored traits had little genetic relationship with persistency measures except for rear udder height, udder width, and foot angle. In these three cases the genetic correlations with persistency measures were relatively high, positive, and preferable. The obtained genetic correlations suggest that increased weights of composite traits like size, overall feet and leg score, and overall udder score in the selection index, as well as selection for better rear udder height and foot angle, might cause a favourable correlated response in persistency.

Keywords: type traits; lactation persistency; dairy cattle

INTRODUCTION

Lactation persistency is a trait of interest to dairy farmers because cows with flat lactation curves are less susceptible to metabolic disorders and health problems. Selection for increased lactation persistency together with production traits could be a way to increase total milk yield without increasing the occurrence of disease or reproductive problems. Such a selection strategy could be advantageous since it leads to changing the shape of a cow's lactation curve. If the lactation of a cow is more persistent, the lactation curve is flatter, with a lower and later peak. As a consequence, a cow with a flatter lactation curve is exposed to less stress due to high peak production, and the incidence of reproductive and metabolic disorders may be reduced to some extent (Gengler et al. 1995; Muir et al. 2004). Measuring lactation persistency by one single term is difficult, so persistency has been defined in many ways (Solkner and Fuchs 1987; Swalve 1994; Gengler et al. 1995; Muir et al. 2004). Usually the persistency of lactation is defined as the ability of an animal to maintain milk production at a high level after the peak yield, or as the ability to maintain relatively constant yield during the lactation (Gengler 1996). Measures defined in this way refer to the shape of the lactation curve and are more or less a function

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of the lactation curve flatness. Other definitions of persistency are based on the variation of test-day yields, because flatness of the lactation curve can be easily expressed using dispersion measures. Weak points of the latter measures are that they can be calculated only for finished lactations and are not easy for breeders to interpret and understand (Solkner and Fuchs 1987).

Conformation was the first group of nonproduction traits scored and included in the selection indices for dairy cattle populations around the world (Misztal et al. 1992; DeHaas et al. 2007; Nemcova et al. 2011; Ptak et al. 2011). The main reason for collecting and using information on type traits in breeding programs is to select more profitable and functional cows. Many type traits are strongly correlated with milk production traits as well as with other low-heritable functional traits, and for many decades selection for increased production has been accompanied by selection for better conformation. It is worth mentioning that selection for type traits associated with better herdlife may help decrease involuntary culling and increase profitability (Misztal et al. 1992; Nemcova et al. 2011).

There are many papers presenting genetic relationships of conformation traits with milk production traits (Misztal et al. 1992; DeGroot et al. 2002; Berry et al. 2004; DeHaas et al. 2007), but the literature on genetic relationships between conformation traits and lactation persistency is sparse (Bar-Anan and Ron 1983). Research done by Muir et al. (2004) showed favourable genetic associations between persistency and two traits: calving ease and fertility. The only country in the world where lactation persistency is routinely evaluated is Canada. Breeding value for persistency is included in the Canadian lifetime profit index as a part of the health and fertility component (Canadian Dairy Network 2014, http://www.cdn.ca/document.php?id=347).

The objective of this study was to estimate genetic parameters for a few measures of lactation persistency and some conformation traits of Polish Holstein-Friesian cows. If the results are promising, lactation persistency can be included in the breeding programme.

MATERIAL AND METHODS

Data were derived from the Polish national recording system (SYMLEK), and were made available by the Polish Federation of Cattle Breeders and Dairy Farmers. There were 148 451 test-day (TD) milk yields from 18 216 first lactations of Polish Holstein-Friesian (HF) cows. The group of 22 conformation traits consisted of 5 composite type traits, stature, and 16 linearly scored traits (Table 1). The composite traits were scored on a scale from 50 to 100 points. Four of them (size,

Table 1. Characteristics of milk persistency and type traits of cows (n = 18 216)

Item	Mean	SD	CV	Heritability[1]
305-day milk yield	5604	1826	32.6	0.27
Persistency (%)				
$P_{2:1}$	91.05	19.65	21.6	0.04
$P_{3:1}$	77.35	21.27	27.5	0.06
P_d	73.67	20.13	27.3	0.06
Composite traits				
Size	81.95	4.16	5.1	0.41
Type and conformation	79.83	3.48	4.4	0.27
Overall feet and leg score	79.01	3.64	4.6	0.15
Overall udder score	78.10	4.52	5.8	0.33
Overall conformation score	79.14	3.27	4.1	0.34
Stature	142.46	3.92	2.8	0.50
Linearly scored traits				
Fore udder	6.16	1.19	19.3	0.19
Rear udder height	5.43	1.21	22.3	0.19
Udder support	5.27	1.16	22.0	0.15
Udder depth	5.50	1.24	22.5	0.33
Udder width	5.42	1.08	19.9	0.15
Front teat placement	5.26	1.30	24.7	0.25
Teat length	5.39	1.40	26.0	0.22
Rear teat placement	5.66	1.25	22.1	0.33
Body depth	5.54	1.16	20.9	0.20
Chest width	5.63	1.50	26.6	0.20
Rump angle	5.80	1.45	25.0	0.26
Rump width	5.50	1.20	21.8	0.26
Rear leg set	5.87	1.44	24.5	0.12
Foot angle	5.11	1.25	24.5	0.08
Rear leg rear view	4.74	1.17	24.7	0.07
Angularity	6.12	1.15	18.8	0.19

SD = standard deviation, CV = coefficient of variation (%), $P_{2:1}$ = milk yield in the second 100 days in milk (DIM) divided by yield in the first 100 DIM, $P_{3:1}$ = milk yield in the third 100 DIM divided by yield in the first 100 DIM, P_d = milk yield at 280 DIM divided by milk yield expected at 60 DIM

[1]SD of heritability: for 305-day milk yield 0.008, for persistency 0.009–0.012, for type traits 0.018–0.051

all heritabilities are significant at $P < 0.05$

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type and conformation, overall feet and leg score, and overall udder score) were evaluated by classifier directly during examination of the cow; overall conformation score was calculated as a linear combination of the above composite traits, with weights 0.1, 0.1, 0.3, and 0.5, respectively. The linear traits were scored on a 9-point scale (Table 2). Cows calved from 2003 to 2007 at the age of 18–48 months and were scored between days 15 and 180 of the first lactation by 12 classifiers. There were 1 to 10 TD records per cow, with 8 TD yields on average. Daily yields were collected between 5 and 305 days in milk (DIM).

A multiple-trait prediction (MTP) method was applied for fitting lactation curves and estimating partial lactation yields. In the MTP method, information about standard lactation curves and the (co)variances among the parameters of the lactation curve model were incorporated (Schaeffer and Jamrozik 1996). To estimate the matrix containing (co)variances among the curve parameters, only cows with the first TD before 50 DIM and minimally 9 TD records per lactation were considered. The parameters of standard lactation curves were estimated within 10 subclasses of age at calving by season of calving. The data were divided into five groups of age at calving: 18–24, 25–26, 27–28, 29–30, and 31–48 months. Two seasons of calving were created (October–March and April–September). Lactation curves were modelled using fourth-order Legendre polynomials (Kirkpartick et al. 1990):

Table 2. Description of the linear type traits

No.	Trait	Score 1	Score 9
1	Fore udder	loose	tight
2	Rear udder height	very low	very high
3	Udder support	weak	strong
4	Udder depth	deep	shallow
5	Udder width	narrow	wide
6	Front teat placement	wide	narrow
7	Teat length	short	long
8	Rear teat placement	wide	narrow
9	Body depth	shallow	deep
10	Chest width	narrow	wide
11	Rump angle	high pins	low pins
12	Rump width	narrow	wide
13	Rear leg set	straight	sickled
14	Foot angle	low	steep
15	Rear leg rear view	toe-out	parallel feet
16	Angularity	coarse	angular

$$y = b_0 + b_1\sqrt{3}x + b_2\frac{\sqrt{5}}{2}(3x^2 - 1) + b_3\frac{\sqrt{7}}{2}(5x^3 - 3x) + b_4\frac{3}{8}(35x^4 - 30x^2 + 3)$$

where:

$$x = 2\frac{t - t_{\min}}{t_{\max} - t_{\min}} - 1$$

t = days in milk
t_{min} = 5 days
t_{max} = 305 days
y = milk yield at t days in milk
b_0–b_4 = parameters to be estimated

Three different measures of persistency were calculated and expressed as percentages: $P_{2:1}$ – milk yield in the second 100 DIM divided by yield in the first 100 DIM, $P_{3:1}$ – milk yield in the third 100 DIM divided by yield in the first 100 DIM, and P_d – milk yield at 280 DIM divided by milk yield at 60 DIM (Gengler 1996; Canadian Dairy Network 2004 – http://www.cdn.ca/document.php?id=28). The first two measures ($P_{2:1}$ and $P_{3:1}$) based on partial yields have been very commonly used because of the ease of their calculation (Solkner and Fuchs 1987; Swalve 1994; Gengler et al. 1995). The third definition (P_d), based on the shape of the lactation curve after the peak, describes the potential to maintain a relatively high level of production in the descending stage of lactation and it is also easy for breeders to understand (Jamrozik et al. 1998). These measures were chosen, based on the results of previous research by Otwinowska-Mindur and Ptak (2015), as the most promising for breeding practice. The 305-day milk yield, milk yields for the first, second, and third 100 DIM, as well as the yields at 60 and 280 DIM, were calculated using the parameters of the lactation curve fitted by the MTP method.

The multiple-trait REML method and the BLUPF90 computing package were employed for (co)variance component estimation (Misztal 2008). Genetic parameters were calculated for three persistency measures together with conformation traits grouped as follows: (1) composite traits and stature, (2) udder linear traits, and (3) other linear traits. The linear model for persistency included fixed effect of herd-year-season of calving (HYS), fixed effect of age of calving class, and random animal effect; the linear model for type traits contained fixed effect of herd-year-season of calving-classifier (HYSC), age of calving class and lactation stage, and random animal effect. Days in milk were divided into 11 lactation stages, defined as 15-day

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intervals. Two restrictions were imposed on the data: a minimum of 5 cows per HYS subclass, and a minimum of 5 cows per HYSC subclass. There were 1223 HYS subclasses, 1238 HYSC subclasses, 5 age-of-calving subclasses, and 35 631 animals (cows and their parents) included in the analysis.

RESULTS AND DISCUSSION

Descriptive characteristics. Characteristics of lactation persistency and conformation traits are presented in Table 1. The mean values of persistency were in the range of 73.67–91.05 (SD = 19.65–21.27). High values of all three measures represent good persistency, and low values indicate poor persistency. Similar averages for all these three persistency measures were obtained by Otwinowska-Mindur and Ptak (2015). Lower means for persistency defined as $P_{2:1}$ (80.8) and $P_{3:1}$ (64.4) in the population of primiparous Simmental cows were obtained by Solkner and Fuchs (1987), and for $P_{3:1}$ (73.6) in the population of dairy cattle in northern Germany by Swalve (1994).

In the case of conformation composite traits, the higher the score, the better the merit of the cow. The means of composite traits ranged from 78.10 (SD = 4.52) for overall udder score to 81.95 (SD = 4.16) for size, and showed that the conformation of Polish cows corresponded well with the conformation standard. The means of most composite traits in our study were similar to those obtained by Ptak et al. (2011) for the Polish population and Zavadilova and Stipkova (2012) for Czech Holstein cows. The average for stature of Polish HF cows was 143 cm (Table 1), slightly less than the mean obtained by Lassen and Mark (2008) for Danish Holstein cows (144.3 cm).

The mean values of linearly scored traits ranged between 4.74 for rear leg rear view and 6.16 for fore udder, with a coefficient of variation of about 23% (Table 1). For most linear type traits the average scores were around or slightly above the middle of the scale (5.0) and were consistent with those presented by Ptak et al. (2011). Berry et al. (2004) obtained lower mean values for traits associated with body size for Irish Holstein-Friesian cows (for example: chest width 4.9, rump angle 4.3), whereas the mean values for most traits associated with udder presented by Berry et al. (2004) and Lassen and Mark (2008) were higher than our averages.

Heritability of persistency. Heritabilities estimated for three measures of persistency are shown in Table 1. All of them were low (0.04 for $P_{2:1}$, 0.06 for both $P_{3:1}$ and P_d) but within the range of values given in the literature. Heritabilities reported by many authors varied from 0.03 to 0.30, depending on the definition of persistency and the population studied (Solkner and Fuchs 1987; Swalve 1994; Gengler et al. 1995; Gengler 1996; Otwinowska-Mindur and Ptak 2015). It meant that slow progress could be achieved through selection. Solkner and Fuchs (1987) obtained estimates higher than ours for first parity persistency: 0.14 for $P_{2:1}$ and 0.19 for $P_{3:1}$. Heritability for $P_{3:1}$ presented by Swalve (1994) and Gengler et al. (1995) was lower (0.11) but still almost twice as high as our estimate for $P_{3:1}$. Heritability obtained by Gengler et al. (1995) for $P_{2:1}$ (0.12) was even three times higher than that estimated in this study for the same measure. Solkner and Fuchs (1987) found that persistency defined using data from the whole lactation was more heritable than that based on data from only the first 200 DIM.

Heritability of type traits. Heritability estimates for type traits are presented in Table 1. All heritabilities were low to moderate (0.07–0.50). Stature and size showed the highest heritabilities of all composite traits (0.50 and 0.41), and overall feet and leg score the lowest (0.15). Misztal et al. (1992), Berry et al. (2004), De Haas et al. (2007), Lassen and Mark (2008), and Nemcova et al. (2011) also obtained the highest heritabilities for stature although this trait was scored differently in different countries. For example, Berry et al. (2004) and Nemcova et al. (2011) regarded stature as a linear conformation trait evaluated on a 9-point scale, whereas Misztal et al. (1992) scored it on a 50-point scale. In Poland, stature is treated as a separate trait (neither linear nor composite) and expressed in centimeters. Stature is closely related to body weight, which is an important functional trait regulating feed efficiency and energy balance traits in dairy cattle (DeHaas et al. 2007). The range of heritabilities for composite traits was similar to the results of the previous study in Polish Holsteins: from 0.11 for overall feet and leg score to 0.39 for size (Ptak et al. 2011). Zavadilova and Stipkova (2012) also reported the lowest heritability for feet and legs (0.12), but they estimated the highest heritability not for size as in this paper but for dairy form (0.28).

Comparing linearly scored traits, this study confirmed our expectation of low values of heritability for feet and legs traits and moderate heritabilities for udder- and body-related traits. The least heritable

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were leg-related traits (from 0.07 for rear leg rear view to 0.12 for rear leg set). For udder-related traits the highest heritabilities were for udder depth and rear teat placement, both 0.33. Heritabilities obtained for rump and udder traits were moderate (0.15–0.33).

The estimates of heritabilities of leg traits were consistent with those reported by Ptak et al. (2011) and Zavadilova and Stipkova (2012), and lower than obtained by Misztal et al. (1992), Berry et al. (2004), Lassen and Mark (2008), and Nemcova et al. (2011). All those results confirm that leg traits are strongly influenced by environmental conditions and rather difficult to improve by selection. The estimates of heritabilities for udder traits were very close to those reported by Berry et al. (2004) and Zavadilova and Stipkova (2012) but lower than those obtained by Lassen and Mark (2008) and Nemcova et al. (2011). Berry et al. (2004) reported higher heritability for chest width (0.26) and much higher for body depth (0.37). In turn, Nemcova et al. (2011) and Zavadilova and Stipkova (2012) estimated higher heritabilities for rump width (0.35 and 0.40) and rump angle (0.31 and 0.34), and similar heritabilities for body depth (0.21 and 0.24). Lassen and Mark (2008) obtained similar heritability for rump width (0.27), and higher for body depth (0.27) and rump angle (0.38). Heritability for chest width (0.18) presented by Nemcova et al. (2011) was consistent with our result but much lower than obtained by Zavadilova and Stipkova (2012) (0.30), even though both estimates were made for the same population. DeHaas et al. (2007) obtained higher heritabilities for body depth (0.39), rump width (0.47), and dairy character (0.40) for Swiss Holstein cows.

Genetic and phenotypic correlations. Estimates of genetic and phenotypic correlations between persistency and type traits are presented in Table 3. Among the five composite type traits, overall udder score, size and overall feet and leg score showed the highest genetic correlations with three persistency measures. For overall udder score the correlations ranged from 0.75 with $P_{2:1}$ to 0.80 with P_d, and for overall feet and leg score they were from 0.58 to 0.61. Size was negatively genetically correlated with persistency: –0.64 with $P_{2:1}$, –0.63 with $P_{3:1}$, and –0.52 with P_d. The lowest genetic correlations were for type and conformation (from –0.02 with P_d to –0.14 with $P_{2:1}$). As expected, the pattern of correlations between stature and persistency was similar to that for size and persistency (range from –0.64 with P_d to –0.75 with $P_{3:1}$).

The relatively high correlations of udder and feet and leg scores with persistency might be a result of the fact that cows with favourable udder and legs were less exposed to infections and maintained a higher level of milk production longer during lactation, so they had better persistency. On the other hand, the relatively high but negative correlation between size and persistency suggested that large, highly productive cows, usually having almost 100% HF genes, had lower persistency. According to the definitions of persistency used in this paper, lower persistency might mean that there was a big difference in yields in the first 100 DIM and in the later stages of lactation (i.e. in the second 100 DIM or in the third 100 DIM). Size and milk yield were strongly and positively genetically correlated (unpublished data), so a negative correlation of persistency with yield should be expected. The results of previous research by Otwinowska-Mindur and Ptak (2015) showed such a relationship between P_d and milk yield.

Among the linear traits the largest and positive genetic correlations with persistency measures were for rear udder height, udder width, rear leg set, and foot angle (Table 3). Except for rear leg set, the optimal values of all remaining traits are located on the right side of the scale, so selection for better persistency would result in a favourable correlated response in rear udder height, udder width, and foot angle. In the case of rear leg set the optimum is in the middle of the scale: in a group of animals with straight legs, selection for better persistency would improve the trait; in a group of cows with correctly formed legs, selection would deteriorate the legs towards a more sickle shape.

The genetic correlations of persistency measures with udder support and rear teat placement were rather low and negative (Table 3). In the case of udder support a negative correlation is unfavourable, because cows with a strong central ligament tend to be more productive and less exposed to udder infections (Ptak et al. 2011). In most cases a negative genetic correlation between persistency and rear teat placement should be regarded as favourable, because selection for better persistency would decrease the scores for rear teat placement towards the optimum of this trait (4 points).

Rear udder height, foot angle, and udder width were the traits most genetically correlated with all three persistency measures (0.2–0.4). The genetic correlations of rear teat placement and rear leg set with persistency were slightly weaker but existing

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Table 3. Genetic and phenotypic correlations between persistency and type traits

Trait	Genetic correlation			Phenotypic correlation		
	$P_{2:1}$	$P_{3:1}$	P_d	$P_{2:1}$	$P_{3:1}$	P_d
Composite						
Size	–0.64	–0.63	–0.52	–0.13	–0.14	–0.10
Type and conformation	–0.14	–0.13	–0.02	–0.02	-0.03	–0.02
Overall feet and leg score	0.58	0.59	0.61	0.10	0.10	0.07
Overall udder score	0.75	0.76	0.80	0.18	0.19	0.13
Overall conformation score	0.50	0.51	0.58	0.13	0.14	0.09
Stature	–0.76	–0.75	–0.64	–0.17	–0.18	–0.13
Linearly scored						
Fore udder	0.04	–0.03	–0.03	0.02	0.02	0.02
Rear udder height	0.27	0.38	0.40	0.03	0.04	0.04
Udder support	–0.17	–0.12	–0.02	0.01	0.02	0.02
Udder depth	0.08	0.05	0.02	0.03	0.03	0.03
Udder width	0.19	0.31	0.35	0.01	0.01	0.01
Front teat placement	–0.05	0.02	0.05	–0.01	–0.01	0.00
Teat length	–0.03	0.08	0.12	0.00	0.00	0.01
Rear teat placement	–0.14	–0.12	–0.10	–0.01	–0.02	-0.02
Body depth	–0.17	–0.07	–0.01	0.00	–0.01	-0.01
Chest width	–0.11	–0.01	–0.01	0.00	–0.02	-0.03
Rump angle	–0.05	0.05	0.01	0.00	0.00	0.00
Rump width	–0.06	0.05	0.03	0.00	0.00	0.00
Rear leg set	0.16	0.16	0.12	0.00	0.01	0.01
Foot angle	0.22	0.23	0.21	0.02	0.02	0.01
Rear leg rear view	0.11	0.02	0.02	0.01	0.01	0.01
Angularity	–0.09	–0.01	0.05	0.01	0.02	0.02

$P_{2:1}$ = milk yield in the second 100 DIM divided by yield in the first 100 DIM, $P_{3:1}$ = milk yield in the third 100 DIM divided by yield in the first 100 DIM, P_d = milk yield at 280 DIM divided by milk yield expected at 60 DIM

standard deviations for genetic correlations were in the range 0.004 – 0.130, standard deviations for phenotypic correlations were in the range 0.001–0.020

genetic and phenotypic correlations ≥ 0.02 in absolute value are significant at $P < 0.05$

(0.10–0.16, ignoring sign). Udder depth, chest width, rear leg set, and angularity showed weak genetic correlations only with $P_{2:1}$ whereas fore udder, front teat placement, rump angle, and rump width were not correlated with any persistency measure.

The phenotypic correlations between persistency measures and conformation traits, presented in Table 3, were low (0.02–0.19, ignoring sign). The highest phenotypic correlations were between stature and persistency (from –0.13 with P_d to –0.18 with $P_{3:1}$) and between overall udder score and persistency (from 0.13 with P_d to 0.19 with $P_{3:1}$). The phenotypic correlations between linearly scored traits and persistency were negligible.

Research on the relationships between lactation persistency and type traits is limited. Bar-Anan and Ron (1983) noted negative genetic correlations between persistency and size (–0.18), dairy character (–0.18), and fore udder (–0.32). These estimates were similar in sign to ours but differed in value from ours. The differences might be due to the way persistency was determined: the mentioned authors used the whole lactation yield in calculating persistency.

CONCLUSION

The genetic correlations of lactation persistency with overall feet and leg score and overall udder score were moderate and positive, whereas those with stature and size were moderate but negative. The majority of linearly scored traits and three persistency measures were weakly genetically

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correlated. Among linear traits, moderate and favourable correlations with persistency were estimated for rear udder height, udder width, and foot angle. Comparing the three persistency measures, $P_{2:1}$ and $P_{3:1}$ showed similar genetic correlations with most of the type traits, while the correlations estimated for P_d differed.

The obtained genetic correlations suggested that increasing the weight of composite traits like size, overall feet and leg score, and udder in the selection index, as well as selection for better rear udder height and foot angle, might lead to a favourable correlated response in persistency.

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